14th INTERNATIONAL NEW YORK CONFERENCE

ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

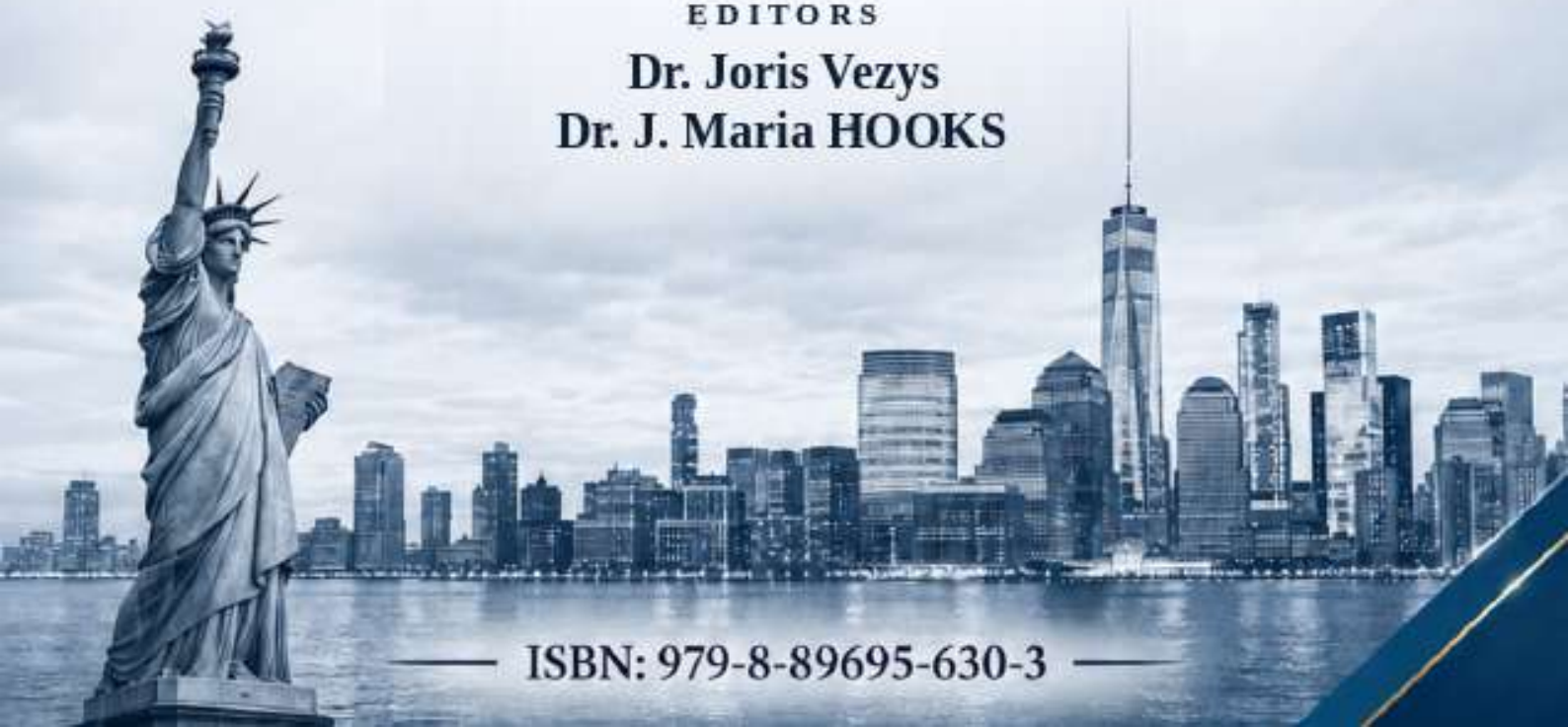
PROCEEDINGS BOOK

November 12-15, 2026 | Manhattan, New York City

EDITORS

Dr. Joris Vezys

Dr. J. Maria HOOKS



ISBN: 979-8-89695-630-3

Copyright © Liberty

THE PROCEEDINGS BOOK

14TH INTERNATIONAL NEW YORK CONFERENCE

ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

November 12–15, 2026 Manhattan, New York City

EDITORS

Dr. Joris VEZYS

Dr. J. Maria HOOKS

Date: 20.11.2026

Liberty Publishing House

Water Street Corridor New York, NY 10038

www.libertyacademicbooks.com

+1 (314) 597-0372

ALL RIGHTS RESERVED NO PART OF THIS BOOK MAY BE REPRODUCED IN ANY FORM, BY PHOTOCOPYING OR BY ANY ELECTRONIC OR MECHANICAL MEANS, INCLUDING INFORMATION STORAGE OR RETRIEVAL SYSTEMS, WITHOUT PERMISSION IN WRITING FROM BOTH THE COPYRIGHT OWNER AND THE PUBLISHER OF THIS BOOK.

© Liberty Academic Publishers 2026

The digital PDF version of this title is available Open Access and distributed under the terms of the Creative Commons Attribution-Non-Commercial 4.0 license (http://creativecommons.org/licenses/by-nc/4.0/) which permits adaptation, alteration, reproduction and distribution for noncommercial use, without further permission provided the original work is attributed. The derivative works do not need to be licensed on the same terms.
adopted by Mariam Rasulan

ISBN: 979-8-89695-630-3

https://www.nyconference.org/

ORGANIZING INSTITUTIONS

CONGRESS ID

CONGRESS TITLE	**14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES**
DATE	November 12–15, 2026
PLACE	Manhattan, New York City, USA

CONGRESS STATISTICS

148	**42**	**67**	**81**
Total Accepted Papers	Total Rejected Papers	Total Papers from Türkiye	Total International Papers

PARTICIPANT COUNTRIES (29)

- USA
- Azerbaijan
- Czech Republic
- Indonesia
- Lebanon
- Nigeria
- Senegal
- Uzbekistan
- Palestine
- Lithuania
- Türkiye
- Bulgaria
- Georgia
- Jordan
- Liberia
- Romania
- South Korea
- Hungary
- Vietnam
- Poland
- Albania
- Croatia
- India
- Kazakhstan
- Morocco
- Saudi Arabia
- Tunisia
- Greece
- Portugal

EVALUATION PROCESS

All applications have undergone a double-blind peer review process

PRESENTATION

Oral Presentations

HONORARY PRESIDENT OF CONFERENCE

Prof. Dr. Enrique MALLEN
Sam Houston State University, USA

ORGANIZATION COMMITTEE

Dr. Hasan YAVUZ
Ambassador, Ministry of Foreign Affairs

Prof. Dr. Habil Andrea BENCSIK
J. Selye University, Komarno, Slovakia

Prof. Dr. Tamar MAKHAROBLIDZE
University of Pittsburgh, USA

Prof. Dr. Kinga Luiza FLAGA-GIERUSZYŃSKA
University of Szczecin, Poland

Prof. Dr. Luiza GABUNIA
Tbilisi State Medical University, Tbilisi, Georgia

Dr. Mustafa Latif EMEK
IKSAD Institute, Türkiye

Leslie R. ROBINSON
Adjunct Professor, New York

Assoc. Prof. Caroline AKHRAS
Notre Dame University

Samira ONTUNÇ
IKSAD Institute

Asena Özge YAŞAR
Archrono Academy LLC, Georgia, USA

Dr. Aleksandra KLICH
University of Szczecin

Seda YAZGAN HADZIBULIC, PhD
Northeastern Illinois University

Dr. Froilan D. MOBO
Philippine Merchant Marine Academy

Dr. J. Maria HOOKS
Methodist Hospital, New York

Dr. Ekaterine LOMIA
Mongolian International University

SCIENCE & ADVISORY COMMITTEE

Prof. Dr. Enrique Mallen
Sam Houston State University, USA

Assoc. Prof. Monica Garoiu
University of Tennessee-Chattanooga, USA

Prof. Dr. Francisco Javier JUEZ GÁLVEZ
Universidad Complutense de Madrid

Prof. Afaq Ahmad
Sultan Qaboos University, Oman

Prof. Dr. GRAA Amel
Djillali Liabes University of Sidi-Bel-Abbès

Prof. Dr. Tamar Makharoblidze
Tbilisi State University

Prof. Dr. Akbar VALADBIGI
Elmi Korbordi University

Prof. Dr. Habil Andrea Bencsik
J. Selye University, Komarno, Slovakia

Prof. Dr. Kinga Luiza Flaga-Gieruszyńska
University of Szczecin, Poland

Prof. Dr. Osman Erkmen
İstanbul Arel University

Prof. Tamalika Sultana
Dhakka University

Prof. Muntazir MEHDI
NUML

Prof. Froilan D. MOBO
Philippine Merchant Marine Academy

Assoc. Prof. Ali Fikret AYDIN
Afyon Kocatepe University

Assoc. Prof. Joanna Studzińska
Kozminski University

Assoc. Prof. Remus Runcan
Aurel Vlaicu University of Arad, Romania

Assoc. Prof. Elżbieta Patkowska
Lublin University of Life Sciences

Assoc. Prof. Mevlüt ALBAYRAK
Ataturk University

Dr. Elza BITSADZE
Akaki Tsereteli State University

Dr. Duygu İNCİ
Kocaeli University

Dr. Aleksandra Klich
University of Szczecin

Dr. Rui Alberto da Silva Martins Isidoro
Universidade Politécnica de Beja, Portugal

Dr. Renu Susan SAMUEL
St. Peter's College

Dr. Caroline AKHRAS
University of Notre Dame

Dr. Valentina MARINESCU
University of Bucharest

Dr. Mahire ÖZÇALIK
Kırıkkale University

Dr. Franck AMOUSSOU
Université d'Abomey-Calavi

Dr. Farah Hashmi
NUML

Dr. Muhammad Faisal
Sindh Madressatul Islam University (SMIU), Karachi, Pakistan

ZHI Huan
Minzu University

Seda HADZIBULIC
Northeastern Illinois University

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

CONFERENCE PROGRAM

Meeting ID: 860 5266 6988
Passcode: 121314

ZOOM LINK:
https://us02web.zoom.us/j/86052666988?pwd=neUkT2hFaaMNdq4pJCmDZB96ucCfsM.1

November 12-15, 2026
Manhattan, New York City

IN PERSON SESSION

November 14, 2026

New York Local Time: 13:^{30}–16:^{00}

Riu Plaza Times Square, New York City

HEAD OF SESSION: Grzegorz Maśloch

Authors	Affiliation	Presentation title
Joris Vezys **Algimantas Bubulis** **Vytautas Jurenas** **Lina Merkeviciene** **Agne Giedraitiene** **Rita Siugzdiniene** **Vacis Tatarunas** **Vishnu Radhakrishnan Nair** **Raminta Rodaite**	*Kaunas University of Technology, Lithuania* *Lithuanian University of Health Sciences, Lithuania* *Lithuanian Energy Institute, Lithuania*	LOW-FREQUENCY ULTRASOUND AS AN EMERGING PHYSICAL ANTIMICROBIAL TECHNOLOGY: EXPERIMENTAL INVESTIGATION AGAINST PROTOTHECA SPP.
Grzegorz Maśloch	*SGH Warsaw School of Economics, Poland*	THE ROLE AND SIGNIFICANCE OF LOCAL GOVERNMENT UNITS IN ENERGY TRANSITION: FROM SOCIAL PARTICIPATION TO ENERGY AUTONOMY
Ahmad ABU ARRA **Muhammed Zakir KESKİN** **Eyüp ŞİŞMAN**	*An-Najah National University, Palestine* *Bartın University, Türkiye* *Yildiz Technical University, Türkiye*	COMPARISON OF A STATION-DERIVED PRECIPITATION GRID (0.1°) WITH ERA5-LAND AND IMERG PRODUCTS IN THE EASTERN PART OF THE KONYA CLOSED BASIN
Ahmad ABU ARRA **Muhammed Zakir KESKİN** **Eyüp ŞİŞMAN**	*An-Najah National University, Palestine* *Bartın University, Türkiye* *Yildiz Technical University, Türkiye*	MULTI-METRIC ASSESSMENT OF IMERG AND ERA5-LAND PRECIPITATION PRODUCTS IN A SEMI-ARID CLOSED BASIN: THE KONYA BASIN, TÜRKIYE
Yucel Aydin **Ali Fuat Ergenç** **Işıl Aydın**	*Istanbul Technical University, Türkiye* *State University of New York at Buffalo, New York, USA*	MULTI-OBJECTIVE STRUCTURAL CONTROL VIA STOCHASTIC DYNAMIC GAMES: A GAME-THEORETIC APPROACH TO VIBRATION SUPPRESSION

Coffee break & Networking session

Mehmet Emin KALGI	*Indiana University Bloomington, USA*	RADICALIZATION BETWEEN RELIGION AND SOCIAL REALITY: THE CASE OF BOKO HARAM
Mehmet Emin KALGI	*Indiana University Bloomington, USA*	REASONS FOR RELIGIOUS CONVERSION FROM CHRISTIANITY TO ISLAM: A FIELD STUDY
Thomas J. Bell	*Texas Wesleyan University, School of Business Administration, USA*	A MODEL CURRICULUM FOR TEACHING RESPONSIBLE AI DEPLOYMENT: ACADEMIC INTEGRITY, CRITICAL THINKING, AND DOMAIN MASTERY
Elindë Dibra	*University of Shkodra "Luigj Gurakuqi", Albania*	LEARNING TO READ, LEARNING TO BELIEVE: THE EARLY POLITICIZATION OF LITERACY IN COMMUNIST ALBANIA, 1945–1990
Jacek Sierak	*SGH Warsaw School of Economics, Poland*	FINANCING GREEN TRANSITION PROJECTS BY POLISH LOCAL GOVERNMENTS

14th INTERNATIONAL NEW YORK CONFERENCE ON

EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

***Participant Countries:* (28)**

USA, Türkiye, Albania, Azerbaijan, Bulgaria, Croatia, Czech Republic, Georgia, India, Indonesia, Jordan, Kazakhstan, Lebanon, Liberia, Morocco, Nigeria, Romania, Saudi Arabia, South Korea, Tunisia, Ukraine, Uzbekistan, Senegal, Hungary, Greece, Palestine, Vietnam, Portugal.

IMPORTANT, PLEASE READ CAREFULLY

- To be able to attend a meeting online, login via **https://zoom.us/join** site, enter ID "Meeting ID or Personal Link Name" and solidify the session.
- The Zoom application is free and no need to create an account.
- The Zoom application can be used without registration.
- The application works on tablets, phones and PCs.
- The participant must be connected to the session 5 minutes before the presentation time.
- All congress participants can connect live and listen to all sessions.
- Moderator is responsible for the presentation and scientific discussion (question-answer) section of the session.

Points to Take into Consideration - TECHNICAL INFORMATION

- Make sure your computer has a microphone and is working.
- You should be able to use screen sharing feature in Zoom.
- Attendance certificates will be sent to you as pdf at the end of the congress.
- Requests such as change of place and time will not be taken into consideration in the congress program.

Before you login to Zoom please indicate your name surname and hall number,
exp. H- 1, Edlira Bylykbashi

12.11.2026 | SESSION-1 | HALL-1

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Akbota Bugibayeva

Authors	Affiliation	Presentation title
Edlira Bylykbashi **Ilta Bylykbashi** **Albana Shahini**	University of Medicine Tirana, Albania	ENDOMETRIAL POLYPS AMONG WOMEN UNDERGOING HYSTEROSCOPY FOR ABNORMAL UTERINE BLEEDING IN ALBANIA
Serxho Golgota **Eritjan Tashi** **Marsel Broqi** **Anxhela Papa** **Emira Hysa** **Alma Teferici** **Kloedina Bratja** **Ina Pojani** **Kristi Reveli** **Irida Ikonomi** **Elona Hysenbelli** **Ilir Peposhi**	*University Hospital Shefqet Ndroqi, Albania*	UNMASKING POSTPARTUM SYSTEMIC LUPUS ERYTHEMATOSUS THROUGH TRANSBRONCHIAL BIOPSY AND PLEURAL CYTOLOGY
Feride Imeraj **Numila Kuneshka-Maliqari**	*University Hospital Center "Mother Teresa", Albania* *University of Medicine, Albania*	LABORATORY RISK STRATIFICATION IN PEDIATRIC PARACETAMOL POISONING
Tedi Minarolli **Birkena Qirjazi**	*University Hospital Center "Mother Theresa", Albania*	SINONASAL DISEASE WITH ORBITAL EXTENSION
Rezana Pengu **Desareda Mero** **Eva Kananllari** **Tina Donefski**	*Fan S. Noli University, Albania*	TRADICIONAL USE OF MEDICINAL PLANTS IN THE PRESPA REGION
Akbota Bugibayeva **Symbat Abzaliyeva** **Kuat Abzaliyev** **Madina Suleimenova** **Tamara Abdirova** **Irina Agababyan**	*Kazakhstan's Medical University, Kazakhstan* *Al-Farabi Kazakh National University, Kazakhstan* *International Information Technology University, Kazakhstan* *Samarkand State Medical University, Uzbekistan*	PREDICTING THE RISK OF CARDIOVASCULAR DISEASES IN THE ELDERLY BASED ON CLINICAL DATA AND HEART RATE VARIABILITY USING MACHINE LEARNING
Klejda Tani **Aisel Oseku** **Surven Metolli**	*University of Tirana, Albania*	EVALUATING FASCIAL MANIPULATION INTEGRATED WITH POSTURAL EXERCISES FOR CHRONIC LOW BACK PAIN MANAGEMENT: A PROSPECTIVE CONTROLLED CLINICAL TRIAL
Jolanda Hyska	*University of Medicine, Albania*	ACCEPTABILITY OF SCHOOL MEAL PROVISION IN ALBANIA: STAKEHOLDER PREFERENCES, REGULATORY FRAMEWORK AND NUTRITIONAL CONSIDERATIONS

(All speakers required to be connected to the session 10 min before the session starts)
Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

12.11.2026 | SESSION-1 | HALL-2

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Güliz TÜRKMENOĞLU

Authors	Affiliation	Presentation title
Güliz TÜRKMENOĞLU	Alanya Alaaddin Keykubat University, Türkiye	A STUDY ON THE USE OF CERATONIA SILIQUA L. AS A MEDICINAL PLANT IN TÜRKİYE
Zeynep Pınar APAYDIN **Şenay GÖRÜCÜ YILMAZ** **Sibel OĞUZKAN BALCI**	Gaziantep University, Türkiye	TIME-DEPENDENT EXPRESSION OF MSI1, NUMB AND ELAV IN IPSC-DERIVED BRAIN ORGANOIDS AND THEIR RELATIONSHIP WITH TAU PATHOLOGY IN ALZHEIMER'S DISEASE MODELING
Sumeyye SAİNKAPLAN **İrem ERGİN** **Oytun Okan ŞENEL**	*Ankara University, Türkiye*	OCULAR ALKALI INJURY IN A DOG FOLLOWING DISINFECTANT EXPOSURE: CLINICAL FINDINGS AND MANAGEMENT
Batuhan Umut ÇAKIL **İrem ERGİN**	*Ankara University, Türkiye*	PERIOCULAR MALIGNANT FIBROUS HISTIOCYTOMA IN A CAT: SURGICAL APPROACH AND CLINICAL FOLLOW-UP
Hafize Boyacı **Selma Söyük**	*İstanbul University-Cerrahpaşa, Türkiye*	IDENTIFYING JOB SATISFACTION AND JOB-RELATED EMOTIONAL EXHAUSTION PROFILES AMONG HEALTHCARE WORKERS: A LATENT PROFILE ANALYSIS
Berna OZDEM **Dilara Hande BARLIK** **Gulsah EVYAPAN**	*Inonu University, Türkiye* *Van Yuzuncu Yil University, Türkiye*	IN VITRO ANTICANCER POTENTIAL OF FERMENTATION SUPERNATANT FROM STREPTOMYCES GOBITRICINI-LIKE ISOLATE BH026 AGAINST SH-SY5Y NEUROBLASTOMA CELLS
Rüveyda Suluhan **Halime Esra Meram**	*Selçuk University, Türkiye*	THE ROLE OF EPIGENETICS AND GENETIC MEMORY IN SEXUALITY AND SEXUAL BEHAVIORS, AND THE NURSING APPROACH
Şerife Çalışkan Söylemez **Eda Yetimoğlu**	*Üsküdar University, Türkiye*	DETERMINANTS OF CERVICAL CANCER MORTALITY AND DISEASE BURDEN IN OECD COUNTRIES: A PANEL DATA ANALYSIS FOR THE 2010–2023 PERIOD

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

12.11.2026 | SESSION-1 | HALL-3

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Manel Essid

Authors	Affiliation	Presentation title
Gibson W. Weh	Potential Scholar Vocational Training Institute, Liberia	BRIDGING ELECTRICAL VOCATIONAL EDUCATION AND INTERDISCIPLINARY INNOVATION: ENHANCING WORKFORCE COMPETENCE THROUGH PRACTICE-BASED TECHNICAL TRAINING IN LIBERIA
Ichrak FETTAH **Doha BELFADIL** **Asiya Rezzouq** **Abderrahim Bouftou** **Sanaa MAJID**	*Hassan II University of Casablanca, Morocco*	DEVELOPMENT AND CHARACTERISATION OF A NANOCOMPOSITE PROTON EXCHANGE MEMBRANE BASED ON POLY (VINYL ALCOHOL) WITH LAYERED DOUBLE HYDROXIDES FOR PROTON EXCHANGE MEMBRANE FUEL CELLS (PEMFC)
Elza Bitsadze **Lia janadze** **Nana oniani-saghinadze**	*Akaki Tsereteli State University, Georgia*	THE ROLE OF BUSINESS PROGRAMMING IN MODERN MANAGEMENT: ALGORITHMIC THINKING, DIGITAL INFRASTRUCTURE, AND HUMAN RESOURCE MANAGEMENT
Johnson A. Obari **Eustace M. Dogo** **Ibrahim M. Abdullahi** **Danlami Maliki**	*Federal University of Technology Minna, Nigeria* *Federal University Lokoja, Nigeria*	THE CUMULATIVE KINETIC ENERGY LOSS OF A VERTICALLY BOUNCING BALL: AN ANALYTICAL APPROACH TOWARDS THE DEVELOPMENT OF AN OPTIMIZATION ALGORITHM
Etibar Vazirov **Farid Tahirov** **Amin Ismayilov**	*ADA University, Azerbaijan* *Baku Modern School, Azerbaijan*	CAN AI DETECT INCONSISTENT DATA? STATISTICAL, RULE-BASED, AND LLM APPROACHES
Manel Essid **Zouhaier Aloui**	*University of Carthage, Tunisia* *King Khalid University, Saudi Arabia*	SYNTHESIS, CRYSTAL STRUCTURE AND OPTICAL PROPERTIES OF A NON-CENTROSYMMETRIC ORGANIC-INORGANIC HEXACHLOROBISMUTHATE(III) HYBRID MATERIAL
Jamila BOUCHGL **Mustapha LAMINE** **Khadija OUAISSA**	*Hassan II University, Morocco* *University Sultan Moulay Slimane, Morocco*	WIND-INDUCED KELVIN–HELMHOLTZ INSTABILITY AT THE AIR–SEA INTERFACE: IMPLICATIONS FOR MARINE HYDRODYNAMICS

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

12.11.2026 | SESSION-1 | HALL-4

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Emine Kambur

Authors	Affiliation	Presentation title
Emine Kambur	Mudanya University, Türkiye	CONNECTIVITY, AUTOMATION AND ROBOTIC SYSTEMS IN SMART FACTORIES
Gökhan Erdi DAĞI **Çelebi ULUYOL**	*Gazi University, Türkiye*	DEVELOPMENT OF AN ARTIFICIAL INTELLIGENCE-BASED DECISION SUPPORT SYSTEM FOR DATA RECOVERY FROM HARD DISK DRIVES
Behiye Canbaz **Çelebi Uluyol**	*Kastamonu University, Türkiye* *Gazi University, Türkiye*	FORMATIVE FEEDBACK STRATEGIES PROVIDED BY GENERATIVE ARTIFICIAL INTELLIGENCE IN EDUCATION AND THEIR EFFECTS ON STUDENT MOTIVATION AND ENGAGEMENT
Yusuf AKIN **Müjdat FIRAT**	*Fırat University, Türkiye*	ENERGY AND FUEL CONSUMPTION ANALYSIS OF A PLUG-IN HYBRID ELECTRIC VEHICLE UNDER WLTC CONDITIONS USING AVL CRUISE M
Hanbey Hazar **Vedat Arslantatar** **Huseyin Sevinc**	*Fırat University, Türkiye*	EFFECTS OF CRUDE BORAGE OIL BLENDING AND DIMETHYL CARBONATE ADDITION ON EXHAUST EMISSIONS OF A SINGLE-CYLINDER DIESEL ENGINE
Hanbey Hazar **Vedat Arslantatar** **Huseyin Sevinc**	*Fırat University, Türkiye*	EXPERIMENTAL EVALUATION OF GASEOUS EMISSIONS FROM A DIESEL ENGINE FUELED WITH CRUDE GARLIC OIL BLENDS AND DIETHYL ETHER
Uğur ACAR	*Osmaniye Korkut Ata University, Türkiye*	DEVELOPMENT OF A GENERALIZABLE MACHINE LEARNING SURROGATE FOR OFF-DESIGN PERFORMANCE PREDICTION OF ORGANIC RANKINE CYCLES

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

12.11.2026 | SESSION-1 | HALL-5

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Özlem ATAY

Authors	Affiliation	Presentation title
Özlem ATAY	Ankara University, Türkiye	ACADEMIC WOMEN IN TURKISH HIGHER EDUCATION MANAGEMENT
Ercan Emre YÜREK **Çelebi ULUYOL**	*Gazi University, Türkiye*	THE EFFECT OF VISUAL TRAINING MATERIALS IN DIFFERENT FORMATS ON AWARENESS IN DIVERSIFIED PHISHING SCENARIOS
Emre YAŞAR **Bilal Nadir ALKAN**	*Isparta University of Applied Sciences, Türkiye* *Independent Researcher, Türkiye*	TOURISM GUIDANCE STUDENTS' EXPERIENCES USING NOTEBOOKLM: ADVANTAGES, LIMITATIONS, AND INTENTIONS FOR FUTURE USE
İlknur BULUT **Filiz KARADAĞ**	*Dokuz Eylul University, Türkiye*	THE IMPACT OF PHILOSOPHY FOR CHILDREN (P4C) PRACTICES ON HIGH ORDER THINKING SKILLS: A SYSTEMATIC REVIEW
Filiz KARADAĞ **İlknur BULUT**	*Dokuz Eylul University, Türkiye*	RECOGNIZING GIFTED STUDENTS ACROSS ACADEMIC PERFORMANCE AND SPECIAL EDUCATIONAL NEEDS PROFILES: A VIGNETTE-BASED COMPARISON OF PRIMARY SCHOOL AND SPECIAL EDUCATION TEACHERS
Mesut ÇOLAKOĞLU **Elif KARAGÜN**	*Kocaeli Metropolitan Municipality, Türkiye* *Kocaeli University, Türkiye*	PERCEPTION OF SUCCESS AMONG 11–13-YEARS OLD CHILDREN ATTENDING RECREATIONAL SPORTS SCHOOLS
Didem Çilengiroğlu **Yıldıray Topcu**	*Ondokuz Mayıs University, Türkiye*	FROM CONTACT TO EVIDENCE: ANALYSIS OF COSMETIC TRACES AND CURRENT ANALYTICAL APPROACHES IN FORENSIC COSMETOLOGY

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

12.11.2026 | SESSION-1 | HALL-6

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Emina Kovačić Ahmetović

Authors	Affiliation	Presentation title
Lorena Kelo **Entela Vinçani**	"Fan S. Noli" University, Albania	USING MICROSOFT EXCEL IN TEACHING ELECTROSTATICS: IMPACT ON GRADE 11 STUDENTS' ACHIEVEMENT AND PERCEPTIONS
Tea Pavičić Zajec **Tamara Ređep, M.Sc.**	*Primary School Varaždin, Croatia*	SECRET MESSAGES IN PRIMARY EDUCATION: USING THE CAESAR CIPHER TO SUPPORT LOGICAL THINKING AND INTERDISCIPLINARY LEARNING
Elda Maraj **Armida Brakaj** **Fizeleni Lekli** **Shkelqim Kuka**	Polytechnic University of Tirana, Albania	A FUZZY LOGIC APPROACH TO SPORTS PERFORMANCE EVALUATION
Eriona Çela	*University of New York Tirana, Albania*	AN ANALYSIS OF TEACHERS` BENEFITS AND CHALLENGES IN INTEGRATING AI TOOLS IN EDUCATIONAL SETTINGS
Emina Kovačić Ahmetović	*University of Zagreb, Croatia*	PERCEIVED SOCIAL SUPPORT AND PARENT–EDUCATIONAL INSTITUTION PARTNERSHIPS: A QUALITATIVE STUDY OF PARENTS OF CHILDREN WITH DISABILITIES IN CROATIA
Dimitrios Kanaros **Polychronis Bourdaniotis**	*Varvakeio Model High School, Greece* *Experimental High School of the University of Patras, Greece*	GLOBAL COURTYARD OF TRADITIONAL GAMES: AN INTERCULTURAL APPROACH TO PHYSICAL EDUCATION
Maria Francisca Marcelino **Eduardo Ortega**	*NOVA University Lisbon, Portugal* *University of Coimbra, Portugal*	WORKPLACE HARASSMENT AND ITS LEGAL IMPLICATIONS: ABSENTEEISM AND TURNOVER INTENTION AMONG WOMEN
Tiago Zambujeira Mancha **Maria Francisca Marcelino**	*NOVA University Lisbon, Portugal*	INVISIBLE CONTAMINANTS, UNCLEAR RESPONSABILITIES: THE LEGAL CHALLENGES OF DRUG RESIDUES IN WASTEWATER

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

12.11.2026 | SESSION-1 | HALL-7

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Josiane El Khoury

Authors	Affiliation	Presentation title
Deacon Torh E. Q. Kalloh	Consolidated Group, Liberia	STRENGTHENING ADMINISTRATIVE LEADERSHIP THROUGH INTERDISCIPLINARY PRACTICES: ENHANCING ORGANIZATIONAL EFFECTIVENESS IN LIBERIA'S PRIVATE SECTOR
Mahtab IRANI	*Istanbul Nişantaşı University, Türkiye*	THE CONDITIONAL ROLE OF STORE INTERIOR DESIGN IN CUSTOMER EXPERIENCE AND BEHAVIORAL INTENTIONS: A QUALITATIVE STUDY IN ISTANBUL
Parvin FEIZI	*Istanbul Nişantaşı University, Türkiye*	SALESPERSON CAPABILITIES AND CUSTOMER OUTCOMES IN ISTANBUL'S READY-TO-WEAR RETAIL SECTOR: A CROSS-SECTIONAL CUSTOMER SURVEY
Xhensila LATO **Edvin LAME**	*Barleti University, Albania* *University of Tirana, Albania*	PARENTAL ALIENATION AND DOMESTIC ABUSE: AN EVIDENCE-BASED LITERATURE REVIEW OF THEIR INTERSECTIONS, CONTROVERSIES, AND IMPLICATIONS FOR PRACTICE
Brunilda Llaftiu	*University of Tirana, Albania*	AI-DRIVEN TAX TECHNOLOGY: ENHANCING GOVERNANCE AND REDUCING EVASION
Josiane El Khoury	*University of Balamand, Lebanon*	EMOTIONAL BRANDING BEYOND BORDERS: CULTURAL NARRATIVES IN MENA AND WESTERN LUXURY JEWELRY ADVERTISING

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

13.11.2026 | SESSION-2 | HALL-1

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Zekeriya Gül

Authors	Affiliation	Presentation title
Işıl Altay	Maltepe University, Türkiye	COMMENT MANAGEMENT IN SOCIAL MEDIA MARKETING COMMUNICATION: A CRITICAL SYNTHESIS OF REPLIES, DELETION CUES, AND DISABLED COMMENTS
Müge KINAY **Hatice NAYMAN HAMAMCI** **Selim AREN**	*Yıldız Technical University, Türkiye*	RISK TOLERANCE AS A BRIDGE BETWEEN PSYCHOLOGICAL CAPITAL AND RISKY INVESTMENT INTENTION
Veysel Mehmet GÜLTEKİN **B. Dilek ÖZBEZEK** **Filiz DEMİR**	*Provincial Directorate of National Education, Türkiye* *Gaziantep University, Türkiye* *Karamanoğlu Mehmetbey University, Türkiye*	THE MEDIATING ROLE OF THRIVING AT WORK IN THE RELATIONSHIP BETWEEN PROSOCIAL MOTIVATION AND WORK ENGAGEMENT: A FIELD STUDY OF HEALTHCARE WORKERS
Res. Assist. Feyza Erdoğan **Vahit Tongur**	*Konya Technical University, Türkiye*	STATISTICAL EVALUATION OF THE PERFORMANCE OF THE DRACO LIZARD OPTIMIZER ON THE CEC-2019 (C06) BENCHMARK FUNCTIONS
Zekeriya Gül	*Gaziantep University, Türkiye*	STOCK MARKET REACTIONS TO THE 2025 IRAN–ISRAEL CONFLICT AND THE 2026 IRAN WAR: COMPARATIVE EVIDENCE FROM GCC COUNTRIES
Şeyma AKBULUT **Çelebi ULUYOL**	*Gazi University, Türkiye*	ANALYSIS OF THE RELATIONSHIP BETWEEN INFORMATION SECURITY MANAGEMENT PROCESSES AND PERSONAL DATA PROTECTION COMPLIANCE MATURITY IN THE ELECTRONIC COMMUNICATIONS SECTOR

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

13.11.2026 | SESSION-2 | HALL-2

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Boyko Tsyntsarski

Authors	Affiliation	Presentation title
T. Aarthi **K. Nilavarasi** **M. Ponmurugan**	Central University of Tamil Nadu, India	FINITE TIME PERFORMANCE OF A CARNOT ENGINE WITH RELATIVISTIC ELECTRON POSITRON PHOTON PLASMA UNDER LOW DISSIPATION REGIME
Florina Ravariu **Cristian Ravariu**	*Union of Professional Visual Artists of Romania Association UAPR, Romania*	THE CIRCLE OF LIFE: WATER MOLECULES NECKLACE, LIFE INSPIRES ART
Arli Aditya Parikesit	*i3L University, Jakarta, Indonesia*	TWO-TIER AI TRIAGE FOR VIRAL GENE ANNOTATION WITHOUT RUNTIME SEQUENCE DATABASE QUERIES: A FIVE-PATHOGEN PROOF OF CONCEPT
Desareda Mero **Rezana Pengu** **Xhuljana Sula**	*Fan S. Noli University, Albania*	GENETIC STRUCTURE AND INBREEDING IN THE POPULATION OF KORÇË, ALBANIA: AN ASSESSMENT THROUGH SURNAME FREQUENCIES
Boyko Tsyntsarski **Ivanka Stoycheva** **Nartzislav Petrov** **Bilyana Petrova** **Angelina Kosateva** **Izabela Ivanova**	*Bulgarian Academy of Sciences, Bulgaria*	ECOLOGICAL TECHNOLOGY FOR CONVERSION OF WASTE BIOMASS TO FUNCTIONAL CARBON MATERIALS
Ibtissam Zriaa **Noureddine Sajai** **Abdellah El Boukili** **Rachid Fakhreddine** **Saida Krimi**	*Hassan II University of Casablanca, Morocco*	NOVEL BOROPHOSPHATE GLASSES: SYNTHESIS, STRUCTURAL, PHYSICOCHEMICAL CHARACTERIZATION AND IN VITRO BIOACTIVITY
Viktoriia SKYBA	*The Pennsylvania State University, USA*	INTENSIFICATION OF DROUGHTS IN THE RIVER BASIN DISTRICTS OF UKRAINE
Iryna ABRAMOVA	*The Pennsylvania State University, USA*	FINANCIAL INCLUSION IN RURAL COMMUNITIES OF UKRAINE DURING WARTIME: EVIDENCE FROM A LOCAL SURVEY

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

13.11.2026 | SESSION-2 | HALL-3

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Etibar Vazirov

Authors	Affiliation	Presentation title
Etibar Vazirov **Ayan Bayramova**	ADA University, Azerbaijan Dunya School, Azerbaijan	BRAIN ACTIVITY CLASSIFICATION WITH DEEP LEARNING AND EEG CHANNEL SELECTION
Etibar Vazirov **Marat Salim**	*ADA University, Azerbaijan* *Czech Technical University in Prague, Czech Republic*	CAN AI REALLY FORGET? EVALUATING MACHINE UNLEARNING UNDER DATA POISONING
Huseyn Huseynov	*Azerbaijan State Oil and Industry University, Azerbaijan*	GENERATIVE AI TOOLS IN HIGHER EDUCATION: OPPORTUNITIES, RISKS AND ACADEMIC INTEGRITY
Mohamed Ziad Mammass **Hasna Abioui**	*Ibn Zohr University, Morocco*	ADOPTION AND USE OF GENERATIVE ARTIFICIAL INTELLIGENCE IN TEACHING AND RESEARCH: A TECHNOLOGY ACCEPTANCE MODEL SURVEY OF MOROCCAN ACADEMICS AND DOCTORAL STUDENTS
Ardi DHIMA **Stavri DHIMA**	*European University of Tirana, Albania* *Independent Energy and Oil and Gas Consultant, Albania*	PLANNING NATURAL GAS INFRASTRUCTURE FOR ALBANIAN CITIES: SPATIAL SEQUENCING, DEMAND-LED NETWORKS AND REGIONAL CORRIDOR INTEGRATION
L.H. Omari **J. Louafi**	*Hassan II University of Casablanca, Morocco*	STRUCTURAL, MORPHOLOGICAL AND OPTICAL PROPERTIES OF THE LA2W2O9/FE2O3 COMPOSITE FOR UV-SHIELDING APPLICATIONS
Khadija OUAISSA **Jamila BOUCHGL** **M'Hamed HMAMOU** **Mustapha Hasnaoui**	*Higher institute of maritime Fisheries, Morocco* *University Sultan Moulay Slimane, Morocco* *Ibn Zohr University, Morocco*	COMPARATIVE EVALUATION OF COMMERCIAL FEED AND AZOLLA (AZOLLA PINNATA) ON GROWTH PERFORMANCE AND ZOOTECHNICAL PARAMETERS OF TILAPIA (OREOCHROMIS NILOTICUS)
Khadija OUAISSA **Jamila BOUCHGL** **Zakaria Achtouk** **M'Hamed HMAMOU** **Mustapha Hasnaoui**	*Higher institute of maritime Fisheries, Morocco* *University Sultan Moulay Slimane, Morocco* *Ibn Zohr University, Morocco*	AZOLLA PINNATA AS A LOCAL BIOMASS RESOURCE FOR SUSTAINABLE AQUACULTURE: A LABORATORY MONITORING APPROACH AND RESEARCH PRIORITIES FOR FEED APPLICATIONS

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

13.11.2026 | SESSION-2 | HALL-4

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Mukaddes Karataş

Authors	Affiliation	Presentation title
Kübranur AĞTOPRAK **Uğur KARAASLAN**	*Belgin Oil, R&D Center, Kocaeli, Türkiye*	EFFECT OF SULFURIZED OLEFIN ON WEAR BEHAVIOR IN LITHIUM COMPLEX GREASES AND EVALUATION OF AW/EP ADDITIVE SYSTEMS
Mukaddes Karataş **Buket Erzen** **Şermin Deniz** **Ramazan Orhan**	*Fırat University, Türkiye*	DISPERSION, AGGLOMERATION, AND MECHANICAL PERFORMANCE IN EPOXY COMPOSITES INCORPORATING GREEN-SYNTHESIZED METAL OXIDE NANOPARTICLES: A CRITICAL REVIEW
Buket Erzen **Mukaddes Karataş** **Şermin Deniz** **Ramazan Orhan**	*Fırat University, Türkiye*	SUSTAINABLE FERRITE–CARBON HYBRID COMPOSITES FOR MICROWAVE ABSORPTION: A CRITICAL REVIEW OF MATERIAL DESIGN AND PERFORMANCE
Mertcan Nazar **Umut Güneş Sefercik**	*Gebze Technical University, Türkiye*	SENSITIVITY OF LiDAR-BASED POWER LINE RISK MAPS TO SEGMENTATION ERRORS AND CLEARANCE REGULATIONS
Umut Güneş Sefercik **Mertcan Nazar**	*Gebze Technical University, Türkiye*	THREE-DIMENSIONAL MONITORING OF FOREST LOSS CAUSED BY FIRES USING RADAR SATELLITE IMAGERY, CASE STUDY: 2021 MANAVGAT FIRE, TÜRKİYE
Aysun Yesilgul **Celebi Uluyol**	*Gazi University, Türkiye*	THE EFFECT OF SOCIAL INTERACTION ELEMENTS IN LEARNING MANAGEMENT SYSTEMS BY THE ATTANDENCE AND MOTIVATION OF STUDENTS

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

13.11.2026 | SESSION-2 | HALL-5

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Emine KAYA ALTOP

Authors	Affiliation	Presentation title
Çağla Gizem KARAİBİŞ **Barış ÖZDEMİR**	*Maltepe University, Türkiye*	TIME PERSPECTIVE PROFILES AND INTOLERANCE OF UNCERTAINTY: A COMPARATIVE STUDY BETWEEN YOUNG AND MIDDLE-AGED ADULTS
Zeynep KÜTAY **Barış ÖZDEMİR**	*Maltepe University, Türkiye*	EXAMINING THE RELATIONSHIP BETWEEN ADVERSE CHILDHOOD EXPERIENCES AND MENTALIZATION IN ADULTS WITH LOW LEVELS OF ATTENTION DEFICIT/HYPERACTIVITY SYMPTOMS
Mustafa Tuncer OKUMUŞ **Şehriban Buse BAYSAL**	*Kahramanmaraş Sütçü İmam University, Türkiye*	THE MEDIATING ROLE OF PERCEIVED ORGANIZATIONAL SUPPORT IN THE RELATIONSHIP BETWEEN WORK-LIFE BALANCE AND WELL-BEING AT WORK AMONG GEN Z TOURISM EMPLOYEES: THE CASE OF ANTALYA
Emine KAYA ALTOP **Sine KAYA**	*Ondokuz Mayıs University, Türkiye*	DEEP LEARNING-BASED WEED DETECTION, SEGMENTATION AND SPATIAL MAPPING FOR PRECISION WEED MANAGEMENT
Emine KAYA ALTOP **Sine KAYA**	*Ondokuz Mayıs University, Türkiye*	AI-DRIVEN PRECISION CROP PROTECTION: INTEGRATING DISEASE DIAGNOSIS, WEED DETECTION, EARLY WARNING AND DECISION SUPPORT
Ömer Ümit Okçu **Nuray ÖZER**	*Tekirdağ Namık Kemal University, Türkiye*	BIOLOGICAL CONTROL OF SCLEROTINIA SCLEROTIORUM IN LETTUCE: RESEARCH TRENDS, BIOLOGICAL CONTROL AGENTS, AND EFFICACY LEVELS
Abdullah ERİŞ	*Erişler Gıda A.Ş., Türkiye*	THE EFFECT OF CORPORATE SOCIAL RESPONSIBILITY PROJECTS ON STAKEHOLDER PERCEPTIONS IN BUSINESSES

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

13.11.2026 | SESSION-2 | HALL-6

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Monika Myrto

Authors	Affiliation	Presentation title
Stelina Ndreu	*University of Tirana, Albania*	SPEAKING WITHOUT FEAR? EXPLORING THE ROLE OF CHATBOTS IN REDUCING ANXIETY DURING EFL SPEAKING PRACTICE
Nestan Akobia	*David Aghmashenebeli University, Georgia*	HOW ENGLISH SPEAKERS EXPRESS HUMOR IN DAILY LIFE
Aysel Ceferova Qezenfer qizi	*Azerbaijan State Oil and Industry University, Azerbaijan*	CULTURAL DIFFERENCES AND THE CHALLENGES OF TRANSLATING AZERBAIJANI DOMESTIC AND TRADITIONAL VOCABULARY INTO ENGLISH: A COMPARATIVE STUDY OF AZERBAIJANI LITERATURE
Irini Arapi(Sylari) **Eftimi Sylari**	*University of Tirana, Albania*	IMPROVING ATTENTION FOR BETTER READING OUTCOMES IN PRIMARY SCHOOLS
Greta Pergjegji	*Albanian Defence Academy, Albania*	THE UNIVERSAL ACQUISITION SYSTEM: A COGNITIVE PERSPECTIVE ON ESP LEARNING
Monika Myrto	*Defence and Security College, Albania*	ASSESSING THE DIVERGENCE BETWEEN CLASSROOM INSTRUCTION AND STANAG 6001 HIGH-LEVEL PROFICIENCY TESTING
Nguyen Chi NGUYEN **Nguyen Thi Hong NHO** **Luong Duy DAL** **Quach Tuyet Minh**	*Dong Thap University, Vietnam*	DEVELOPING A DIGITAL COMPETENCE ASSESSMENT TOOLKIT FOR GRADE 11 STUDENTS IN LITERATURE SUBJECT BASED ON THE DIGCOMP COMPETENCE FRAMEWORK
Elsuida Hani	*University of Tirana, Albania*	BEYOND THE TEXTBOOK: THE USE OF AUTHENTIC MATERIALS IN TEACHING ENGLISH IDIOMS TO ALBANIAN EFL LEARNERS

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

14.11.2026 | SESSION-3 | HALL-1

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Nazim ERYILMAZ

Authors	Affiliation	Presentation title
Arzu Al **Ege Gündüz**	Marmara University, Türkiye	ARTIFICIAL INTELLIGENCE IN FINANCIAL DECISION-MAKING AND INTERNATIONAL DIPLOMACY
Nurgül Güneş **Evrim Gemici**	*Istanbul Health and Technology University, Türkiye*	FROM STORIES TO MEMORY: STORYTELLING IN SHORT-FORM VIDEO MARKETING AND COGNITIVE BRAND OUTCOMES IN THE FASHION INDUSTRY
NAZIM ERYILMAZ	*University of Kansas, USA*	HOW CAN THE SAME ISSUE LEAD TO DIVERGENT POLITICAL OUTCOMES? IMMIGRATION-SPECIFIC CRIME ATTRIBUTION AND ITS EFFECTS ON SUPPORT FOR EXECUTIVE POWER AND GUN CONTROL POLICY
Elif Bostanoğlu **Didem Balkanlı** **Benan İnan** **Sinan Kutluay**	*Istanbul Technical University, Türkiye* *Yildiz Technical University, Türkiye*	COMPARATIVE ANALYSIS OF CHLORELLA VULGARIS CULTIVATION AT THE LABORATORY SCALE USING MUNICIPAL WASTEWATER FROM TWO ADVANCED BIOLOGICAL WASTEWATER TREATMENT PLANTS
Havvanur TULUM **Ayşe Sanem ŞAHLI**	*Hacettepe University, Türkiye*	DETERMINATION AND EDUCATION OF AWARENESS REGARDING HEARING LOSS RISK FACTORS AND EARLY PREVENTION AMONG IN PREGNANT WOMEN
Özge Başak KARAKAYA **Ayşe Sanem ŞAHLI**	*Hacettepe University, Türkiye*	PARENTAL AWARENESS OF THE EFFECTS OF SCREEN EXPOSURE ON CHILDREN'S HEARING, SPEECH AND LANGUAGE SKILLS

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

14.11.2026 | SESSION-3 | HALL-2

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Bledar KRAJA

Authors	Affiliation	Presentation title
Bledar KRAJA	*University of Medicine Tirana, Albania*	DISEASE BURDEN, MODIFIABLE RISK FACTORS, AND HEALTH POLICY RESPONSES IN ALBANIA: PRIORITIES FOR 2021-2030
Elona Hasalla **Ilda Taka** **Celjana Toti** **Gerta Kacani** **Etleva Dobroniku**	*University of Elbasan "Aleksander Xhuvani", Albania* *University of Tirana, Albania*	FROM DIGITAL SETUP TO CLINICAL REALITY: DETERMINANTS OF PREDICTABILITY IN CLEAR ALIGNER THERAPY
Ilda Taka **Elona Hasalla**	*University of Elbasan, Albania*	THE ROLE OF NURSING CARE IN THE MANAGEMENT OF PATIENTS WITH BRAIN METASTASES TREATED WITH STEREOTACTIC RADIOSURGERY: A NARRATIVE REVIEW
Vladimir SAVELJEV	*Independent researcher, Daejeon, South Korea*	MULTILAYERED MOIRÉ EFFECT IN TWISTED LAYERS
Ameni Brahmia **Linda Bejaoui** **Rached Ben Hassen**	*University of Tunis El Manar, Tunisia* *King Khalid University, Saudi Arabia*	NOVEL MONO- AND BIS-ENAMINONE COUMARINS: CRYSTAL STRUCTURE, THEORETICAL INSIGHTS AND ANTIMICROBIAL POTENTIAL
Amarilda Hysenshahaj **Dorina Toçi** **Alban Ylli** **Jolanda Hyska**	*University of Medicine Tirana, Albania*	STROKE INCIDENCE IN ALBANIA COMPARED WITH BALKAN AND EUROPEAN COUNTRIES: SEX AND AGE DIFFERENCES
Maroua RIAD **Ahmad AL-SHAMI** **Jamal MABROUKI**	*Mohammed V University in Rabat, Morocco*	BREAST CANCER DORMANCY AND MINIMAL RESIDUAL DISEASE: MOLECULAR MECHANISMS AND THERAPEUTIC CHALLENGES
Israr Ahmad	*Coppin State University, USA*	FIXED-TIME SYNCHRONIZATION OF HYPERCHAOTIC SYSTEMS

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

14.11.2026 | SESSION-3 | HALL-3

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Wahiba HENNICHE

Authors	Affiliation	Presentation title
Amal Algouti	Cadi Ayyad University, Morocco	THE ILLUSION OF ORGANIZATIONAL CHANGE: WHEN INNOVATION BECOMES SYMBOLIC RATHER THAN TRANSFORMATIVE
Altay Mahmudov	*Azerbaijan State University of Economics, Azerbaijan*	RETHINKING MACROECONOMIC NOWCASTING AND FORECASTING: INTEGRATING ECONOMETRICS AND ARTIFICIAL INTELLIGENCE
Wahiba HENNICHE	*King Khalid University, Saudi Arabia*	SUSTAINABILITY DISCLOSURE AND THE COST OF DEBT: PANEL EVIDENCE FROM SAUDI NON-FINANCIAL LISTED FIRMS
Olgerta Idrizi	*Mediterranean University of Albania, Albania*	CAN WE TRUST AI PREDICTIONS OF PUBLIC PROJECT OVERRUNS? A STATISTICAL RE-EVALUATION
Elena Denisa MATEEVICI **Ivona RĂPAN** **Anca CRISTEA** **Felicia MICU**	*Institute of National Economy, Romania* *The Institute for World Economy, Romania* *Elina Matei Basarab Economic Technological High School, Romania*	THE STRATEGIC ROLE OF SOCIAL MARKETING IN ENHANCING THE SOCIOECONOMIC IMPACT OF SOCIAL ENTERPRISES
Isak Kafexholli **Alma Braimllari**	*University of Tirana, Albania*	THE GRAVITY MODEL IN ANALYZING MIGRATION FROM THE WESTERN BALKANS: A LITERATURE REVIEW
Anita Boros	*Ludovika University of Public Service, Hungary*	FROM LEGAL PRINCIPLE TO TECHNICAL REQUIREMENT: THE INTERDISCIPLINARY ARCHITECTURE OF ADMINISTRATIVE INSTRUMENTS CONCRETISING SUSTAINABILITY IN CIRCULAR ECONOMY REGULATION

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

14.11.2026 | SESSION-3 | HALL-4

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Hacer YILMAZ

Authors	Affiliation	Presentation title
Emine Betül KARABIYIK **Nilüfer DARICA**	Hasan Kalyoncu University, Türkiye	EXAMINING THE RELATIONSHIP BETWEEN NATURE RELATEDNESS AND SELF-COMPASSION AMONG PRE-SERVICE PRESCHOOL TEACHERS
Zeynep İrem Tuncer **Fatma Karaman**	*Fırat University, Türkiye* *Graduate School of Social Sciences, Türkiye*	A COMPARATIVE ANALYSIS OF FORBIDDEN LOVE, TRAGIC ENDINGS, AND THE PSYCHOLOGY OF INFIDELITY IN EFFI BRIEST AND AŞK-I MEMNU
Latife Martlı **Fatma Karaman**	*Fırat University, Türkiye*	A COMPARISON OF THE THEMES OF GUILT, AUTHORITY, AND ALIENATION IN FRANZ KAFKA'S "THE TRIAL" AND SABAHATTİN ALİ'S "İÇİMİZDEKİ ŞEYTAN"
Selin OTHAN **Arzu ÖNEL**	*Göle Bedirhan Bey Anatolian Imam Hatip High School, Türkiye* *Kafkas University Institue of Scince, Türkiye*	IN NATURE, BUT WHERE IN THE MIND? THE VISIBILITY AND ECOLOGICAL ROLE OF PLANTS IN HIGH SCHOOL STUDENTS' IDEAS ABOUT NATURE
Hacer YILMAZ	*Fırat University, Türkiye*	PROOF OF MARRIAGE IN THE LATE OTTOMAN EMPIRE: THE CASES OF EMİNE AND SAFİNAZ
Hasan Atakan YILDIRIM	*Akdeniz University, Türkiye*	THE RECREATION OF TRADITIONAL MINIATURE ART NARRATIVES THROUGH AI-ASSISTED ANIMATION
Asel Irmak FIÇICIOĞLU **Muazzez GÜRGAN ESER** **Çetin YAĞCILAR**	*Tekirdağ Namık Kemal University, Türkiye*	ASSESSMENT OF GROWTH PERFORMANCE AND PIGMENT CONTENT IN DUNALIELLA SALINA CULTURES GROWN IN CLOSED PHOTOBIOREACTOR SYSTEMS AT 40 G L^{-1} SALINITY
Bilge PEHLİVAN **Muazzez GÜRGAN ESER** **Çetin YAĞCILAR**	*Tekirdağ Namık Kemal University, Türkiye*	INVESTIGATION INTO THE EFFECTS OF TWO DIFFERENT PHOTOPERIOD REGIMES ON EARLY DEVELOPMENT IN ZEBRAFISH (DANIO RERIO)

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

14.11.2026 | SESSION-3 | HALL-5

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Mohammed Waheeb

Authors	Affiliation	Presentation title
Dijana Gracin	*Dr. Franjo Tuđman Defense and Security University, Croatia*	HATE SPEECH IN CROATIA: THE APPLICATION OF ARTICLE 325 OF THE CRIMINAL CODE AND THE BOUNDARIES OF FREEDOM OF EXPRESSION
Corneliu Tuni **Mihai Susanu**	*University of European Political and Economic Studies, Romania*	EUROPEAN UNION ENLARGEMENT TO THE EAST AND CHANGES IN THE MEDIATION LEGISLATION WITHIN THE REPUBLIC OF MOLDOVA
Mihai Susanu **Corneliu Tuni**	*University of European Political and Economic Studies, Romania*	EUROPEAN UNION ENLARGEMENT TO THE EAST AND HOW LEGISLATIVE CHANGES WILL AFFECT THE ECONOMIC ENVIRONMENT OF THE REPUBLIC OF MOLDOVA
Mohammed Waheeb	*Hashemite University, Jordan*	THE ROLE OF THE CLIMATIC ENVIRONMENT IN THE GLOBAL DISTINCTION OF THE JORDANIAN NICOLAUS DATE DURING THE BYZANTINE ERA: A HISTORICAL AND GEOGRAPHICAL/AGRICULTURAL STUDY
Mohammed Waheeb **ENSAR FIRAT**	*Hashemite University, Jordan* *Mohammed V University, Morocco*	TYPES OF DIVINE RETRIBUTION ASSOCIATED WITH CLIMATIC AND GEOLOGICAL PHENOMENA IN THE NOBLE QURAN: AN INTERDISCIPLINARY ANALYTICAL STUDY BETWEEN MODERN CLIMATIC STUDIES AND THE QURANIC TEXT
Xhiljola Abdihoxha	*European University of Tirana, Albania*	TRANSLATING CULTURE OR MEDIATING CULTURE? THE REPRESENTATION OF ALBANIAN CULTURAL CONCEPTS FOR INTERNATIONAL AUDIENCES
Aliou SENE	*Cheikh Anta Diop University of Dakar, Senegal*	FROM ARCHIVES TO DATA: RENEWING THE WRITING OF SENEGAL'S CULTURAL HISTORY

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

14.11.2026 | SESSION-3 | HALL-6

New York Local Time: 08:^{00}–10:^{30}

Ankara Local Time: 16:^{00}–18:^{30}

HEAD OF SESSION: Ayse Gul GEMCI

Authors	Affiliation	Presentation title
Safiye İrem Dizdar	Yeni Yüzyıl University, Türkiye	REFERENCES THAT THE MAE KAMPONG MODEL COULD PROVIDE FOR THE VILLAGE OF TAHTAKUŞLAR AS AN EXAMPLE OF COLLECTIVE SUSTAINABILITY
Yasemin Hekimoğlu **Elif Özgen Aydın**	*Bolu Abant Izzet Baysal University, Türkiye*	HEALING SPACE, GENDERED PLACE: A TOPOANALYTICAL READING OF THE HOSPITAL IN TURKISH LITERATURE
Elif ATICI TEKTAŞ **Melike KALKAN**	*Balıkesir University, Türkiye* *Uşak University, Türkiye*	FROM SPATIAL LOSS TO DIGITAL MEMORY: PRESERVATION AND TRANSMISSION OF URBAN MEMORY AFTER EARTHQUAKES
Eda Gizem Almalı **Asena Soyluk**	*Gazi University, Türkiye*	WOOL AS A CLIMATE-SENSITIVE INSULATION ALTERNATIVE WITH TRACES OF THE PAST: THE ERZURUM EXAMPLE
Ayse Gul GEMCI	*Istanbul Sabahattin Zaim University, Türkiye*	RECLAIMED SURFACES: SPATIAL DYNAMICS OF UNAUTHORIZED STREET ART AT KARAKOY FERRY TERMINAL
Mehmet Erzi **Assoc. Prof. Dr. Mehdi Öztürk**	*Istanbul Arel University, Türkiye*	EFFECT OF SEISMIC ISOLATION ON THE EARTHQUAKE PERFORMANCE AND CONSTRUCTION COST OF REINFORCED CONCRETE BUILDINGS
Şeyma Aydın **Oktay Özkan**	Erciyes University, Türkiye	ENHANCING THE EFFICIENCY OF PHOTOCATALYTIC AMOXICILLIN REMOVAL THROUGH RESPONSE SURFACE METHODOLOGY: A COMPARATIVE ANALYSIS OF LITERATURE-BASED AND EXPERIMENTALLY REFINED BOX–BEHNKEN DESIGNS
Serhat YANIK **Fatih Mehmet Coşkun**	*Independent Researcher, Türkiye* *Medeniyet University, Türkiye*	FREQUENCY DEPENDENT RESPONSE OF Bi_2O_3 PTFE EPOXY STACKS WITH FILTER PAPER

(All speakers required to be connected to the session 10 min before the session starts)

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

CONFERENCE GALLERY

INTERNATIONAL
NEW YORK
CONFERENCE
November 12-15, 2026
New York

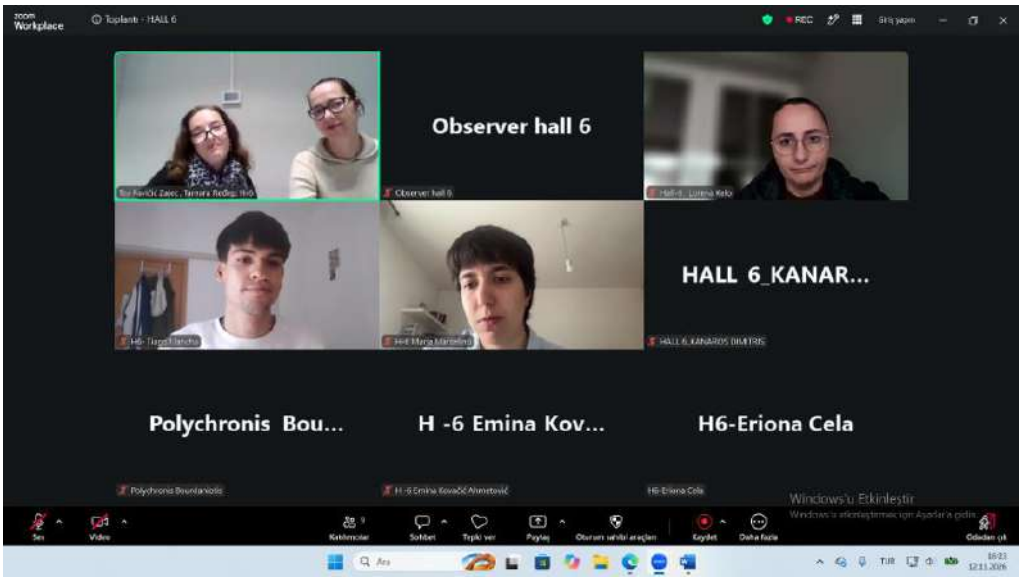
INTERNATIONAL
NEW YORK
CONFERENCE
November 12-15, 2026

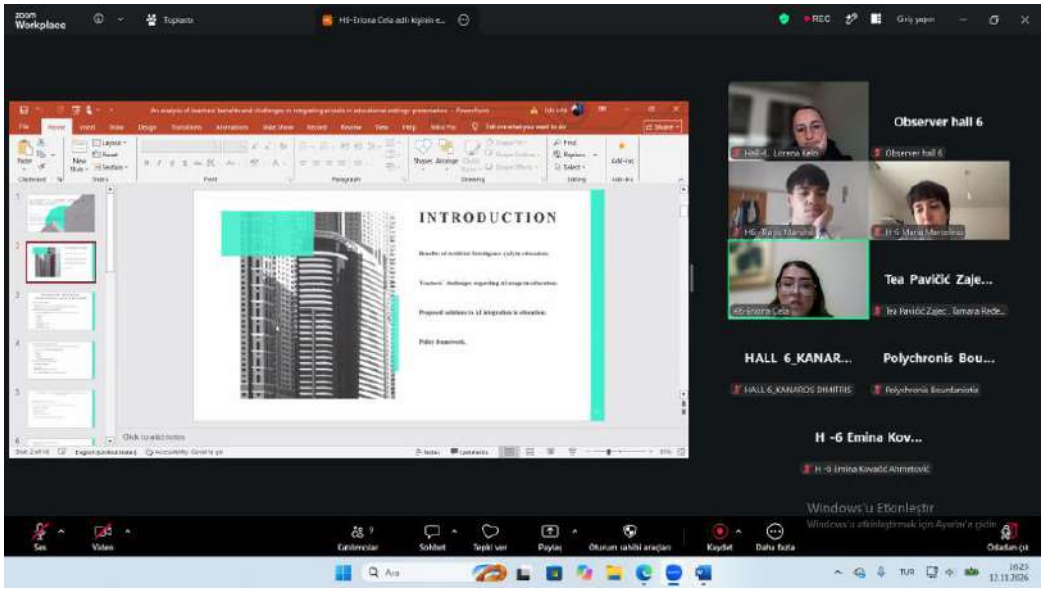
November 12-15, 2026
IKSAD
AMERICAS

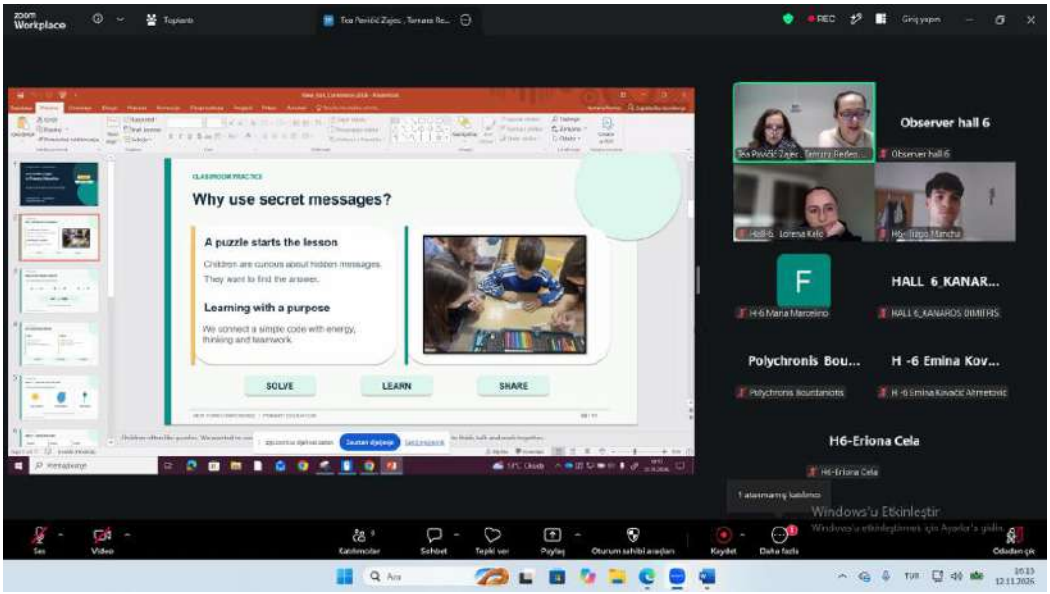
INTERNATIONAL
NEW YORK
CONFERENCE
November 12-15, 2026
New York

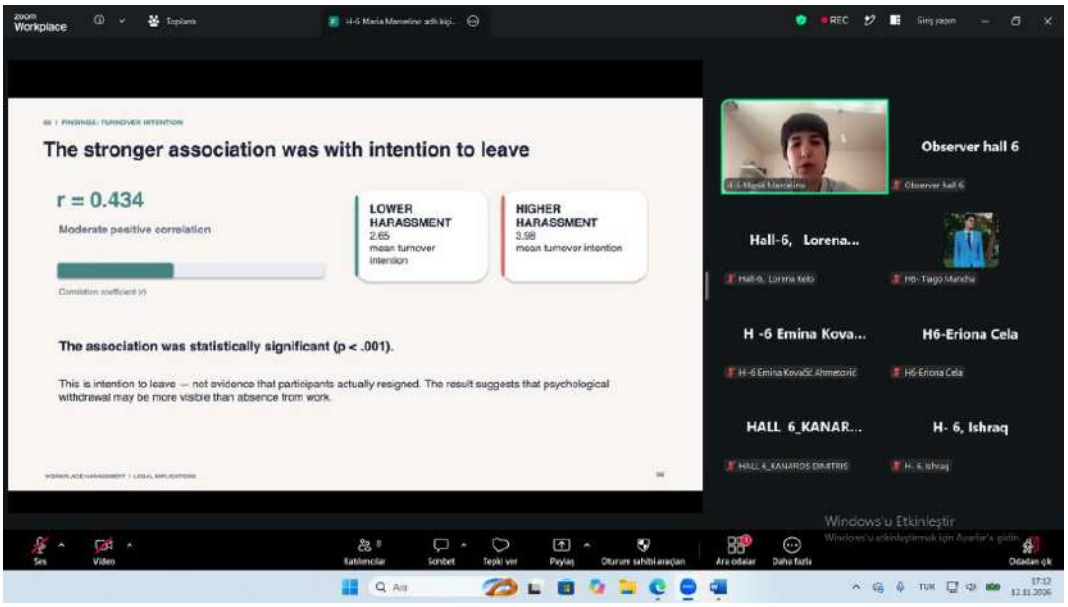
INTERNATIONAL
NEW YORK
CONFERENCE
November 12-15, 2026

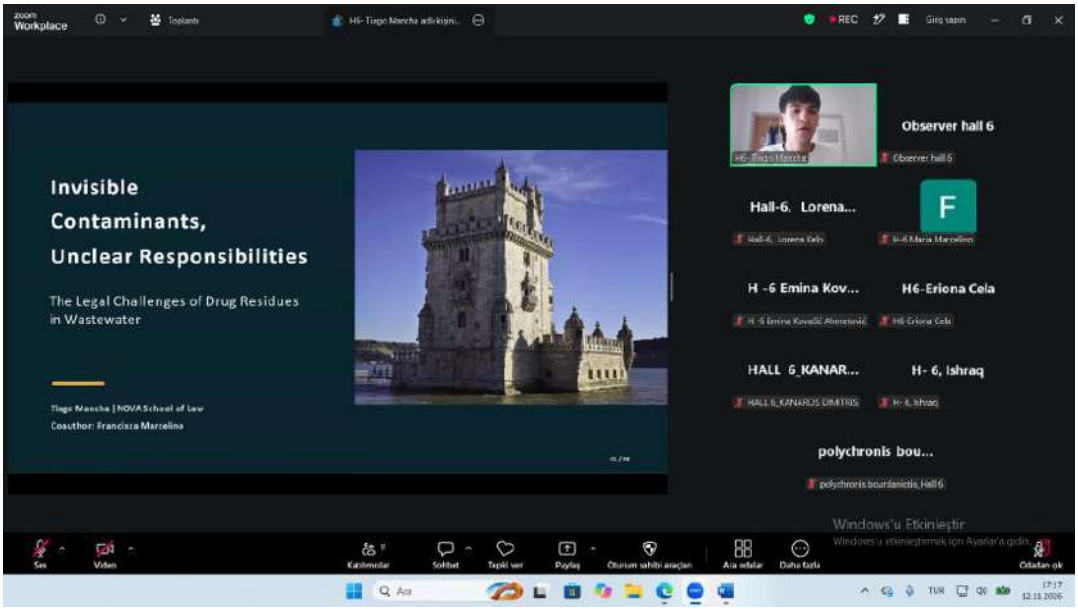
NEW YORK
CONFERENCE
November 12-15, 2026

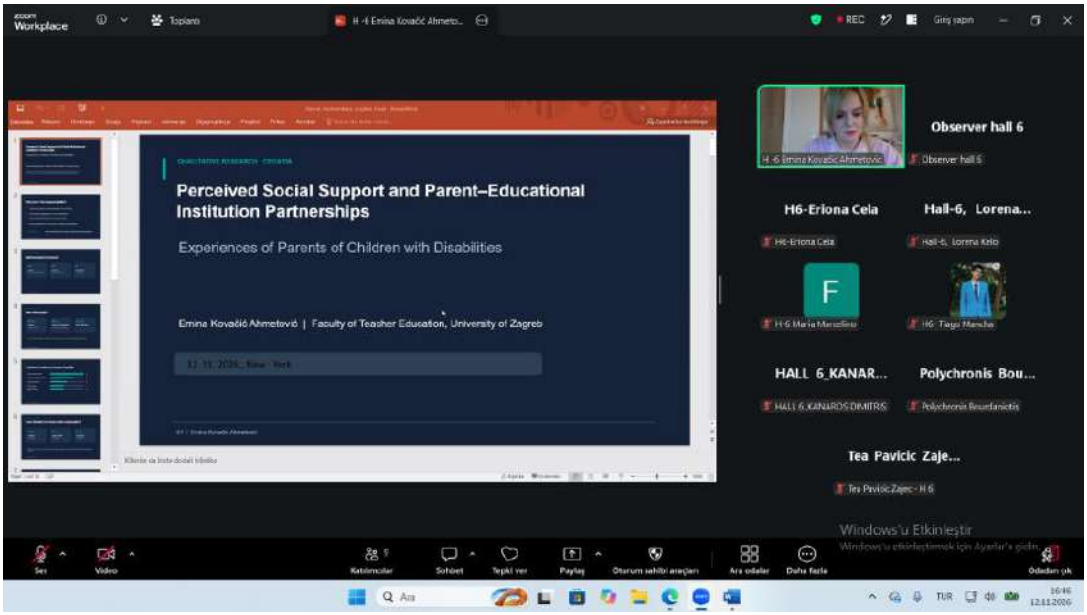

Observer hall 6
HALL 6_KANAR...
Polychronis Bou...
H -6 Emina Kov...
H6-Eriona Cela

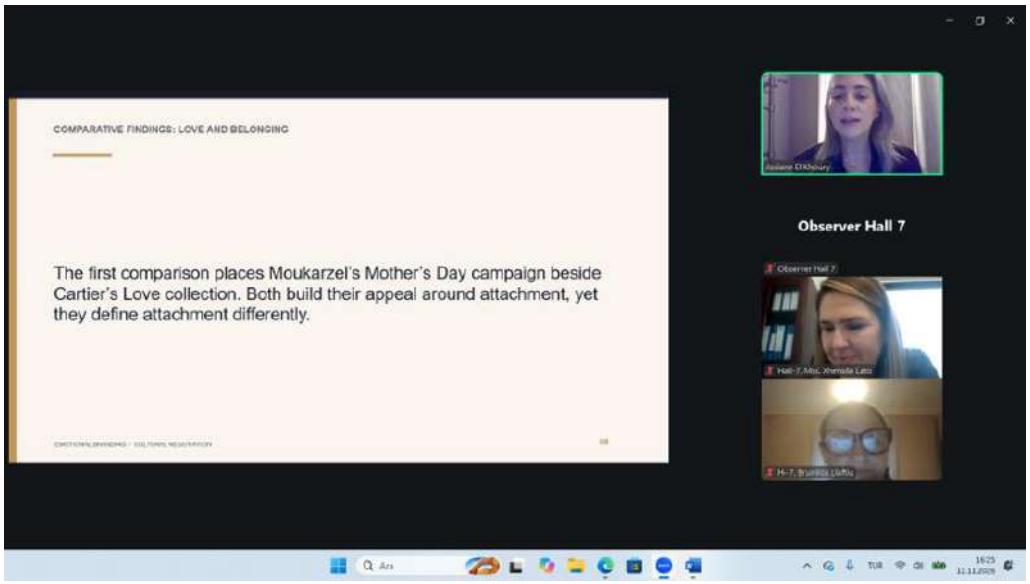

INTRODUCTION
Observer hall 6
Tea Pavičić Zaje...
HALL 6_KANAR...
Polychronis Bou...
H -6 Emina Kov...

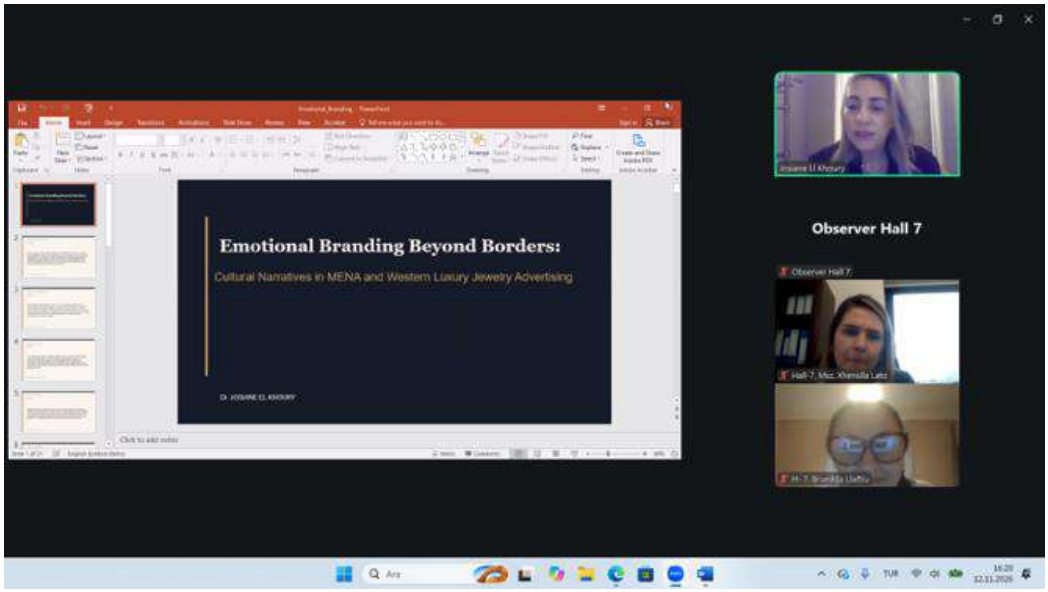

Why use secret messages?
A puzzle starts the lesson
Learning with a purpose
SOLVE
LEARN
SHARE
Observer hall 6
HALL 6_KANAR...
Polychronis Bou...
H -6 Emina Kov...
H6-Eriona Cela

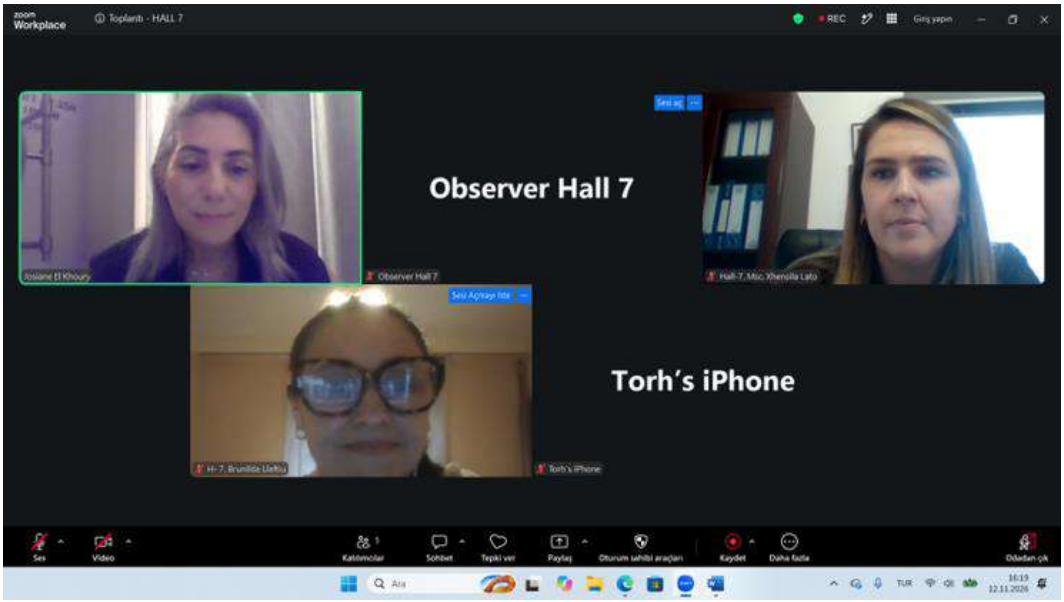

The stronger association was with intention to leave
r = 0.434
Moderate positive correlation
LOWER HARASSMENT
2.65
mean turnover intention
HIGHER HARASSMENT
3.98
mean turnover intention
The association was statistically significant (p < .001).
This is intention to leave — not evidence that participants actually resigned. The result suggests that psychological withdrawal may be more visible than absence from work.
Observer hall 6
Hall-6, Lorena...
H -6 Emina Kova...
H6-Eriona Cela
HALL 6_KANAR...
H- 6, Ishraq

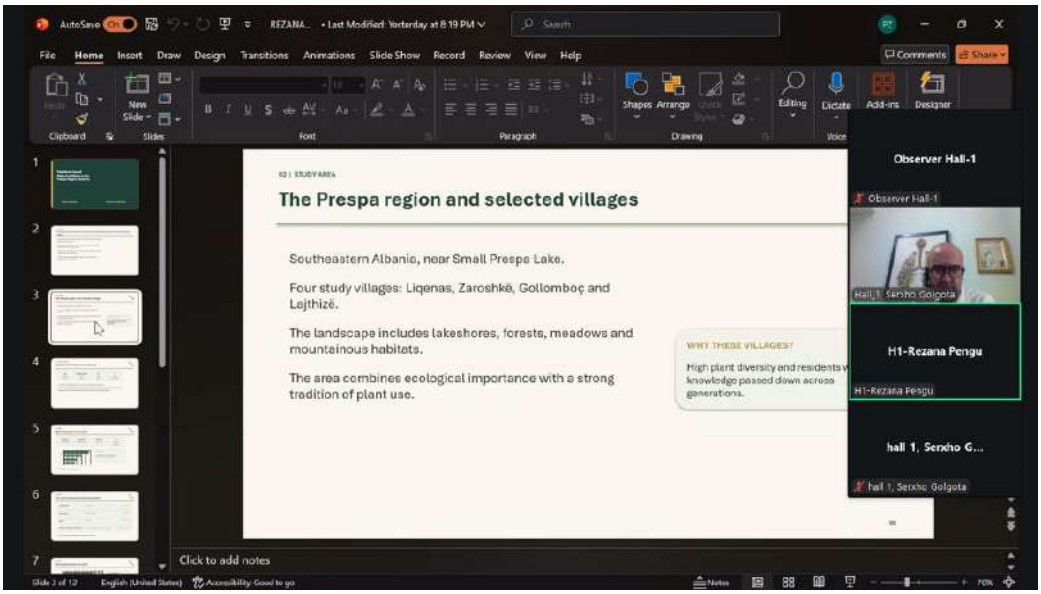

Invisible Contaminants, Unclear Responsibilities
The Legal Challenges of Drug Residues in Wastewater
Tiago Mancha | NOVA School of Law
Coauthor: Francisca Marcelino
Observer hall 6
Hall-6, Lorena...
H -6 Emina Kov...
H6-Eriona Cela
HALL 6_KANAR...
H- 6, Ishraq
polychronis bou...

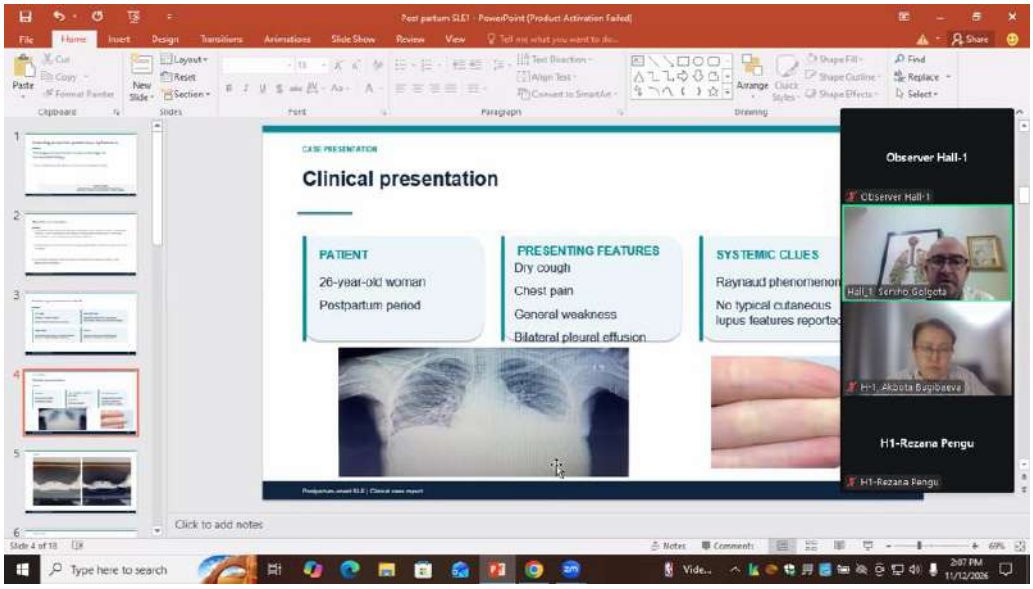

Perceived Social Support and Parent–Educational Institution Partnerships
Experiences of Parents of Children with Disabilities
Emina Kovačić Ahmetović | Faculty of Teacher Education, University of Zagreb
Observer hall 6
H6-Eriona Cela
Hall-6, Lorena...
HALL 6_KANAR...
Polychronis Bou...
Tea Pavicic Zaje...

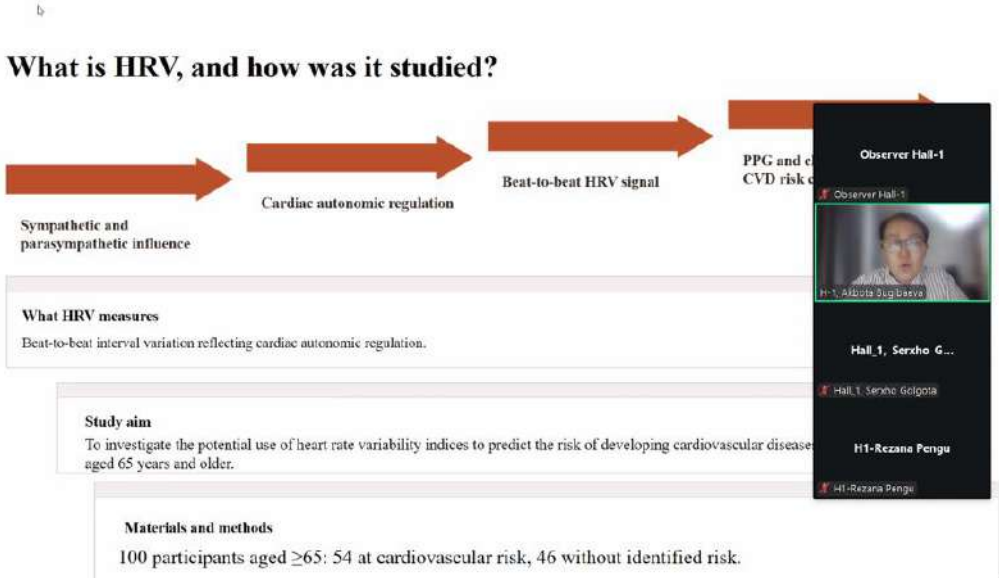

COMPARATIVE FINDINGS: LOVE AND BELONGING
The first comparison places Moukarzel's Mother's Day campaign beside Cartier's Love collection. Both build their appeal around attachment, yet they define attachment differently.
Observer Hall 7

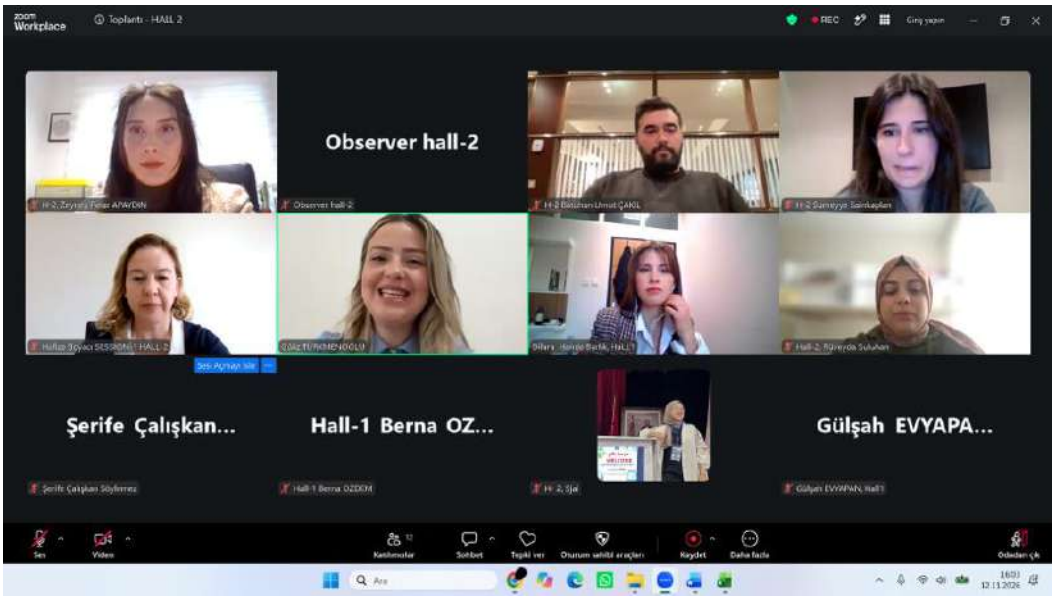

Emotional Branding Beyond Borders:
Cultural Narratives in MENA and Western Luxury Jewelry Advertising
Observer Hall 7


zoom Workplace
Toplantı - HALL 7
Observer Hall 7
Torh's iPhone


The Prespa region and selected villages
Southeastern Albania, near Small Prespa Lake.
Four study villages: Liqenas, Zaroshkë, Gollomboç and Lejthizë.
The landscape includes lakeshores, forests, meadows and mountainous habitats.
The area combines ecological importance with a strong tradition of plant use.
Observer Hall-1
H1-Rezana Pengu
hall 1, Serxho G...
Click to add notes


Clinical presentation
PATIENT
26-year-old woman
Postpartum period
PRESENTING FEATURES
Dry cough
Chest pain
General weakness
Bilateral pleural effusion
SYSTEMIC CLUES
Observer Hall-1
H1-Rezana Pengu
Click to add notes


What is HRV, and how was it studied?
Sympathetic and parasympathetic influence
Cardiac autonomic regulation
Beat-to-beat HRV signal
What HRV measures
Beat-to-beat interval variation reflecting cardiac autonomic regulation.
Study aim
To investigate the potential use of heart rate variability indices to predict the risk of developing cardiovascular disease
aged 65 years and older.
Materials and methods
100 participants aged ≥65: 54 at cardiovascular risk, 46 without identified risk.
Observer Hall-1
Hall_1, Serxho G...
H1-Rezana Pengu


Observer hall-2
Şerife Çalışkan...
Hall-1 Berna OZ...
Gülşah EVYAPA...

Observer hall-2

Observer Hall-3

Toplantı - HALL 4
Observer Hall 4
Windows'u Etkinleştir

Toplantı - HALL 4
Observer Hall 4
Windows'u Etkinleştir

Toplantı - HALL 5
Observer Hall-5

TABLE OF CONTENTS

AUTHOR(S)	PRESENTATION TITLE	No
Joris Vezys Algimantas Bubulis Vytautas Jurenas Lina Merkeviciene Agne Giedraitiene Rita Siugzdiniene Vacis Tatarunas Vishnu Radhakrishnan Nair Raminta Rodaite	LOW-FREQUENCY ULTRASOUND AS AN EMERGING PHYSICAL ANTIMICROBIAL TECHNOLOGY: EXPERIMENTAL INVESTIGATION AGAINST PROTOTHECA SPP.	1
Grzegorz Maśloch	THE ROLE AND SIGNIFICANCE OF LOCAL GOVERNMENT UNITS IN ENERGY TRANSITION: FROM SOCIAL PARTICIPATION TO ENERGY AUTONOMY	3
Ahmad ABU ARRA Muhammed Zakir KESKİN Eyüp ŞİŞMAN	COMPARISON OF A STATION-DERIVED PRECIPITATION GRID (0.1°) WITH ERA5-LAND AND IMERG PRODUCTS IN THE EASTERN PART OF THE KONYA CLOSED BASIN	4
Ahmad ABU ARRA Muhammed Zakir KESKİN Eyüp ŞİŞMAN	MULTI-METRIC ASSESSMENT OF IMERG AND ERA5-LAND PRECIPITATION PRODUCTS IN A SEMI-ARID CLOSED BASIN: THE KONYA BASIN, TÜRKIYE	12
Yucel Aydin Ali Fuat Ergenç Işıl Aydın	MULTI-OBJECTIVE STRUCTURAL CONTROL VIA STOCHASTIC DYNAMIC GAMES: A GAME-THEORETIC APPROACH TO VIBRATION SUPPRESSION	21
Mehmet Emin KALGI	RADICALIZATION BETWEEN RELIGION AND SOCIAL REALITY: THE CASE OF BOKO HARAM	33
Mehmet Emin KALGI	REASONS FOR RELIGIOUS CONVERSION FROM CHRISTIANITY TO ISLAM: A FIELD STUDY	34
Thomas J. Bell	A MODEL CURRICULUM FOR TEACHING RESPONSIBLE AI DEPLOYMENT: ACADEMIC INTEGRITY, CRITICAL THINKING, AND DOMAIN MASTERY	38
Jacek Sierak	FINANCING GREEN TRANSITION PROJECTS BY POLISH LOCAL GOVERNMENTS	39
Edlira Bylykbashi Ilta Bylykbashi Albana Shahini	ENDOMETRIAL POLYPS AMONG WOMEN UNDERGOING HYSTEROSCOPY FOR ABNORMAL UTERINE BLEEDING IN ALBANIA	41
Serxho Golgota Eritjan Tashi Marsel Broqi Anxhela Papa Emira Hysa Alma Teferici Kloedina Bratja Ina Pojani Kristi Reveli Irida Ikonomi Elona Hysenbelli Ilir Peposhi	UNMASKING POSTPARTUM SYSTEMIC LUPUS ERYTHEMATOSUS THROUGH TRANSBRONCHIAL BIOPSY AND PLEURAL CYTOLOGY	47
Feride Imeraj Numila Kuneshka-Maliqari	LABORATORY RISK STRATIFICATION IN PEDIATRIC PARACETAMOL POISONING	48
Tedi Minarolli Birkena Qirjazi	SINONASAL DISEASE WITH ORBITAL EXTENSION	49
Rezana Pengu Desareda Mero Eva Kananllari Tina Donefski	TRADICIONAL USE OF MEDICINAL PLANTS IN THE PRESPA REGION	50
Akbota Bugibayeva Symbat Abzaliyeva Kuat Abzaliyev Madina Suleimenova Tamara Abdirova Irina Agababyan	PREDICTING THE RISK OF CARDIOVASCULAR DISEASES IN THE ELDERLY BASED ON CLINICAL DATA AND HEART RATE VARIABILITY USING MACHINE LEARNING	55
Klejda Tani Aisel Oseku Surven Metolli	EVALUATING FASCIAL MANIPULATION INTEGRATED WITH POSTURAL EXERCISES FOR CHRONIC LOW BACK PAIN MANAGEMENT: A PROSPECTIVE CONTROLLED CLINICAL TRIAL	56
Jolanda Hyska	ACCEPTABILITY OF SCHOOL MEAL PROVISION IN ALBANIA: STAKEHOLDER PREFERENCES, REGULATORY FRAMEWORK AND NUTRITIONAL CONSIDERATIONS	62

AUTHOR(S)	PRESENTATION TITLE	No
Güliz TÜRKMENOĞLU	A STUDY ON THE USE OF CERATONIA SILIQUA L. AS A MEDICINAL PLANT IN TÜRKİYE	70
Zeynep Pınar APAYDIN Şenay GÖRÜCÜ YILMAZ Sibel OĞUZKAN BALCI	TIME-DEPENDENT EXPRESSION OF MSI1, NUMB AND ELAV IN IPSC-DERIVED BRAIN ORGANOIDS AND THEIR RELATIONSHIP WITH TAU PATHOLOGY IN ALZHEIMER'S DISEASE MODELING	78
Sumeyye SAİNKAPLAN İrem ERGİN Oytun Okan ŞENEL	OCULAR ALKALI INJURY IN A DOG FOLLOWING DISINFECTANT EXPOSURE: CLINICAL FINDINGS AND MANAGEMENT	89
Batuhan Umut ÇAKIL İrem ERGİN	PERIOCULAR MALIGNANT FIBROUS HISTIOCYTOMA IN A CAT: SURGICAL APPROACH AND CLINICAL FOLLOW-UP	95
Hafize Boyacı Selma Söyük	IDENTIFYING JOB SATISFACTION AND JOB-RELATED EMOTIONAL EXHAUSTION PROFILES AMONG HEALTHCARE WORKERS: A LATENT PROFILE ANALYSIS	102
Berna OZDEM Dilara Hande BARLIK Gulsah EVYAPAN	IN VITRO ANTICANCER POTENTIAL OF FERMENTATION SUPERNATANT FROM STREPTOMYCES GOBITRICINI-LIKE ISOLATE BH026 AGAINST SH-SY5Y NEUROBLASTOMA CELLS	112
Rüveyda Suluhan Halime Esra Meram	THE ROLE OF EPIGENETICS AND GENETIC MEMORY IN SEXUALITY AND SEXUAL BEHAVIORS, AND THE NURSING APPROACH	113
Şerife Çalışkan Söylemez Eda Yetimoğlu	DETERMINANTS OF CERVICAL CANCER MORTALITY AND DISEASE BURDEN IN OECD COUNTRIES: A PANEL DATA ANALYSIS FOR THE 2010–2023 PERIOD	120
Gibson W. Weh	BRIDGING ELECTRICAL VOCATIONAL EDUCATION AND INTERDISCIPLINARY INNOVATION: ENHANCING WORKFORCE COMPETENCE THROUGH PRACTICE-BASED TECHNICAL TRAINING IN LIBERIA	121
Ichrak FETTAH Doha BELFADIL Asiya Rezzouq Abderrahim Bouftou Sanaa MAJID	DEVELOPMENT AND CHARACTERISATION OF A NANOCOMPOSITE PROTON EXCHANGE MEMBRANE BASED ON POLY (VINYL ALCOHOL) WITH LAYERED DOUBLE HYDROXIDES FOR PROTON EXCHANGE MEMBRANE FUEL CELLS (PEMFC)	122
Elza Bitsadze Lia janadze Nana oniani-saghinadze	THE ROLE OF BUSINESS PROGRAMMING IN MODERN MANAGEMENT: ALGORITHMIC THINKING, DIGITAL INFRASTRUCTURE, AND HUMAN RESOURCE MANAGEMENT	123
Johnson A. Obari Eustace M. Dogo Ibrahim M. Abdullahi Danlami Maliki	THE CUMULATIVE KINETIC ENERGY LOSS OF A VERTICALLY BOUNCING BALL: AN ANALYTICAL APPROACH TOWARDS THE DEVELOPMENT OF AN OPTIMIZATION ALGORITHM	124
Etibar Vazirov Farid Tahirov Amin Ismayilov	CAN AI DETECT INCONSISTENT DATA? STATISTICAL, RULE-BASED, AND LLM APPROACHES	125
Manel Essid Zouhaier Aloui	SYNTHESIS, CRYSTAL STRUCTURE AND OPTICAL PROPERTIES OF A NON-CENTROSYMMETRIC ORGANIC-INORGANIC HEXACHLOROBISMUTHATE(III) HYBRID MATERIAL	134
Jamila BOUCHGL Mustapha LAMINE Khadija OUAISSA	WIND-INDUCED KELVIN–HELMHOLTZ INSTABILITY AT THE AIR–SEA INTERFACE: IMPLICATIONS FOR MARINE HYDRODYNAMICS	135
Emine Kambur	CONNECTIVITY, AUTOMATION AND ROBOTIC SYSTEMS IN SMART FACTORIES	143
Gökhan Erdi DAĞI Çelebi ULUYOL	DEVELOPMENT OF AN ARTIFICIAL INTELLIGENCE-BASED DECISION SUPPORT SYSTEM FOR DATA RECOVERY FROM HARD DISK DRIVES	144
Behiye Canbaz Çelebi Uluyol	FORMATIVE FEEDBACK STRATEGIES PROVIDED BY GENERATIVE ARTIFICIAL INTELLIGENCE IN EDUCATION AND THEIR EFFECTS ON STUDENT MOTIVATION AND ENGAGEMENT	154
Yusuf AKIN Müjdat FIRAT	ENERGY AND FUEL CONSUMPTION ANALYSIS OF A PLUG-IN HYBRID ELECTRIC VEHICLE UNDER WLTC CONDITIONS USING AVL CRUISE M	167
Hanbey Hazar Vedat Arslantatar Huseyin Sevinc	EFFECTS OF CRUDE BORAGE OIL BLENDING AND DIMETHYL CARBONATE ADDITION ON EXHAUST EMISSIONS OF A SINGLE-CYLINDER DIESEL ENGINE	178
Hanbey Hazar Vedat Arslantatar Huseyin Sevinc	EXPERIMENTAL EVALUATION OF GASEOUS EMISSIONS FROM A DIESEL ENGINE FUELED WITH CRUDE GARLIC OIL BLENDS AND DIETHYL ETHER	186
Uğur ACAR	DEVELOPMENT OF A GENERALIZABLE MACHINE LEARNING SURROGATE FOR OFF-DESIGN PERFORMANCE PREDICTION OF ORGANIC RANKINE CYCLES	194
Özlem ATAY	ACADEMIC WOMEN IN TURKISH HIGHER EDUCATION MANAGEMENT	216

AUTHOR(S)	PRESENTATION TITLE	No
Ercan Emre YÜREK Çelebi ULUYOL	THE EFFECT OF VISUAL TRAINING MATERIALS IN DIFFERENT FORMATS ON AWARENESS IN DIVERSIFIED PHISHING SCENARIOS	227
Emre YAŞAR Bilal Nadir ALKAN	TOURISM GUIDANCE STUDENTS' EXPERIENCES USING NOTEBOOKLM: ADVANTAGES, LIMITATIONS, AND INTENTIONS FOR FUTURE USE	235
Mesut ÇOLAKOĞLU Elif KARAGÜN	PERCEPTION OF SUCCESS AMONG 11–13-YEARS OLD CHILDREN ATTENDING RECREATIONAL SPORTS SCHOOLS	245
Didem Çilengiroğlu Yıldıray Topcu	FROM CONTACT TO EVIDENCE: ANALYSIS OF COSMETIC TRACES AND CURRENT ANALYTICAL APPROACHES IN FORENSIC COSMETOLOGY	252
Lorena Kelo Entela Vinçani	USING MICROSOFT EXCEL IN TEACHING ELECTROSTATICS: IMPACT ON GRADE 11 STUDENTS' ACHIEVEMENT AND PERCEPTIONS	264
Tea Pavičić Zajec Tamara Ređep, M.Sc.	SECRET MESSAGES IN PRIMARY EDUCATION: USING THE CAESAR CIPHER TO SUPPORT LOGICAL THINKING AND INTERDISCIPLINARY LEARNING	274
Elda Maraj Armida Brakaj Fizeleni Lekli Shkelqim Kuka	A FUZZY LOGIC APPROACH TO SPORTS PERFORMANCE EVALUATION	278
Eriona Çela	AN ANALYSIS OF TEACHERS` BENEFITS AND CHALLENGES IN INTEGRATING AI TOOLS IN EDUCATIONAL SETTINGS	284
Emina Kovačić Ahmetović	PERCEIVED SOCIAL SUPPORT AND PARENT–EDUCATIONAL INSTITUTION PARTNERSHIPS: A QUALITATIVE STUDY OF PARENTS OF CHILDREN WITH DISABILITIES IN CROATIA	291
Dimitrios Kanaros Polychronis Bourdaniotis	GLOBAL COURTYARD OF TRADITIONAL GAMES: AN INTERCULTURAL APPROACH TO PHYSICAL EDUCATION	305
Maria Francisca Marcelino Eduardo Ortega	WORKPLACE HARASSMENT AND ITS LEGAL IMPLICATIONS: ABSENTEEISM AND TURNOVER INTENTION AMONG WOMEN	311
Tiago Zambujeira Mancha Maria Francisca Marcelino	INVISIBLE CONTAMINANTS, UNCLEAR RESPONSABILITIES: THE LEGAL CHALLENGES OF DRUG RESIDUES IN WASTEWATER	312
Deacon Torh E. Q. Kalloh	STRENGTHENING ADMINISTRATIVE LEADERSHIP THROUGH INTERDISCIPLINARY PRACTICES: ENHANCING ORGANIZATIONAL EFFECTIVENESS IN LIBERIA'S PRIVATE SECTOR	313
Mahtab IRANI	THE CONDITIONAL ROLE OF STORE INTERIOR DESIGN IN CUSTOMER EXPERIENCE AND BEHAVIORAL INTENTIONS: A QUALITATIVE STUDY IN ISTANBUL	314
Parvin FEIZI	SALESPERSON CAPABILITIES AND CUSTOMER OUTCOMES IN ISTANBUL'S READY-TO-WEAR RETAIL SECTOR: A CROSS-SECTIONAL CUSTOMER SURVEY	315
Xhensila LATO Edvin LAME	PARENTAL ALIENATION AND DOMESTIC ABUSE: AN EVIDENCE-BASED LITERATURE REVIEW OF THEIR INTERSECTIONS, CONTROVERSIES, AND IMPLICATIONS FOR PRACTICE	316
Brunilda Llaftiu	AI-DRIVEN TAX TECHNOLOGY: ENHANCING GOVERNANCE AND REDUCING EVASION	323
Josiane El Khoury	EMOTIONAL BRANDING BEYOND BORDERS: CULTURAL NARRATIVES IN MENA AND WESTERN LUXURY JEWELRY ADVERTISING	331
Işıl Altay	COMMENT MANAGEMENT IN SOCIAL MEDIA MARKETING COMMUNICATION: A CRITICAL SYNTHESIS OF REPLIES, DELETION CUES, AND DISABLED COMMENTS	332
Müge KINAY Hatice NAYMAN HAMAMCI Selim AREN	RISK TOLERANCE AS A BRIDGE BETWEEN PSYCHOLOGICAL CAPITAL AND RISKY INVESTMENT INTENTION	333
Veysel Mehmet GÜLTEKİN B. Dilek ÖZBEZEK Filiz DEMİR	THE MEDIATING ROLE OF THRIVING AT WORK IN THE RELATIONSHIP BETWEEN PROSOCIAL MOTIVATION AND WORK ENGAGEMENT: A FIELD STUDY OF HEALTHCARE WORKERS	341
Feyza Erdoğan Vahit Tongur	STATISTICAL EVALUATION OF THE PERFORMANCE OF THE DRACO LIZARD OPTIMIZER ON THE CEC-2019 (C06) BENCHMARK FUNCTIONS	349
Zekeriya Gül	STOCK MARKET REACTIONS TO THE 2025 IRAN–ISRAEL CONFLICT AND THE 2026 IRAN WAR: COMPARATIVE EVIDENCE FROM GCC COUNTRIES	360
Şeyma AKBULUT Çelebi ULUYOL	ANALYSIS OF THE RELATIONSHIP BETWEEN INFORMATION SECURITY MANAGEMENT PROCESSES AND PERSONAL DATA PROTECTION COMPLIANCE MATURITY IN THE ELECTRONIC COMMUNICATIONS SECTOR	361
T. Aarthi K. Nilavarasi M. Ponmurugan	FINITE TIME PERFORMANCE OF A CARNOT ENGINE WITH RELATIVISTIC ELECTRON POSITRON PHOTON PLASMA UNDER LOW DISSIPATION REGIME	373

AUTHOR(S)	PRESENTATION TITLE	No
Florina Ravariu Cristian Ravariu	THE CIRCLE OF LIFE: WATER MOLECULES NECKLACE, LIFE INSPIRES ART	374
Arli Aditya Parikesit	TWO-TIER AI TRIAGE FOR VIRAL GENE ANNOTATION WITHOUT RUNTIME SEQUENCE DATABASE QUERIES: A FIVE-PATHOGEN PROOF OF CONCEPT	381
Desareda Mero Rezana Pengu Xhuljana Sula	GENETIC STRUCTURE AND INBREEDING IN THE POPULATION OF KORÇË, ALBANIA: AN ASSESSMENT THROUGH SURNAME FREQUENCIES	391
Boyko Tsyntsarski Ivanka Stoycheva Nartzislav Petrov Bilyana Petrova Angelina Kosateva Izabela Ivanova	ECOLOGICAL TECHNOLOGY FOR CONVERSION OF WASTE BIOMASS TO FUNCTIONAL CARBON MATERIALS	399
Ibtissam Zriaa Noureddine Sajai Abdellah El Boukili Rachid Fakhreddine Saida Krimi	NOVEL BOROPHOSPHATE GLASSES: SYNTHESIS, STRUCTURAL, PHYSICOCHEMICAL CHARACTERIZATION AND IN VITRO BIOACTIVITY	400
Etibar Vazirov Ayan Bayramova	BRAIN ACTIVITY CLASSIFICATION WITH DEEP LEARNING AND EEG CHANNEL SELECTION	401
Etibar Vazirov Marat Salim	CAN AI REALLY FORGET? EVALUATING MACHINE UNLEARNING UNDER DATA POISONING	410
Huseyn Huseynov	GENERATIVE AI TOOLS IN HIGHER EDUCATION: OPPORTUNITIES, RISKS AND ACADEMIC INTEGRITY	417
Mohamed Ziad Mammass Hasna Abioui	ADOPTION AND USE OF GENERATIVE ARTIFICIAL INTELLIGENCE IN TEACHING AND RESEARCH: A TECHNOLOGY ACCEPTANCE MODEL SURVEY OF MOROCCAN ACADEMICS AND DOCTORAL STUDENTS	418
Ardi DHIMA Stavri DHIMA	PLANNING NATURAL GAS INFRASTRUCTURE FOR ALBANIAN CITIES: SPATIAL SEQUENCING, DEMAND-LED NETWORKS AND REGIONAL CORRIDOR INTEGRATION	419
L.H. Omari J. Louafi	STRUCTURAL, MORPHOLOGICAL AND OPTICAL PROPERTIES OF THE LA2W2O9/FE2O3 COMPOSITE FOR UV-SHIELDING APPLICATIONS	420
Khadija OUAISSA Jamila BOUCHGL M'Hamed HMAMOU Mustapha Hasnaoui	COMPARATIVE EVALUATION OF COMMERCIAL FEED AND AZOLLA (AZOLLA PINNATA) ON GROWTH PERFORMANCE AND ZOOTECHNICAL PARAMETERS OF TILAPIA (OREOCHROMIS NILOTICUS)	421
Khadija OUAISSA Jamila BOUCHGL Zakaria Achtouk M'Hamed HMAMOU Mustapha Hasnaoui	AZOLLA PINNATA AS A LOCAL BIOMASS RESOURCE FOR SUSTAINABLE AQUACULTURE: A LABORATORY MONITORING APPROACH AND RESEARCH PRIORITIES FOR FEED APPLICATIONS	422
Kübranur AĞTOPRAK Uğur KARAASLAN	EFFECT OF SULFURIZED OLEFIN ON WEAR BEHAVIOR IN LITHIUM COMPLEX GREASES AND EVALUATION OF AW/EP ADDITIVE SYSTEMS	428
Mukaddes Karataş Buket Erzen Şermin Deniz Ramazan Orhan	DISPERSION, AGGLOMERATION, AND MECHANICAL PERFORMANCE IN EPOXY COMPOSITES INCORPORATING GREEN-SYNTHESIZED METAL OXIDE NANOPARTICLES: A CRITICAL REVIEW	442
Buket Erzen Mukaddes Karataş Şermin Deniz Ramazan Orhan	SUSTAINABLE FERRITE–CARBON HYBRID COMPOSITES FOR MICROWAVE ABSORPTION: A CRITICAL REVIEW OF MATERIAL DESIGN AND PERFORMANCE	453
Mertcan Nazar Umut Güneş Sefercik	SENSITIVITY OF LiDAR-BASED POWER LINE RISK MAPS TO SEGMENTATION ERRORS AND CLEARANCE REGULATIONS	467
Umut Güneş Sefercik Mertcan Nazar	THREE-DIMENSIONAL MONITORING OF FOREST LOSS CAUSED BY FIRES USING RADAR SATELLITE IMAGERY, CASE STUDY: 2021 MANAVGAT FIRE, TÜRKİYE	475
Aysun Yesilgul Celebi Uluyol	THE EFFECT OF SOCIAL INTERACTION ELEMENTS IN LEARNING MANAGEMENT SYSTEMS BY THE ATTANDENCE AND MOTIVATION OF STUDENTS	483
Çağla Gizem KARAİBİŞ Barış ÖZDEMİR	TIME PERSPECTIVE PROFILES AND INTOLERANCE OF UNCERTAINTY: A COMPARATIVE STUDY BETWEEN YOUNG AND MIDDLE-AGED ADULTS	494
Zeynep KÜTAY Barış ÖZDEMİR	EXAMINING THE RELATIONSHIP BETWEEN ADVERSE CHILDHOOD EXPERIENCES AND MENTALIZATION IN ADULTS WITH LOW LEVELS OF ATTENTION DEFICIT/HYPERACTIVITY SYMPTOMS	503

AUTHOR(S)	PRESENTATION TITLE	No
Mustafa Tuncer OKUMUŞ Şehriban Buse BAYSAL	THE MEDIATING ROLE OF PERCEIVED ORGANIZATIONAL SUPPORT IN THE RELATIONSHIP BETWEEN WORK-LIFE BALANCE AND WELL-BEING AT WORK AMONG GEN Z TOURISM EMPLOYEES: THE CASE OF ANTALYA	513
Emine KAYA ALTOP Sine KAYA	DEEP LEARNING-BASED WEED DETECTION, SEGMENTATION AND SPATIAL MAPPING FOR PRECISION WEED MANAGEMENT	522
Emine KAYA ALTOP Sine KAYA	AI-DRIVEN PRECISION CROP PROTECTION: INTEGRATING DISEASE DIAGNOSIS, WEED DETECTION, EARLY WARNING AND DECISION SUPPORT	532
Ömer Ümit Okçu Nuray ÖZER	BIOLOGICAL CONTROL OF SCLEROTINIA SCLEROTIORUM IN LETTUCE: RESEARCH TRENDS, BIOLOGICAL CONTROL AGENTS, AND EFFICACY LEVELS	543
Abdullah ERİŞ	THE EFFECT OF CORPORATE SOCIAL RESPONSIBILITY PROJECTS ON STAKEHOLDER PERCEPTIONS IN BUSINESSES	554
Stelina Ndreu	SPEAKING WITHOUT FEAR? EXPLORING THE ROLE OF CHATBOTS IN REDUCING ANXIETY DURING EFL SPEAKING PRACTICE	555
Nestan Akobia	HOW ENGLISH SPEAKERS EXPRESS HUMOR IN DAILY LIFE	560
Aysel Ceferova Qezenfer qizi	CULTURAL DIFFERENCES AND THE CHALLENGES OF TRANSLATING AZERBAIJANI DOMESTIC AND TRADITIONAL VOCABULARY INTO ENGLISH: A COMPARATIVE STUDY OF AZERBAIJANI LITERATURE	561
Irini Arapi(Sylari) Eftimi Sylari	IMPROVING ATTENTION FOR BETTER READING OUTCOMES IN PRIMARY SCHOOLS	562
Greta Pergjegji	THE UNIVERSAL ACQUISITION SYSTEM: A COGNITIVE PERSPECTIVE ON ESP LEARNING	571
Monika Myrto	ASSESSING THE DIVERGENCE BETWEEN CLASSROOM INSTRUCTION AND STANAG 6001 HIGH-LEVEL PROFICIENCY TESTING	580
Nguyen Chi NGUYEN Nguyen Thi Hong NHO Luong Duy DAL Quach Tuyet Minh	DEVELOPING A DIGITAL COMPETENCE ASSESSMENT TOOLKIT FOR GRADE 11 STUDENTS IN LITERATURE SUBJECT BASED ON THE DIGCOMP COMPETENCE FRAMEWORK	589
Elsuida Hani	BEYOND THE TEXTBOOK: THE USE OF AUTHENTIC MATERIALS IN TEACHING ENGLISH IDIOMS TO ALBANIAN EFL LEARNERS	590
Arzu Al Ege Gündüz	ARTIFICIAL INTELLIGENCE IN FINANCIAL DECISION-MAKING AND INTERNATIONAL DIPLOMACY	599
Nurgül Güneş Evrim Gemici	FROM STORIES TO MEMORY: STORYTELLING IN SHORT-FORM VIDEO MARKETING AND COGNITIVE BRAND OUTCOMES IN THE FASHION INDUSTRY	609
NAZIM ERYILMAZ	HOW CAN THE SAME ISSUE LEAD TO DIVERGENT POLITICAL OUTCOMES? IMMIGRATION-SPECIFIC CRIME ATTRIBUTION AND ITS EFFECTS ON SUPPORT FOR EXECUTIVE POWER AND GUN CONTROL POLICY	619
Elif Bostanoğlu Didem Balkanlı Benan İnan Sinan Kutluay	COMPARATIVE ANALYSIS OF CHLORELLA VULGARIS CULTIVATION AT THE LABORATORY SCALE USING MUNICIPAL WASTEWATER FROM TWO ADVANCED BIOLOGICAL WASTEWATER TREATMENT PLANTS	632
Havvanur TULUM Ayşe Sanem ŞAHLI	DETERMINATION AND EDUCATION OF AWARENESS REGARDING HEARING LOSS RISK FACTORS AND EARLY PREVENTION AMONG IN PREGNANT WOMEN	640
Özge Başak KARAKAYA Ayşe Sanem ŞAHLI	PARENTAL AWARENESS OF THE EFFECTS OF SCREEN EXPOSURE ON CHILDREN'S HEARING, SPEECH AND LANGUAGE SKILLS	647
Bledar KRAJA	DISEASE BURDEN, MODIFIABLE RISK FACTORS, AND HEALTH POLICY RESPONSES IN ALBANIA: PRIORITIES FOR 2021-2030	654
Elona Hasalla Ilda Taka Celjana Toti Gerta Kacani Etleva Dobroniku	FROM DIGITAL SETUP TO CLINICAL REALITY: DETERMINANTS OF PREDICTABILITY IN CLEAR ALIGNER THERAPY	655
Ilda Taka Elona Hasalla	THE ROLE OF NURSING CARE IN THE MANAGEMENT OF PATIENTS WITH BRAIN METASTASES TREATED WITH STEREOTACTIC RADIOSURGERY: A NARRATIVE REVIEW	656
Ameni Brahmia Linda Bejaoui Rached Ben Hassen	NOVEL MONO- AND BIS-ENAMINONE COUMARINS: CRYSTAL STRUCTURE, THEORETICAL INSIGHTS AND ANTIMICROBIAL POTENTIAL	657
Amarilda Hysenshahaj Dorina Toçi Alban Ylli Jolanda Hyska	STROKE INCIDENCE IN ALBANIA COMPARED WITH BALKAN AND EUROPEAN COUNTRIES: SEX AND AGE DIFFERENCES	658

AUTHOR(S)	PRESENTATION TITLE	No
Maroua RIAD Ahmad AL-SHAMI Jamal MABROUKI	BREAST CANCER DORMANCY AND MINIMAL RESIDUAL DISEASE: MOLECULAR MECHANISMS AND THERAPEUTIC CHALLENGES	665
Israr Ahmad	FIXED-TIME SYNCHRONIZATION OF HYPERCHAOTIC SYSTEMS	666
Amal Algouti	THE ILLUSION OF ORGANIZATIONAL CHANGE: WHEN INNOVATION BECOMES SYMBOLIC RATHER THAN TRANSFORMATIVE	667
Altay Mahmudov	RETHINKING MACROECONOMIC NOWCASTING AND FORECASTING: INTEGRATING ECONOMETRICS AND ARTIFICIAL INTELLIGENCE	668
Wahiba HENNICHE	SUSTAINABILITY DISCLOSURE AND THE COST OF DEBT: PANEL EVIDENCE FROM SAUDI NON-FINANCIAL LISTED FIRMS	669
Olgerta Idrizi	CAN WE TRUST AI PREDICTIONS OF PUBLIC PROJECT OVERRUNS? A STATISTICAL RE-EVALUATION	670
Elena Denisa MATEEVICI Ivona RĂPAN Anca CRISTEA Felicia MICU	THE STRATEGIC ROLE OF SOCIAL MARKETING IN ENHANCING THE SOCIOECONOMIC IMPACT OF SOCIAL ENTERPRISES	677
Isak Kafexholli Alma Braimllari	THE GRAVITY MODEL IN ANALYZING MIGRATION FROM THE WESTERN BALKANS: A LITERATURE REVIEW	687
Anita Boros	FROM LEGAL PRINCIPLE TO TECHNICAL REQUIREMENT: THE INTERDISCIPLINARY ARCHITECTURE OF ADMINISTRATIVE INSTRUMENTS CONCRETISING SUSTAINABILITY IN CIRCULAR ECONOMY REGULATION	695
Emine Betül KARABIYIK Nilüfer DARICA	EXAMINING THE RELATIONSHIP BETWEEN NATURE RELATEDNESS AND SELF-COMPASSION AMONG PRE-SERVICE PRESCHOOL TEACHERS	704
Zeynep İrem Tuncer Fatma Karaman	A COMPARATIVE ANALYSIS OF FORBIDDEN LOVE, TRAGIC ENDINGS, AND THE PSYCHOLOGY OF INFIDELITY IN EFFI BRIEST AND AŞK-I MEMNU	705
Latife Martlı Fatma Karaman	A COMPARISON OF THE THEMES OF GUILT, AUTHORITY, AND ALIENATION IN FRANZ KAFKA'S "THE TRIAL" AND SABAHATTİN ALİ'S "İÇİMİZDEKİ ŞEYTAN"	713
Selin OTHAN Arzu ÖNEL	IN NATURE, BUT WHERE IN THE MIND? THE VISIBILITY AND ECOLOGICAL ROLE OF PLANTS IN HIGH SCHOOL STUDENTS' IDEAS ABOUT NATURE	725
Hacer YILMAZ	PROOF OF MARRIAGE IN THE LATE OTTOMAN EMPIRE: THE CASES OF EMİNE AND SAFİNAZ	734
Hasan Atakan YILDIRIM	THE RECREATION OF TRADITIONAL MINIATURE ART NARRATIVES THROUGH AI-ASSISTED ANIMATION	743
Asel Irmak FIÇICIOĞLU Muazzez GÜRGAN ESER Çetin YAĞCILAR	ASSESSMENT OF GROWTH PERFORMANCE AND PIGMENT CONTENT IN DUNALIELLA SALINA CULTURES GROWN IN CLOSED PHOTOBIOREACTOR SYSTEMS AT 40 G L^{-1} SALINITY	755
Bilge PEHLİVAN Muazzez GÜRGAN ESER Çetin YAĞCILAR	INVESTIGATION INTO THE EFFECTS OF TWO DIFFERENT PHOTOPERIOD REGIMES ON EARLY DEVELOPMENT IN ZEBRAFISH (DANIO RERIO)	761
Dijana Gracin	HATE SPEECH IN CROATIA: THE APPLICATION OF ARTICLE 325 OF THE CRIMINAL CODE AND THE BOUNDARIES OF FREEDOM OF EXPRESSION	771
Corneliu Tuni Mihai Susanu	EUROPEAN UNION ENLARGEMENT TO THE EAST AND CHANGES IN THE MEDIATION LEGISLATION WITHIN THE REPUBLIC OF MOLDOVA	780
Mihai Susanu Corneliu Tuni	EUROPEAN UNION ENLARGEMENT TO THE EAST AND HOW LEGISLATIVE CHANGES WILL AFFECT THE ECONOMIC ENVIRONMENT OF THE REPUBLIC OF MOLDOVA	788
Mohammed Waheeb	THE ROLE OF THE CLIMATIC ENVIRONMENT IN THE GLOBAL DISTINCTION OF THE JORDANIAN NICOLAUS DATE DURING THE BYZANTINE ERA: A HISTORICAL AND GEOGRAPHICAL/AGRICULTURAL STUDY	798
Mohammed Waheeb ENSAR FIRAT	TYPES OF DIVINE RETRIBUTION ASSOCIATED WITH CLIMATIC AND GEOLOGICAL PHENOMENA IN THE NOBLE QURAN: AN INTERDISCIPLINARY ANALYTICAL STUDY BETWEEN MODERN CLIMATIC STUDIES AND THE QURANIC TEXT	809
Xhiljola Abdihoxha	TRANSLATING CULTURE OR MEDIATING CULTURE? THE REPRESENTATION OF ALBANIAN CULTURAL CONCEPTS FOR INTERNATIONAL AUDIENCES	819
Aliou SENE	FROM ARCHIVES TO DATA: RENEWING THE WRITING OF SENEGAL'S CULTURAL HISTORY	827
Safiye İrem Dizdar	REFERENCES THAT THE MAE KAMPONG MODEL COULD PROVIDE FOR THE VILLAGE OF TAHTAKUŞLAR AS AN EXAMPLE OF COLLECTIVE SUSTAINABILITY	832

AUTHOR(S)	PRESENTATION TITLE	No
Yasemin Hekimoğlu Elif Özgen Aydın	HEALING SPACE, GENDERED PLACE: A TOPOANALYTICAL READING OF THE HOSPITAL IN TURKISH LITERATURE	833
Elif ATICI TEKTAŞ Melike KALKAN	FROM SPATIAL LOSS TO DIGITAL MEMORY: PRESERVATION AND TRANSMISSION OF URBAN MEMORY AFTER EARTHQUAKES	843
Eda Gizem Almalı Asena Soyluk	WOOL AS A CLIMATE-SENSITIVE INSULATION ALTERNATIVE WITH TRACES OF THE PAST: THE ERZURUM EXAMPLE	851
Ayse Gul GEMCI	RECLAIMED SURFACES: SPATIAL DYNAMICS OF UNAUTHORIZED STREET ART AT KARAKOY FERRY TERMINAL	865
Mehmet Erzi Mehdi Öztürk	COMPARATIVE ASSESSMENT OF SEISMIC ISOLATION EFFECTS ON THE EARTHQUAKE RESPONSE AND STRUCTURAL COST OF AN EIGHT-STORY REINFORCED CONCRETE BUILDING	866
Şeyma Aydın Oktay Özkan	ENHANCING THE EFFICIENCY OF PHOTOCATALYTIC AMOXICILLIN REMOVAL THROUGH RESPONSE SURFACE METHODOLOGY: A COMPARATIVE ANALYSIS OF LITERATURE-BASED AND EXPERIMENTALLY REFINED BOX–BEHNKEN DESIGNS	874
Serhat YANIK Fatih Mehmet Coşkun	FREQUENCY DEPENDENT RESPONSE OF BI_2O_3 PTFE EPOXY STACKS WITH FILTER PAPER	875

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

LOW-FREQUENCY ULTRASOUND AS AN EMERGING PHYSICAL ANTIMICROBIAL TECHNOLOGY: EXPERIMENTAL INVESTIGATION AGAINST PROTOTHECA SPP.

Joris Vezys
Algimantas Bubulis
Vytautas Jurenas
Lina Merkeviciene
Agne Giedraitiene
Rita Siugzdiniene
Vacis Tatarunas
Vishnu Radhakrishnan Nair
Raminta Rodaite
https://orcid.org/0009-0000-3731-0588, Kaunas University of Technology, Faculty of Mechanical Engineering and Design, Department of Mechanical Engineering, Kaunas, Lithuania.
https://orcid.org/0000-0001-5222-7539, Kaunas University of Technology, Institute of Mechatronics, Kaunas, Lithuania.
https://orcid.org/0000-0003-0856-9288, Kaunas University of Technology, Institute of Mechatronics, Kaunas, Lithuania.
https://orcid.org/0009-0006-7617-3698, Lithuanian University of Health Sciences, Veterinary Faculty, Department of Anatomy and Physiology, Kaunas, Lithuania.
https://orcid.org/0000-0001-9645-2121, Lithuanian University of Health Sciences, Institute of Microbiology and Virology, Faculty of Veterinary Medicine, Kaunas, Lithuania.
https://orcid.org/0009-0005-6665-0430, Lithuanian University of Health Sciences, Institute of Microbiology and Virology, Faculty of Veterinary Medicine, Kaunas, Lithuania.
https://orcid.org/0000-0002-2389-1550, Lithuanian University of Health Sciences, Faculty of Pharmacy, Department of Drug Chemistry, Kaunas, Lithuania.
8https://orcid.org/0009-0009-0107-3803, Lithuanian Energy Institute, Center for Hydrogen Energy Technologies, Kaunas, Lithuania.
https://orcid.org/0009-0008-7915-2563, Lithuanian Energy Institute, Center for Hydrogen Energy Technologies, Kaunas, Lithuania

Abstract

Prototheca spp. are achlorophyllous, opportunistic microorganisms increasingly recognized as causative agents of persistent infections in humans and animals. In dairy cattle, protothecal mastitis is particularly problematic due to its chronic nature, negative impact on animal health and milk production, and limited response to conventional antimicrobial treatment. The intrinsic resistance of Prototheca spp. to many commonly applied therapeutic approaches highlights the need for alternative and complementary strategies capable of enhancing antimicrobial efficacy without relying exclusively on pharmacological intervention.

This study investigates controlled low-frequency ultrasound as a physical approach for influencing Prototheca spp. and supporting complementary antimicrobial technologies. A modified ultrasonic treatment system operating at 43 kHz was developed for reproducible exposure of biological samples under controlled laboratory conditions. The experimental platform enables simultaneous treatment of multiple samples while maintaining comparable exposure conditions and provides a basis for systematic investigation of the physical mechanisms associated with ultrasound–sample interaction.

Particular attention is devoted to the mechanical phenomena generated during ultrasonic excitation, including microvibrations, acoustic pressure variations, fluid motion and energy transfer at solid–liquid interfaces. Experimental characterization of the ultrasonic system is used to evaluate the spatial distribution and repeatability of the applied excitation and to establish relationships between physical exposure parameters and

subsequent biological response. This approach is intended to distinguish controlled mechanical effects from uncontrolled high-intensity phenomena and to support the optimization of treatment conditions.

The investigation additionally incorporates functional nanostructured antimicrobial coatings deposited on sample-contact surfaces. Their integration enables the combined effects of ultrasound-induced mechanical stimulation, functional surface properties and antimicrobial activity to be examined within a single experimental framework. Such an approach may provide opportunities for improving interactions between antimicrobial surfaces and target microorganisms while reducing dependence on conventional chemical treatment alone.

The study combines mechanical engineering, acoustics, materials science and microbiology to develop a measurable and reproducible platform for ultrasound-assisted antimicrobial research. The results are expected to contribute to the understanding and optimization of non-pharmacological and combined treatment strategies against persistent microorganisms and to support further development of ultrasound-based biomedical and veterinary applications.

Keywords: Prototheca spp.; low-frequency ultrasound; ultrasound-assisted antimicrobial treatment; nanostructured coatings; acoustic characterization; biomedical engineering.

THE ROLE AND SIGNIFICANCE OF LOCAL GOVERNMENT UNITS IN ENERGY TRANSITION: FROM SOCIAL PARTICIPATION TO ENERGY AUTONOMY

Grzegorz Maśloch
ORCID: 0000-0001-7298-051X, SGH Warsaw School of Economics,
Department of Local Government Economy and Financing, Collegium of Management and Finance,
Warsaw, Poland.

Abstract

In the face of mounting climate challenges, rising energy prices, and the necessity of ensuring security of supply, local energy transition has become one of the most critical priorities for socio-economic development. The objective of this article is a multi-faceted analysis of the role and significance of local government units as primary animators and leaders in the transition towards low-carbon energy sources. Local authorities have evolved from being mere passive implementers of top-down national policies into active creators of regional climate and energy policy.

The study provides a detailed examination of mechanisms supporting the pursuit of energy autonomy at the local level, which directly enhances the resilience and independence of municipalities in the face of external crises. An essential part of the discussion focuses on the functioning and development of energy communities, including energy cooperatives and energy clusters, which provide modern organisational and legal frameworks for the effective use of local renewable energy sources (RES). These forms enable the retention of capital within the local economy, the mitigation of energy poverty, and the optimisation of energy supply and demand management.

Furthermore, the article emphasises the pivotal role of direct public participation in the process of a just transition. Broadly understood social participation, public consultations, and environmental education form the foundation for building acceptance for new investments in RES. Engaging residents facilitates their transformation from passive consumers into active prosumers and co-managers of local energy systems.

The research methodology includes a critical analysis of literature, a review of national and EU strategic documents, and case studies of selected Polish local government units. The results clearly indicate that building lasting energy autonomy requires coherent, multi-level governance, the availability of dedicated financial instruments, and the continuous strengthening of local social capital. In this process, local government units play an irreplaceable role as integrators, bridging national administration, market sectors, and local communities, thereby serving as the cornerstone of success for a just and effective local energy transition.

Keywords: energy transition, local government units, energy autonomy, energy communities.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

COMPARISON OF A STATION-DERIVED PRECIPITATION GRID (0.1°) WITH ERA5-LAND AND IMERG PRODUCTS IN THE EASTERN PART OF THE KONYA CLOSED BASIN

Ahmad ABU ARRA
Dr. Yildiz Technical University, Faculty of Civil Engineering, Department of Civil Engineering, İstanbul-Türkiye
An-Najah National University, Department of Civil and Architectural Engineering, Nablus-Palestine
ORCID ID: https://orcid.org/0000-0001-8679-1752
Muhammed Zakir KESKİN
Res. Asst., Bartın University, Faculty of Architecture, Engineering and Design, Department of Civil Engineering, Bartın-Türkiye
ORCID ID: https://orcid.org/0009-0005-6724-491X
Eyüp ŞİŞMAN
Prof. Dr., Yildiz Technical University, Faculty of Civil Engineering, Department of Civil Engineering, İstanbul-Türkiye
ORCID: 0000-0003-3696-9967

Abstract

Research on water resources and drought in semi-arid areas requires spatially continuous precipitation data, while weather stations provide only point observations. Gridded products such as the ERA5-Land reanalysis and the IMERG satellite estimates full coverage, but comparing them with single stations mixes real product error with the scale mismatch between a point and a grid cell. This is the main point. This study therefore compares the products with a station-derived 0.1° grid in the eastern part of the Konya Closed Basin (KCB) (Türkiye), using monthly data for January 1998 to September 2025 from 28 stations. Station data were interpolated to a 0.1° grid by inverse-distance weighting (IDW), and the quality of that grid was tested by leaving out the station in each cell in turn. This is called croos-validation. ERA5-Land and IMERG, taken at the same grid points, were evaluated with R, RMSE, MAE, PBIAS, NSE and KGE, first for each grid point and then for the region. Both products reproduced the monthly precipitation (median R = 0.84 for ERA5-Land and 0.90 for IMERG against the grid). IMERG overestimated (median PBIAS +20 %) and ERA5-Land underestimated (-17 %), and neither product was better at every location. ERA5-Land had the higher KGE in 19 of 28 grid points and IMERG the higher R in all of them. Using the interpolated grid instead of the station raised the median KGE by 0.12 (IMERG) and 0.05 (ERA5-Land) and changed the better product at 11 grid points, so the choice of reference matters. The interpolated grid itself was least reliable at high elevation (RMSE 22 mm/month above 1400 m against 13 mm/month below 1100 m).

Keywords: ERA5-Land; IMERG; precipitation; spatial interpolation; 0.1° grid; Konya Closed Basin; performance metrics

1. Introduction

Spatially continuous precipitation fields are needed for water balance studies, drought monitoring and flood analysis, yet rain gauges sample only a tiny part of the land surface (Kidd et al., 2017). In semi-arid basins such as the Konya Closed Basin, where irrigated agriculture depends on scarce rainfall and groundwater (Kartal and Nones, 2024), gauges are few and often located in valleys and towns rather than on the slopes where precipitation is highest. Satellite and reanalysis products, such as the Integrated Multi-satellitE Retrievals for GPM (IMERG; Huffman et al., 2020) and the ERA5-Land reanalysis (Muñoz-Sabater et al., 2021), give gridded fields at about 0.1° and are attractive substitutes. Their errors, however, vary with region, season and terrain, so they must be checked against ground data (Beck et al., 2017; Sun et al., 2018; Tang et al., 2020).

Most evaluations compare a product with individual stations. This point-to-grid comparison mixes two things: the error of the product and the difference between a point and a grid cell of roughly 10 km, which is large when rainfall is convective and patchy. One way to reduce this mismatch is to convert the station data to the same regular grid as the product and to compare grid with grid. Interpolation, however, brings its own error, which grows where stations are few and where elevation changes quickly (Hofstra et al., 2008; Daly et al., 2008). Inverse-distance weighting (IDW; Shepard, 1968) is simple, transparent and widely used for this purpose, with known limits in complex terrain (Lu and Wong, 2008).

Studies in Türkiye have shown that product skill differs among regions and seasons. Amjad et al. (2020) found IMERG to have the strongest monthly correlation among four products against 256 gauges, whereas ERA5 overestimated precipitation; Hisam et al. (2023) reported that most products underestimated heavy rain and lost accuracy above 1000 m; and Yılmaz (2025) found that agreement with gauges was better in rainy than in dry seasons. These studies compare products with stations, and the effect of the interpolated reference on the conclusions has received little attention in the Konya basin.

The aim of this study is to compare ERA5-Land and IMERG with a station-derived 0.1° precipitation grid in the eastern part of the Konya Closed Basin, and to show how the comparison depends on the reference. The objectives are: (1) to build the station-derived grid and test its quality, including its dependence on elevation and station density; (2) to evaluate the two products at each grid point with R, RMSE, MAE, PBIAS, NSE and KGE and then for the region; (3) to map the spatial variation of performance and identify where each product is better; and (4) to compare the grid-to-grid results with the point-to-grid results obtained with the stations themselves.

2. Study Area, Data and Methods

2.1 Study area and stations

The Konya Closed Basin lies in Central Anatolia and has a semi-arid continental climate. The station network has 61 stations in six groups whose records start in 1972, 2005, 2013, 2014, 2015 and 2016 and end in 2025. The eastern part was defined as the stations east of 33.0°E (Figure 1a), which gives 28 stations: 11 at 970–1100 m on the plains and the rest on mountain slopes up to 2012 m a.s.l. (Hasan Dağı). Their records contain between 117 and 333 months in the study period, because the more recent groups (G4–G6) start in 2014–2016. The mean distance of a station to its four nearest neighbours, used here as a measure of station density, ranges from 20 to 49 km (median 31 km).

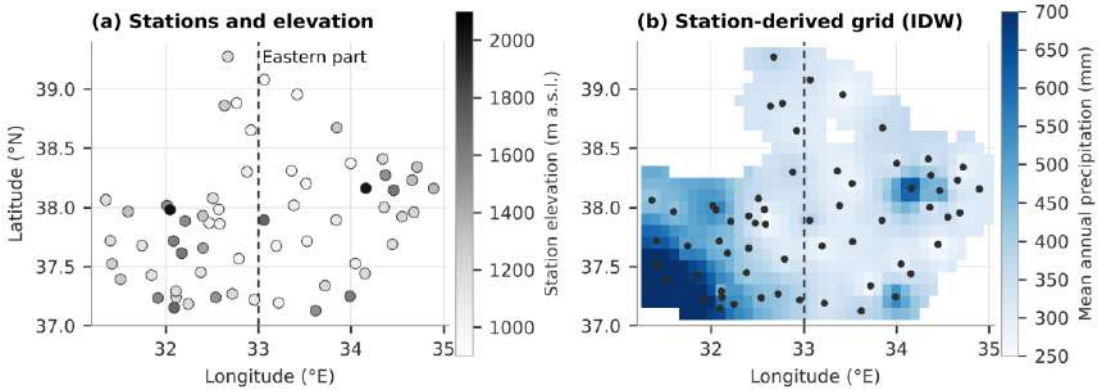


Figure 1. (a) The 61 stations of the network, shaded by elevation, and the eastern part. (b) Station-derived 0.1° grid of mean annual precipitation for 2016–2025, when all stations were active; cells more than 30 km from a station are masked.

2.2 Station-derived grid

Monthly station precipitation was interpolated to a regular 0.1° grid by IDW (Shepard, 1968). For a grid point x_0 the estimate is:

$$Z_0 = \frac{\sum_{j=1}^{k} w_j Z_j}{\sum_{j=1}^{k} w_j}, \qquad w_j = d_j^{-p} \tag{1}$$

where Z_j is the monthly precipitation at the j-th nearest station, d_j its distance in km and p the power. Here k = 8 and p = 2, and a grid point was estimated only when at least four stations had data in that month. The grid was built from all 61 stations of the network, including those west of 33.0°E, so that points near the western edge of the eastern part are not affected by a missing neighbourhood. Elevation was not used in the interpolation; instead, its effect on the quality of the grid was measured (Section 2.4).

Two references were used. In the point reference the product is compared with the station in its grid cell. In the grid reference it is compared with the IDW value at the same cell computed from the other stations only, with the station in the cell left out. This leave-one-out estimate represents a cell without a station, which is the situation for most cells of the basin; with the station included, the IDW value at its own cell would essentially repeat that station. The agreement between the leave-one-out grid and the station gives the skill of the grid itself.

2.3 Products and alignment

IMERG monthly precipitation (Final Run, 0.1°) was available from January 1998 to September 2025, and ERA5-Land monthly total precipitation (0.1°, mm per month) up to December 2025. For each station the values of the nearest 0.1° grid point were used (mean distance 4.2 km); the two products were therefore sampled at 28 grid points in the eastern part. Only months with a station value and both product values between January 1998 and September 2025 were used, giving 117–333 months per grid point (at most 333). No gap-filling was applied.

2.4 Performance metrics and analysis

Let O_i be the reference value and S_i the product value for month i (i = 1, …, n), with means $\bar{O}$ and $\bar{S}$. R, RMSE, MAE, PBIAS (positive = overestimation by the product), the Nash–Sutcliffe efficiency (NSE; Nash and Sutcliffe, 1970) and the Kling–Gupta efficiency (KGE; Gupta et al., 2009) were computed as:

$$R = \frac{\sum_{i=1}^{n}(O_i - \bar{O})(S_i - \bar{S})}{\sqrt{\sum_{i=1}^{n}(O_i - \bar{O})^2 \sum_{i=1}^{n}(S_i - \bar{S})^2}} \tag{2}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - O_i)^2}, \qquad MAE = \frac{1}{n}\sum_{i=1}^{n}|S_i - O_i| \tag{3}$$

$$PBIAS = 100 \times \frac{\sum_{i=1}^{n}(S_i - O_i)}{\sum_{i=1}^{n} O_i}, \qquad NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \tag{4}$$

$$KGE = 1 - \sqrt{(R-1)^2 + (\alpha - 1)^2 + (\beta - 1)^2} \tag{5}$$

where $\alpha = \sigma_S/\sigma_O$ and $\beta = \mu_S/\mu_O$. NSE and KGE equal 1 for a perfect match; a KGE of $1 - \sqrt{2} \approx -0.41$ is the score of using the mean of the reference (Knoben et al., 2019). The metrics were computed for every grid point

and for both references; the regional value is the median over the 28 grid points, and the number of points in which each product is better was counted. To examine the role of terrain and station density, the metrics were related to station elevation and to the mean distance to the four nearest stations by Spearman rank correlation and by elevation classes (<1100, 1100–1400 and >1400 m). Seasonal PBIAS was computed from pooled monthly values for DJF, MAM, JJA and SON. The spatial pattern was assessed by the correlation, across grid points, of mean annual precipitation in 2016–2025 and of monthly values.

3. Results

3.1 Quality of the station-derived grid

The leave-one-out IDW grid reproduced the station values well in the eastern part: the median R was 0.84, the median RMSE 14.7 mm/month and the median PBIAS +7 % (all 61 stations of the network: R = 0.87, RMSE = 14.6 mm/month). Its error was not uniform. RMSE increased with elevation (ρ = +0.51, p = 0.006) and the grid underestimated the highest stations: the median PBIAS of the grid was +10 % below 1100 m, +21 % at 1100–1400 m and -28 % above 1400 m (Table 2, Figure 4c). Skill also fell where stations were sparser: R decreased with the distance to the four nearest stations (ρ = -0.44, p = 0.018; Figure 4d). The grid is thus a good reference on the plains and a weaker one in the mountains, which must be kept in mind when product errors are interpreted there.

3.2 Regional performance of the products

Table 1 gives the median grid-point performance of the two products with both references. Against the station-derived grid, both products reproduced the temporal variation (median R = 0.90 for IMERG and 0.84 for ERA5-Land), and IMERG had the higher R in 28 of 28 grid points. The errors, however, were of opposite sign: IMERG overestimated precipitation (median PBIAS +19.5 %, positive in 27 of 28 grid points) and ERA5-Land underestimated it (-17.5 %, negative in 21 of 28 grid points). IMERG had the lower RMSE in 15 and the lower MAE in 19 of 28 grid points, but ERA5-Land had the higher KGE in 19 of 28 (median KGE 0.69 against 0.64), because its variability is closer to that of the reference (median α = 0.96 against 1.26 for IMERG) while its bias is of similar size. The metrics therefore did not rank the products in the same order, and no product was better at every grid point.

Table 1. Median performance of the products over the 28 grid points of the eastern part, against the station (point) and against the leave-one-out station-derived grid. PBIAS is positive when the product overestimates. The better value of each metric within a reference is in bold.

Reference	Product	R	RMSE (mm)	MAE (mm)	PBIAS (%)	NSE	KGE
Station (point)	IMERG	0.81	19.5	13.5	+35.4	0.34	0.52
	ERA5-Land	0.74	16.8	11.4	-11.8	0.44	0.60
Station-derived grid	IMERG	0.90	13.6	9.3	+19.5	0.60	0.64
	ERA5-Land	0.84	14.3	10.3	-17.5	0.55	0.69

Replacing the station by the interpolated grid improved the agreement for both products (Table 1). The median KGE rose by 0.12 for IMERG and 0.05 for ERA5-Land, the median R by 0.08 and 0.08, and the median RMSE fell by 5.4 and 3.0 mm/month; KGE improved at 20 (IMERG) and 18 (ERA5-Land) of 28 grid points. This is expected, because an interpolated field is smoother than a point series and removes part of the local variability that a 10 km cell cannot represent. The choice of reference also changed which product was better: with the station, IMERG had the higher KGE in 10 grid points and ERA5-Land in 18; with the grid, in 9 and 19. The better product changed at 11 of the 28 grid points (Figure 3).

3.3 Spatial variation of performance

The maps (Figure 2) show that performance varied within the region. Against the grid, the KGE of IMERG ranged from -0.02 to 0.90 and that of ERA5-Land from 0.42 to 0.86. IMERG had its lowest KGE in the south-east (34.0°E, 37.2°N and 34.2°E, 37.4°N), in the east (34.7°E, 38.0°N) and in the north (33.1°E, 39.1°N), where its overestimation was strongest (PBIAS up to +63 %). The underestimation of ERA5-Land was strongest (PBIAS -35 to -29 %) at four grid points in the centre-west (33.2–33.8°E, 37.3–37.9°N) and at one in the east (34.0°E, 38.4°N). Neither product was better everywhere (Figure 3): IMERG had the higher KGE at those grid points and in a small group around 34.0–34.7°E, 38.1–38.4°N, while ERA5-Land was better in most of the remaining area, including the north and the south-east where IMERG overestimated most.

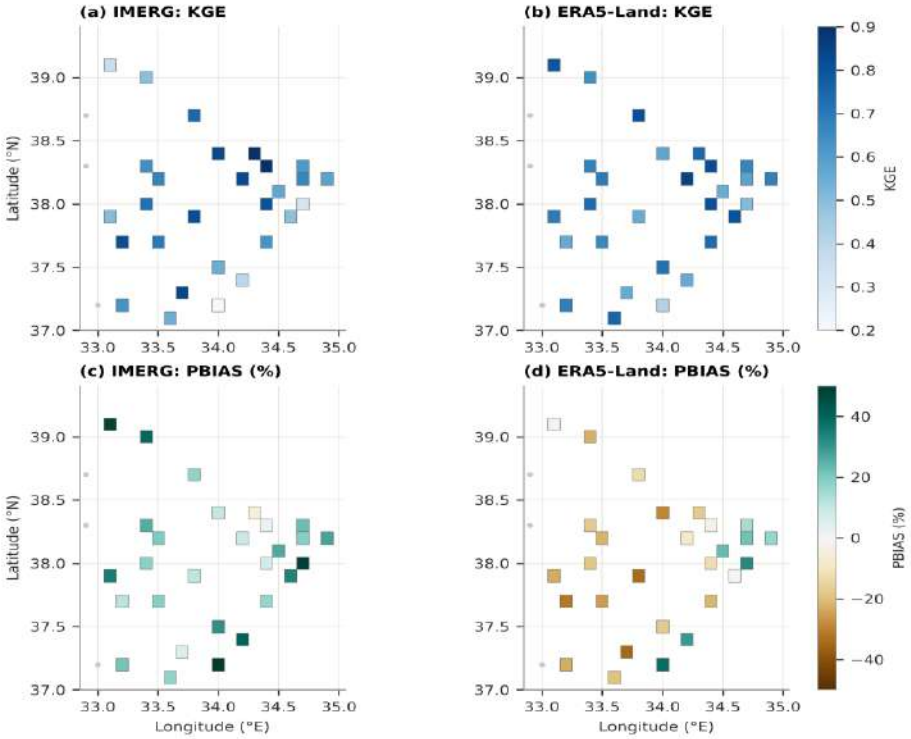


Figure 2. KGE (a, b) and PBIAS (c, d) of IMERG and ERA5-Land at the 0.1° grid points of the eastern part, against the leave-one-out station-derived grid. In (c, d) brown means underestimation and green overestimation. Grey dots are stations west of 33.0°E.

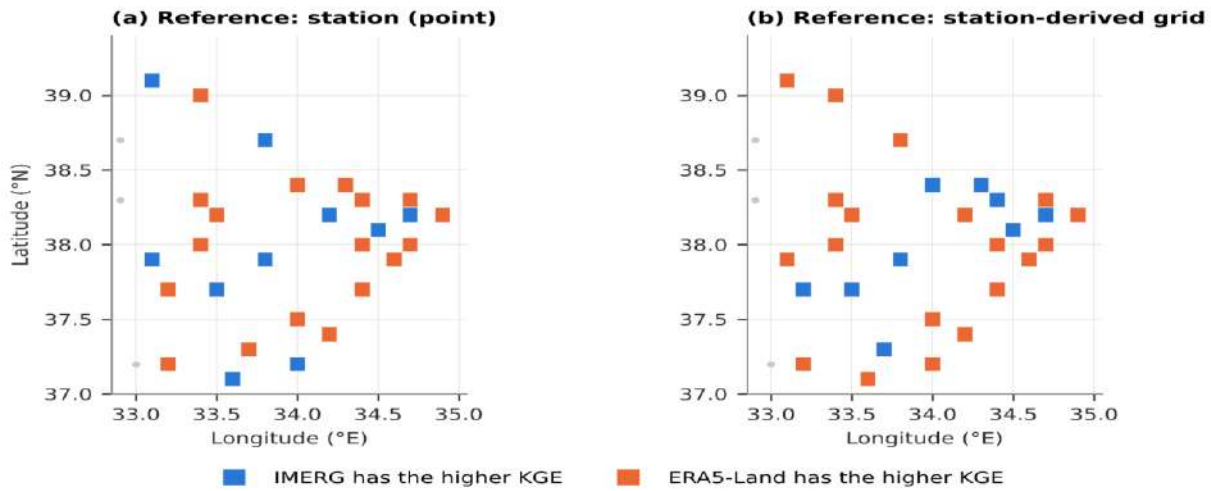


Figure 3. Product with the higher KGE at each grid point when the reference is (a) the station in the cell and (b) the leave-one-out station-derived grid.

3.4 Effects of elevation, station density and season

The skill of the products did not decrease uniformly with elevation (Table 2). Against the grid, the KGE of IMERG fell from 0.67 below 1100 m to 0.56 above 1400 m, whereas that of ERA5-Land stayed between 0.68 and 0.73; none of the rank correlations with elevation was significant (IMERG ρ = -0.12, p = 0.536; ERA5-Land ρ = +0.15, p = 0.461). With the station as reference, the KGE of ERA5-Land decreased with elevation (ρ = -0.42, p = 0.025), and the PBIAS of IMERG decreased (ρ = -0.41, p = 0.028). The bias of ERA5-Land against the grid became less negative with elevation (ρ = +0.53, p = 0.003) and more negative where stations were sparser (ρ = -0.63, p < 0.001; Figure 4b). These trends are partly produced by the reference: the grid underestimates the highest stations (Table 2), so a product can appear less biased there than it is. The patterns in the mountains therefore cannot be attributed to the products alone, and only 6 of 28 grid points are above 1400 m.

Table 2. Median performance by elevation class against the station-derived grid, and median error of the grid itself (leave-one-out) against the stations.

Elevation class	Points	KGE IMERG	KGE ERA5-Land	PBIAS IMERG (%)	PBIAS ERA5-Land (%)	Grid RMSE (mm)	Grid PBIAS (%)
< 1100 m	11	0.67	0.68	+20.0	-22.5	13.1	+9.9
1100–1400 m	11	0.63	0.68	+19.0	-0.3	14.7	+21.4
> 1400 m	6	0.56	0.73	+21.9	-5.4	22.0	-28.5

Seasonally (pooled, against the grid), IMERG overestimated mainly in winter (DJF +43 %) and autumn (SON +25 %), with little bias in summer (+0 %), whereas ERA5-Land was close to unbiased in winter and spring (-4 and +3 %) but underestimated in summer (-30 %) and autumn (-24 %). This is the same seasonal structure as at the two long-record stations Karaman and Kulu.

4. Conclusions

A station-derived 0.1° grid built by IDW was used to compare ERA5-Land and IMERG with station data in the eastern Konya Closed Basin for January 1998 to September 2025. Both products reproduced the timing of monthly precipitation (median R = 0.84–0.90 against the grid), but IMERG overestimated (median PBIAS +20 %) and ERA5-Land underestimated (-17 %). No product was better at every location: ERA5-Land had the higher KGE at 19 of 28 grid points and IMERG the higher R everywhere against the grid. Using the interpolated grid as reference raised the scores and changed the better product at 11 grid points, and the quality of the grid itself decreased in the mountains and where stations are sparse. The spatial pattern of mean annual precipitation was weakly reproduced by both products. It is recommended that product evaluations report the quality of the interpolated reference, that the product be selected by location and use, and that the comparison be extended to all grid cells of the basin, to elevation-aware interpolation and to drought indices.

Acknowledgments and funding:

- The authors thank the Turkish State Meteorological Service (MGM) for providing the station data.
- This work was supported by the research fund of the Coordinatorship of Scientific Research Projects of Yıldız Technical University (BAP, Research Universities Support Program [ADEP], FBA-2026-7704). The authors thank the Scientific Research Projects Coordination Unit for its financial support.
- During the preparation of this manuscript, the authors used Claude (Anthropic, San Francisco, CA, USA; Claude Opus 5.5) as an assistive tool for English-language editing, limited text organization, and selected coding tasks under the authors' scientific and methodological direction. All scientific methods, analytical procedures, parameters, candidate distributions, thresholds, and evaluation metrics were defined by the

authors. The computational workflow, analytical logic, and implementation strategy were established by the authors, while Claude assisted with code generation, refinement, debugging, and implementation in Python. The resulting code was executed by the authors on the study datasets in their own computational environment; the AI tool did not directly access, create, alter, impute, or manipulate the research data. All scripts and their outputs, including figures, tables, and numerical results, were reviewed, checked, and validated by the authors and, where necessary, revised. During the proof stage, Claude (Anthropic; Claude Opus 5.5) was also used to check the internal consistency of the text, numbers, equations, captions, cross-references, and supplementary material, and to suggest wording for the resulting corrections. All suggested changes were verified by the authors against the underlying analysis outputs and cited sources. The AI tools were not used for independent scientific interpretation, formulation of conclusions, or scientific decision-making. The authors have reviewed and edited all AI-assisted outputs and take full responsibility for the accuracy, originality, scientific integrity, and final content of the manuscript.

References

- Amjad, M., Yilmaz, M. T., Yücel, İ., & Yilmaz, K. K. (2020). Performance evaluation of satellite- and model-based precipitation products over varying climate and complex topography. Journal of Hydrology, 584, 124707. https://doi.org/10.1016/j.jhydrol.2020.124707
- Beck, H. E., Vergopolan, N., Pan, M., Levizzani, V., van Dijk, A. I. J. M., Weedon, G. P., Brocca, L., Pappenberger, F., Huffman, G. J., & Wood, E. F. (2017). Global-scale evaluation of 22 precipitation datasets using gauge observations and hydrological modeling. Hydrology and Earth System Sciences, 21, 6201–6217. https://doi.org/10.5194/hess-21-6201-2017
- Daly, C., Halbleib, M., Smith, J. I., Gibson, W. P., Doggett, M. K., Taylor, G. H., Curtis, J., & Pasteris, P. P. (2008). Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. International Journal of Climatology, 28, 2031–2064. https://doi.org/10.1002/joc.1688
- Gupta, H. V., Kling, H., Yilmaz, K. K., & Martinez, G. F. (2009). Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological modelling. Journal of Hydrology, 377, 80–91. https://doi.org/10.1016/j.jhydrol.2009.08.003
- Hisam, E., Danandeh Mehr, A., Alganci, U., & Seker, D. Z. (2023). Comprehensive evaluation of satellite-based and reanalysis precipitation products over the Mediterranean region in Turkey. Advances in Space Research, 71(7), 3005–3021. https://doi.org/10.1016/j.asr.2022.11.007
- Hofstra, N., Haylock, M., New, M., Jones, P., & Frei, C. (2008). Comparison of six methods for the interpolation of daily, European climate data. Journal of Geophysical Research, 113, D21110. https://doi.org/10.1029/2008JD010100
- Huffman, G. J., Bolvin, D. T., Braithwaite, D., Hsu, K.-L., Joyce, R. J., Kidd, C., Nelkin, E. J., Sorooshian, S., Stocker, E. F., Tan, J., Wolff, D. B., & Xie, P. (2020). Integrated Multi-satellitE Retrievals for the Global Precipitation Measurement (GPM) mission (IMERG). In V. Levizzani et al. (Eds.), Satellite Precipitation Measurement (Vol. 1, pp. 343–353). Springer. https://doi.org/10.1007/978-3-030-24568-9_19
- Kartal, V., & Nones, M. (2024). Assessment of meteorological, hydrological and groundwater drought in the Konya closed basin, Türkiye. Environmental Earth Sciences, 83, 285.
- Kidd, C., Becker, A., Huffman, G. J., Muller, C. L., Joe, P., Skofronick-Jackson, G., & Kirschbaum, D. B. (2017). So, how much of the Earth's surface is covered by rain gauges? Bulletin of the American Meteorological Society, 98, 69–78. https://doi.org/10.1175/BAMS-D-14-00283.1
- Knoben, W. J. M., Freer, J. E., & Woods, R. A. (2019). Technical note: Inherent benchmark or not? Comparing Nash–Sutcliffe and Kling–Gupta efficiency scores. Hydrology and Earth System Sciences, 23, 4323–4331. https://doi.org/10.5194/hess-23-4323-2019

- Lu, G. Y., & Wong, D. W. (2008). An adaptive inverse-distance weighting spatial interpolation technique. Computers & Geosciences, 34(9), 1044–1055. https://doi.org/10.1016/j.cageo.2007.07.010
- Muñoz-Sabater, J., Dutra, E., Agustí-Panareda, A., et al. (2021). ERA5-Land: A state-of-the-art global reanalysis dataset for land applications. Earth System Science Data, 13, 4349–4383. https://doi.org/10.5194/essd-13-4349-2021
- Nash, J. E., & Sutcliffe, J. V. (1970). River flow forecasting through conceptual models, Part I – A discussion of principles. Journal of Hydrology, 10(3), 282–290. https://doi.org/10.1016/0022-1694(70)90255-6
- Shepard, D. (1968). A two-dimensional interpolation function for irregularly-spaced data. In Proceedings of the 23rd ACM National Conference (pp. 517–524). ACM. https://doi.org/10.1145/800186.810616
- Sun, Q., Miao, C., Duan, Q., Ashouri, H., Sorooshian, S., & Hsu, K.-L. (2018). A review of global precipitation data sets: Data sources, estimation, and intercomparisons. Reviews of Geophysics, 56, 79–107. https://doi.org/10.1002/2017RG000574
- Tang, G., Clark, M. P., Papalexiou, S. M., Ma, Z., & Hong, Y. (2020). Have satellite precipitation products improved over last two decades? A comprehensive comparison of GPM IMERG with nine satellite and reanalysis datasets. Remote Sensing of Environment, 240, 111697. https://doi.org/10.1016/j.rse.2020.111697
- Yılmaz, M. (2025). Performance of various gridded precipitation and temperature products against gauged observations over Turkey. Earth Science Informatics, 18, 9. https://doi.org/10.1007/s12145-024-01512-2

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

MULTI-METRIC ASSESSMENT OF IMERG AND ERA5-LAND PRECIPITATION PRODUCTS IN A SEMI-ARID CLOSED BASIN: THE KONYA BASIN, TÜRKIYE

Ahmad ABU ARRA
Dr. Yildiz Technical University, Faculty of Civil Engineering, Department of Civil Engineering, İstanbul-Türkiye
An-Najah National University, Department of Civil and Architectural Engineering, Nablus-Palestine
ORCID ID: https://orcid.org/0000-0001-8679-1752
Muhammed Zakir KESKİN
Res. Asst., Bartın University, Faculty of Architecture, Engineering and Design, Department of Civil Engineering, Bartın-Türkiye
ORCID ID: https://orcid.org/0009-0005-6724-491X
Eyüp ŞİŞMAN
Prof. Dr., Yildiz Technical University, Faculty of Civil Engineering, Department of Civil Engineering, İstanbul-Türkiye
ORCID: 0000-0003-3696-9967

Abstract

Reliable and accurate precipitation data are vital for water resource management in all regions, and especially in semi-arid regions such as the Konya Closed Basin (KCB) in Türkiye. This is also of high importance in data-scarce regions, where meteorological stations are sparse and unevenly distributed. Satellite and reanalysis products are therefore used as alternatives to, or supplements for, station measurements. However, their accuracy and resolution vary by location and must be checked and validated. This study evaluates the satellite-based IMERG and the ERA5-Land reanalysis against two long-record stations in the KCB, Karaman in the south and Kulu in the north (about 54 years of record each), over their common period, January 1998 to September 2025. Monthly series were taken at the nearest 0.1° grid point and compared with station measurements using the continuous performance metrics. The metrics include the correlation coefficient (R), root mean square error (RMSE), mean absolute error (MAE), percent bias (PBIAS), Nash–Sutcliffe efficiency (NSE), and Kling–Gupta efficiency (KGE), as well as quantile–quantile (Q–Q) plots. Both products reproduced the monthly precipitation well (R = 0.79–0.89). Still, their errors differed in kind: IMERG overestimated precipitation (PBIAS +28 to +36 %), mainly from autumn to winter, whereas ERA5-Land underestimated it (PBIAS -13 to -14 %), mainly in summer and autumn and at the upper tail. ERA5-Land performed better at Karaman (KGE 0.73 vs. 0.51) and IMERG at Kulu (KGE 0.69 vs. 0.65). The metrics did not always rank the products in the same order. The results support selecting a product based on the intended application and location, and extending the comparison to other stations in the basin.

Keywords: IMERG; ERA5-Land; precipitation products; performance metrics; semi-arid; Konya Closed Basin

1. Introduction

Precipitation is the main input to the water balance and hydrological cycle, and its accurate measurement underpins flood control, irrigation planning, and drought monitoring. In semi-arid regions, precipitation is low, highly variable in space and time, and often poorly sampled by ground networks. The Konya Closed Basin (KCB) in Türkiye is a clear example (Kartal and Nones, 2024). Water-related decisions in such a basin require precipitation information that is continuous and accurate (Muñoz-Sabater et al., 2021).

Satellite-based and reanalysis products offer such information. The Integrated Multi-satellitE Retrievals for GPM (IMERG) combines passive microwave and infrared observations from the Global Precipitation Measurement mission and is adjusted with monthly gauge analyses in its Final Run (Hou et al., 2014; Huffman et al., 2020). ERA5-Land is a land-surface reanalysis driven by atmospheric forcing from ERA5 and provides

hourly to monthly fields at about 9 km resolution for several decades (Hersbach et al., 2020; Muñoz-Sabater et al., 2021). These products fill gaps in station networks, but their errors are known to depend on the region, season, rainfall intensity, and terrain (Beck et al., 2017; Sun et al., 2018; Tang et al., 2020). Based on that, local validation is needed before they are used.

Several studies have evaluated gridded products over Türkiye. Amjad et al. (2020), using 256 gauges, found that IMERG had the strongest monthly correlation among four satellite and reanalysis products, while ERA5 consistently overestimated precipitation. Hisam et al. (2023) compared eight products with 193 stations in the Mediterranean region and reported that most products underestimated heavy rainfall and lost accuracy above 1000 m elevation. Yılmaz (2025) found that product performance differed among regions of Türkiye and that agreement with gauges was better in rainy seasons than in the dry season. Studies that compare IMERG and ERA5-Land against long-gauge records within the semi-arid Konya basin, and that show how the answer varies between its northern and southern parts, remain limited.

A second difficulty is that a single score can give a partial or even misleading picture. Correlation ignores bias, bias measures ignore timing, and efficiency scores combine several error sources in one number (Gupta et al., 2009; Knoben et al., 2019). A product may therefore rank first on one metric and second on another. Using several complementary metrics, together with distributional diagnostics, is the safer way to judge a product.

This study aims to evaluate the performance of IMERG and ERA5-Land against ground measurements at two long-record stations in the Konya Closed Basin, one in the south and one in the north. The objectives are: (1) to quantify the agreement of monthly precipitation using R, RMSE, MAE, PBIAS, NSE and KGE; (2) to compare how the two products represent the distribution of monthly precipitation, including low and high extremes, with Q–Q plots; (3) to examine seasonal behavior; and (4) to assess whether the metrics agree on the ranking of the products and whether the ranking changes between the northern and southern sites.

2. Study Area, Data and Methods

2.1 Study area and ground observations

The KCB has a semi-arid climate. Two stations with the longest records were selected to represent the southern and northern parts of the basin (Figure 1): Karaman in the south and Kulu in the north, about 210 km apart. Both stations have complete monthly records from January 1972 to December 2025. Over 1998–2024 their mean annual precipitation is 316 mm (Karaman) and 357 mm (Kulu), with a dry summer (July–August monthly means below 10 mm at Karaman and below 9 mm at Kulu). The highest totals in winter and spring, with a secondary maximum in May–June at Kulu. Monthly station totals were obtained from the Turkish State Meteorological Service (MGM).

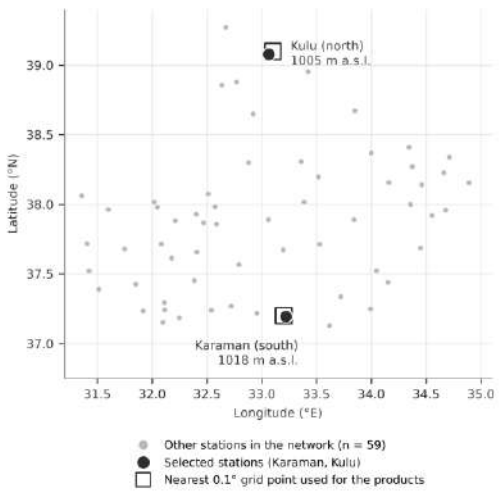


Figure 1. Location of the two selected stations (Karaman and Kulu), their nearest 0.1° grid points, and the other 59 stations of the basin network.

2.2 Precipitation products

IMERG monthly precipitation (Final Run, 0.1°) is available in the dataset used here from January 1998 to September 2025. ERA5-Land monthly total precipitation (0.1°), expressed in mm per month, is available from 1950 and was used here up to December 2025. For each station, the monthly values of the grid cell nearest to the station were extracted without interpolation; the nearest grid point is 1.9 km (Karaman) and 3.8 km (Kulu) from the station. To keep the comparison fair, all statistics were computed on the period common to the stations and both products, January 1998 to September 2025.

2.3 Continuous Performance metrics

Let O_i be the observed and S_i the product value for month i ($i = 1, \ldots, n$), with means $\bar{O}$ and $\bar{S}$. The correlation coefficient (R, with R^2 as its square), root mean square error (RMSE), mean absolute error (MAE), percent bias (PBIAS) and Nash–Sutcliffe efficiency (NSE; Nash and Sutcliffe, 1970) are:

$$R = \frac{\sum_{i=1}^{n}(O_i - \overline{O})(S_i - \overline{S})}{\sqrt{\sum_{i=1}^{n}(O_i - \overline{O})^2 \sum_{i=1}^{n}(S_i - \overline{S})^2}} \quad (1)$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - O_i)^2} \quad (2)$$

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}|S_i - O_i| \quad (3)$$

$$\mathrm{PBIAS} = 100 \times \frac{\sum_{i=1}^{n}(S_i - O_i)}{\sum_{i=1}^{n} O_i} \quad (4)$$

$$\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2} \quad (5)$$

PBIAS is defined here so that positive values mean that the product overestimates precipitation. The Kling–Gupta efficiency (KGE; Gupta et al., 2009) combines correlation, variability and bias:

$$\mathrm{KGE} = 1 - \sqrt{(R-1)^2 + (\alpha - 1)^2 + (\beta - 1)^2} \quad (6)$$

where $\alpha = \sigma_S/\sigma_O$ is the ratio of the standard deviations and $\beta = \mu_S/\mu_O$ is the ratio of the means of the product and the observations. NSE and KGE equal 1 for a perfect match. An NSE of 0 means the product is no better than the observed mean, and a KGE of $1 - \sqrt{2} \approx -0.41$ corresponds to that same benchmark (Knoben et al., 2019). Values of NSE above 0.50 are often regarded as satisfactory at a monthly step (Moriasi et al., 2007).

2.4 Distribution and seasonal diagnostics

Quantile–quantile (Q–Q) plots compare the sorted monthly values of each product with the sorted station values (Wilk and Gnanadesikan, 1968; Wilks, 2011); points on the 1:1 line indicate the same distribution, and departures at the ends show errors in low and high extremes. The 5th, 50th, 95th and 99th percentiles, the

maximum and the number of near-dry months (below 1 mm) were also compared. Seasonal behaviour was summarised by the mean annual cycle and by PBIAS in the four seasons (DJF, MAM, JJA, SON). All calculations used the 1998–2025 common period.

3. Results

3.1 Agreement of monthly precipitation

Both products follow the timing of the observed monthly series at both stations (Figure 2). Correlations are high, from R = 0.79 (ERA5-Land, Kulu) to R = 0.89 (IMERG, Kulu) (Table 1). The size of the errors, however, differs by product and by site. At Karaman, ERA5-Land has the lower RMSE (14.5 vs. 19.4 mm) and MAE (9.5 vs. 12.7 mm), the smaller bias (PBIAS -13.5% vs. +36.2%), and the higher NSE (0.63 vs. 0.34) and KGE (0.73 vs. 0.51), while IMERG has the higher correlation (0.84 vs. 0.81). At Kulu the picture changes: IMERG has the higher R, the lower RMSE (15.0 vs. 16.4 mm), and the higher NSE (0.67 vs. 0.60) and KGE (0.69 vs. 0.65), whereas ERA5-Land has the lower MAE (10.7 vs. 11.4 mm) and the smaller bias (PBIAS -14.1% vs. +28.1%).

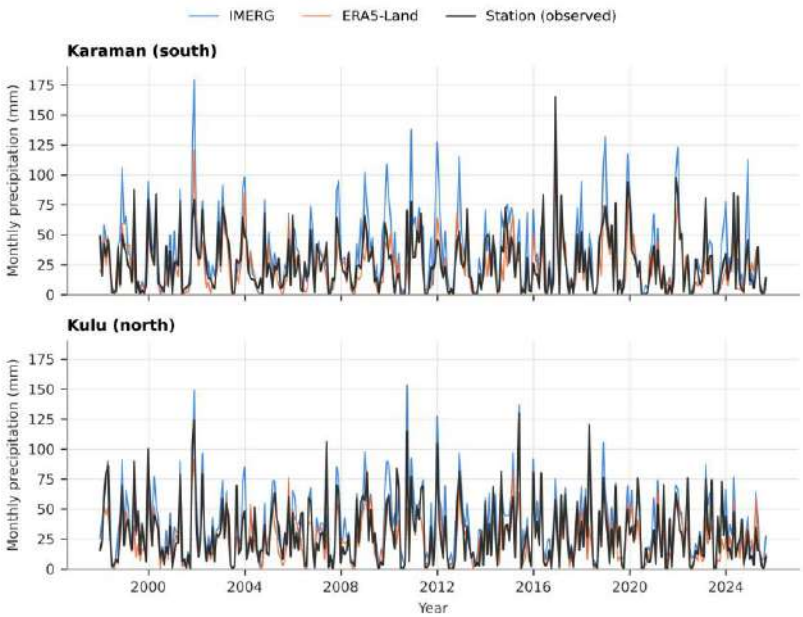


Figure 2. Monthly precipitation observed at the stations and given by IMERG and ERA5-Land at the nearest grid point, January 1998-September 2025.

Table 1. Performance of IMERG and ERA5-Land against the station measurements.

Station	Product	R	R^2	RMSE (mm)	MAE (mm)	PBIAS (%)	NSE	KGE	α	β
Karaman	IMERG	0.84	0.70	19.4	12.7	+36.2	0.34	0.51	1.28	1.36
	ERA5-Land	0.81	0.65	14.5	9.5	-13.5	0.63	0.73	0.86	0.87
Kulu	IMERG	0.89	0.80	15.0	11.4	+28.1	0.67	0.69	1.06	1.28
	ERA5-Land	0.79	0.63	16.4	10.7	-14.1	0.60	0.65	0.76	0.86

The KGE components show why the two products lose skill in different ways. The IMERG error is dominated by bias: $\beta = 1.36$ at Karaman and 1.28 at Kulu, i.e. about 28–36% more precipitation than observed, with $\alpha = 1.28$ and 1.06. ERA5-Land has smaller bias ($\beta = 0.87$ and 0.86) but under-represents variability, especially at Kulu ($\alpha = 0.76$). The scatter plots (Figure 3) agree with this: IMERG points lie mostly above the 1:1 line, while ERA5-Land points lie mostly below it and flatten at large observed values. NSE exceeds 0.50 in three of the four cases (IMERG at Karaman is the exception, NSE = 0.34), and all KGE values are well above the −0.41 benchmark. Aggregated to annual totals (1998–2024, 27 years), year-to-year variation was captured less consistently than month-to-month variation: annual correlations were 0.68 (IMERG) and 0.56 (ERA5-Land) at Karaman and 0.87 and 0.54 at Kulu, so only IMERG at Kulu reproduced annual totals well.

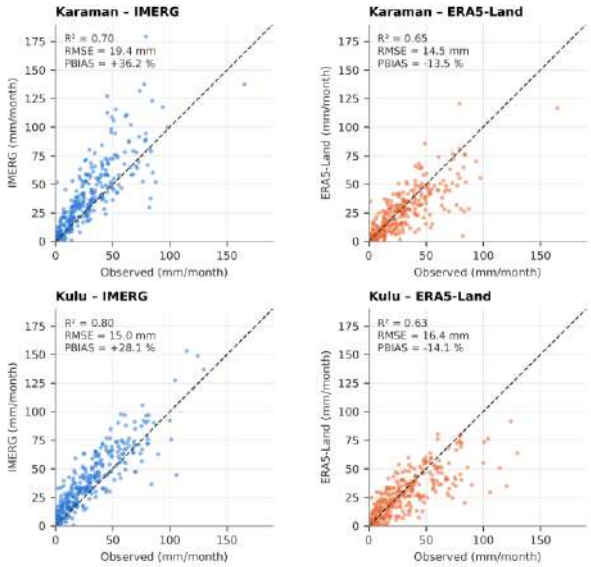


Figure 3. Scatter plots of monthly precipitation from IMERG and ERA5-Land against the station measurements. The dashed line is the 1:1 line; R^2, RMSE and PBIAS are given in each panel.

3.2 Distribution and extremes

The Q–Q plots (Figure 4) and the percentiles in Table 2 show that agreement is stronger for the bulk of monthly totals than for the extremes. ERA5-Land stays close to the 1:1 line for most of the distribution and falls clearly below it in the upper tail: its 95th percentile is 18% and 25% below the observed value at Karaman and Kulu, and its 99th percentile 8% and 31% below. Its largest monthly total is 121 mm at Karaman and 91 mm at Kulu, against 165 mm and 130 mm observed. IMERG lies above the 1:1 line over the whole distribution at Karaman (95th percentile +27%, 99th percentile +50%), whereas at Kulu it is above the line for low and middle values, comes close to it between roughly 70 and 100 mm, and exceeds it again in the few highest months (95th percentile +11%, 99th percentile +12%).

The two products also differ at the dry end. Months with less than 1 mm are frequent in the observations (35 at Karaman and 22 at Kulu), and ERA5-Land reproduces this closely (35 and 17 months), whereas IMERG almost never produces such months (9 and 5). In the driest quarter of months (observed values at or below 6.2 mm at Karaman and 8.4 mm at Kulu), the observed mean is 2.0 and 3.2 mm, ERA5-Land gives 3.7 and 5.6 mm, and IMERG gives 6.2 and 10.5 mm.

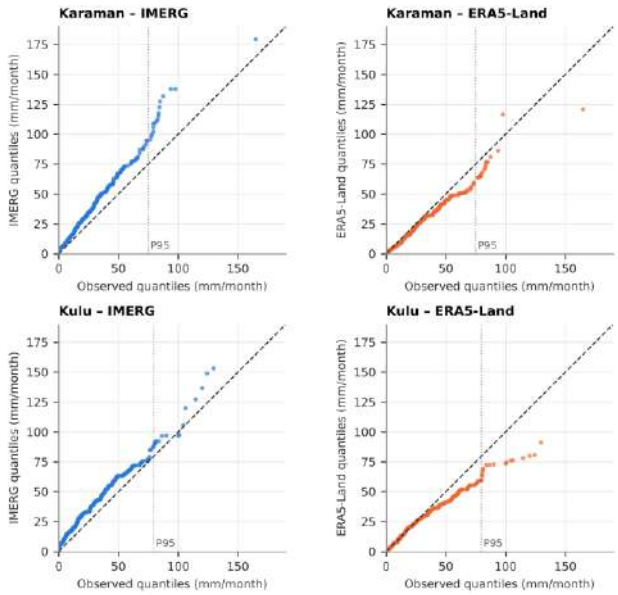


Figure 4. Q–Q plots of monthly precipitation: product quantiles against station quantiles. The dashed line is the 1:1 line and the dotted line marks the observed 95th percentile (P95).

Table 2. Percentiles, maximum and number of near-dry months (below 1 mm) of monthly precipitation, 1998–2025.

Station	Series	P50 (mm)	P95 (mm)	P99 (mm)	Max (mm)	Months < 1 mm
Karaman	Observed	20.7	74.7	86.7	165.0	35
	IMERG	29.5	94.8	130.3	179.3	9
	ERA5-Land	16.9	61.0	79.8	120.6	35
Kulu	Observed	23.4	79.6	111.8	129.8	22
	IMERG	32.7	88.7	124.8	153.3	5
	ERA5-Land	22.6	59.8	77.4	91.3	17

*3.*3 Seasonal behaviour

The mean annual cycle (Figure 5) is reproduced by both products, with a wet period from autumn to early summer and a dry July–August. The seasonal biases, however, have opposite patterns (Table 3). IMERG overestimates most strongly in winter (+56% at Karaman, +42% at Kulu) and autumn (+46% and +22%) and is close to unbiased in summer (+2% and +9%). ERA5-Land is close to unbiased in winter and spring but underestimates summer precipitation by about 48% at Karaman and 45% at Kulu, and autumn precipitation by about 26–27%. Correlation is also season-dependent: for ERA5-Land at Kulu it is lowest in spring (R = 0.64, against 0.90 in winter).

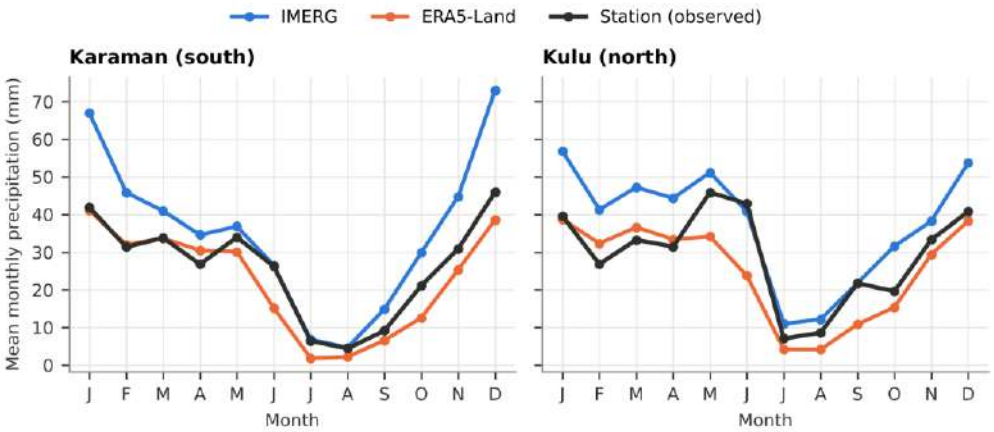


Figure 5. Mean annual cycle of monthly precipitation (1998–2025) at the stations and in the two products.

Table 3. Seasonal PBIAS (%) of each product, 1998–2025 (positive = overestimation), and observed mean monthly precipitation (mm) in each season.

Station	Series	DJF	MAM	JJA	SON
Karaman	Observed mean (mm)	39.7	31.6	12.4	20.3
	IMERG PBIAS (%)	+55.8	+18.7	+2.5	+46.4
	ERA5-Land PBIAS (%)	-6.1	-0.3	-48.1	-27.2
Kulu	Observed mean (mm)	35.7	36.9	19.5	24.9
	IMERG PBIAS (%)	+41.7	+28.9	+9.2	+22.5
	ERA5-Land PBIAS (%)	+2.2	-5.7	-45.0	-25.8

3.4 Ranking of the products across metrics and sites

Counting the six metrics R, RMSE, MAE, |PBIAS|, NSE and KGE, IMERG is better on 1 of 6 at Karaman and on 4 of 6 at Kulu. No product is best on every metric at either site: at Karaman IMERG wins only on correlation, and at Kulu ERA5-Land wins on MAE and bias while IMERG wins on R, RMSE, NSE and KGE. Considering each month separately, ERA5-Land is closer to the observation than IMERG in 58% of months at Karaman and 59% at Kulu.

4. Conclusions

IMERG and ERA5-Land were evaluated against two long-record stations in the semi-arid Konya Closed Basin for January 1998–September 2025. Both products reproduce the timing of monthly precipitation well (R = 0.79–0.89), but IMERG overestimates precipitation (PBIAS +28 to +36%, mainly from autumn to winter) and rarely produces dry months, while ERA5-Land underestimates it (PBIAS about -13 to -14%, mainly in summer, autumn and at the upper tail). ERA5-Land performs better at the southern station (KGE 0.73 vs. 0.51) and IMERG at the northern station (KGE 0.69 vs. 0.65), and the metrics do not always agree on the ranking. Agreement is stronger for monthly totals than for extremes. The study therefore recommends (1) using several complementary metrics together with Q-Q and seasonal diagnostics, (2) selecting the product according to the intended application and location, and (3) extending the comparison to all stations in the basin and to drought indices, so that the best product can be identified for each part of the basin.

Acknowledgments and funding:

- The authors thank the Turkish State Meteorological Service (MGM) for providing the station data.

- This work was supported by the research fund of the Coordinatorship of Scientific Research Projects of Yıldız Technical University (BAP, Research Universities Support Program [ADEP], FBA-2026-7704). The authors thank the Scientific Research Projects Coordination Unit for its financial support.

- During the preparation of this manuscript, the authors used Claude (Anthropic, San Francisco, CA, USA; Claude Opus 5.5) as an assistive tool for English-language editing, limited text organization, and selected coding tasks under the authors' scientific and methodological direction. All scientific methods, analytical procedures, parameters, candidate distributions, thresholds, and evaluation metrics were defined by the authors. The computational workflow, analytical logic, and implementation strategy were established by the authors, while Claude assisted with code generation, refinement, debugging, and implementation in Python. The resulting code was executed by the authors on the study datasets in their own computational environment; the AI tool did not directly access, create, alter, impute, or manipulate the research data. All scripts and their outputs, including figures, tables, and numerical results, were reviewed, checked, and validated by the authors and, where necessary, revised. During the proof stage, Claude (Anthropic; Claude Opus 5.5) was also used to check the internal consistency of the text, numbers, equations, captions, cross-references, and supplementary material, and to suggest wording for the resulting corrections. All suggested changes were verified by the authors against the underlying analysis outputs and cited sources. The AI tools were not used for independent scientific interpretation, formulation of conclusions, or scientific decision-making. The authors have reviewed and edited all AI-assisted outputs and take full responsibility for the accuracy, originality, scientific integrity, and final content of the manuscript.

References

- Amjad, M., Yilmaz, M. T., Yücel, İ., & Yilmaz, K. K. (2020). Performance evaluation of satellite- and model-based precipitation products over varying climate and complex topography. *Journal of Hydrology*, 584, 124707. https://doi.org/10.1016/j.jhydrol.2020.124707
- Beck, H. E., Vergopolan, N., Pan, M., Levizzani, V., van Dijk, A. I. J. M., Weedon, G. P., Brocca, L., Pappenberger, F., Huffman, G. J., & Wood, E. F. (2017). Global-scale evaluation of 22 precipitation datasets using gauge observations and hydrological modeling. *Hydrology and Earth System Sciences*, 21, 6201–6217. https://doi.org/10.5194/hess-21-6201-2017
- Gupta, H. V., Kling, H., Yilmaz, K. K., & Martinez, G. F. (2009). Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological modelling. *Journal of Hydrology*, 377, 80–91. https://doi.org/10.1016/j.jhydrol.2009.08.003
- Hersbach, H., Bell, B., Berrisford, P., et al. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, 146, 1999–2049. https://doi.org/10.1002/qj.3803
- Hisam, E., Danandeh Mehr, A., Alganci, U., & Seker, D. Z. (2023). Comprehensive evaluation of satellite-based and reanalysis precipitation products over the Mediterranean region in Turkey. *Advances in Space Research*, 71(7), 3005–3021. https://doi.org/10.1016/j.asr.2022.11.007
- Hou, A. Y., Kakar, R. K., Neeck, S., Azarbarzin, A. A., Kummerow, C. D., Kojima, M., Oki, R., Nakamura, K., & Iguchi, T. (2014). The Global Precipitation Measurement mission. *Bulletin of the American Meteorological Society*, 95, 701–722. https://doi.org/10.1175/BAMS-D-13-00164.1
- Huffman, G. J., Bolvin, D. T., Braithwaite, D., Hsu, K.-L., Joyce, R. J., Kidd, C., Nelkin, E. J., Sorooshian, S., Stocker, E. F., Tan, J., Wolff, D. B., & Xie, P. (2020). Integrated Multi-satellitE Retrievals for the Global Precipitation Measurement (GPM) mission (IMERG). In V. Levizzani et al. (Eds.), *Satellite Precipitation Measurement* (Vol. 1, pp. 343–353). Springer. https://doi.org/10.1007/978-3-030-24568-9_19
- Kartal, V., & Nones, M. (2024). Assessment of meteorological, hydrological and groundwater drought in the Konya closed basin, Türkiye. *Environmental Earth Sciences*, 83, 285.

- Knoben, W. J. M., Freer, J. E., & Woods, R. A. (2019). Technical note: Inherent benchmark or not? Comparing Nash–Sutcliffe and Kling–Gupta efficiency scores. *Hydrology and Earth System Sciences*, 23, 4323–4331. https://doi.org/10.5194/hess-23-4323-2019
- Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE*, 50(3), 885–900. https://doi.org/10.13031/2013.23153
- Muñoz-Sabater, J., Dutra, E., Agustí-Panareda, A., et al. (2021). ERA5-Land: A state-of-the-art global reanalysis dataset for land applications. *Earth System Science Data*, 13, 4349–4383. https://doi.org/10.5194/essd-13-4349-2021
- Nash, J. E., & Sutcliffe, J. V. (1970). River flow forecasting through conceptual models, Part I – A discussion of principles. *Journal of Hydrology*, 10(3), 282–290. https://doi.org/10.1016/0022-1694(70)90255-6
- Sun, Q., Miao, C., Duan, Q., Ashouri, H., Sorooshian, S., & Hsu, K.-L. (2018). A review of global precipitation data sets: Data sources, estimation, and intercomparisons. *Reviews of Geophysics*, 56, 79–107. https://doi.org/10.1002/2017RG000574
- Tang, G., Clark, M. P., Papalexiou, S. M., Ma, Z., & Hong, Y. (2020). Have satellite precipitation products improved over last two decades? A comprehensive comparison of GPM IMERG with nine satellite and reanalysis datasets. *Remote Sensing of Environment*, 240, 111697. https://doi.org/10.1016/j.rse.2020.111697
- Wilk, M. B., & Gnanadesikan, R. (1968). Probability plotting methods for the analysis of data. *Biometrika*, 55(1), 1–17.
- Wilks, D. S. (2011). *Statistical Methods in the Atmospheric Sciences* (3rd ed.). Academic Press.
- Yılmaz, M. (2025). Performance of various gridded precipitation and temperature products against gauged observations over Turkey. *Earth Science Informatics*, 18, 9. https://doi.org/10.1007/s12145-024-01512-2

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

MULTI-OBJECTIVE STRUCTURAL CONTROL VIA STOCHASTIC DYNAMIC GAMES: A GAME-THEORETIC APPROACH TO VIBRATION SUPPRESSION

Yucel Aydin
Ali Fuat Ergenç
Işıl Aydın
State University of New York at Buffalo, New York, USA.

Abstract

Abstract

This study presents a game-theoretic approach to multi-agent structural vibration control under combined earthquake–wind loading. Semi-active dampers act as agents with local measurements, asymmetric information, and team or mixed objectives. In this approach, each damper's decision problem is modeled as a stochastic dynamic game (SDG). Cooperative damper teams minimize the common structural cost by accounting for the signaling value that their actions carry to neighboring dampers. Mixed or misaligned configurations are modeled as coalitional or Stackelberg games; for large damper arrays, mean-field approaches (mean-field games, MFG, and mean-field-type games) are used. This game-theoretic approach offers a roadmap for decentralized, information-asymmetric, and learning-enabled vibration suppression.

In the application to a ten-story shear building under combined earthquake–wind loading, semi-active dampers act as agents with local measurements, delayed common information, and team or mixed objectives, and each damper's decision problem is modeled as a stochastic dynamic game. Cooperative damper teams that account for the signaling value of their actions recover 78–93% of the centralized gain. Coalitional and Stackelberg configurations add a small extra gain and identify the few dampers that matter. For large damper arrays, mean-field and mean-field-type approaches are illustrated with small LQ and parametric-gain models through three results: the price of simplicity, interacting populations together with finite and stationary horizons, and risk-sensitive gain. The decision roadmap figure is a simulation-based guide for decentralized, information-asymmetric, and learning-enabled vibration suppression.

Keywords: Multi-agent structural vibration control; Stochastic dynamic games (SDG); Mean-field game (MFG); multi-agent reinforcement learning (MARL).

INTRODUCTION

The vibration of a multi-story structure under combined earthquake and wind loading is treated as a *multi-agent* decision system formed by floor-level semi-active dampers. Each damper sees only local measurements (stroke velocity, floor acceleration, neighboring-floor acceleration); the measurements, objectives, and hazard type of the other dampers are known only partially or with delay. Under this asymmetric information, each damper's decision problem is posed as a stochastic dynamic game (SDG). When the dampers minimize the common structural cost the setting is a *team*; when their objectives are misaligned it is a *coalitional* or *Stackelberg* game; and when their number becomes very large it is a *mean-field game*. The following sections give the damper–agent formulation given by the building model as the concrete counterpart of these three cases, the solution concept suited to each, and their numerical results on a ten-story building.

Başar, Djehiche, and Tembine (2026) treat mean-field-type game theory, in which cost and dynamics depend on the law of the state and control and each decision maker's action affects this law, together with its linear-

quadratic, risk-sensitive, regime-switching, Stackelberg (hierarchical), and asymmetric-information versions and non-asymptotic approximation bounds for an arbitrary number of decision makers.

Risk-sensitive mean-field games were introduced by Tembine, Zhu, and Başar (2014), developed for the linear-quadratic and robust case by Moon and Başar (2017), and for discrete time by Saldi, Başar, and Raginsky (2020).

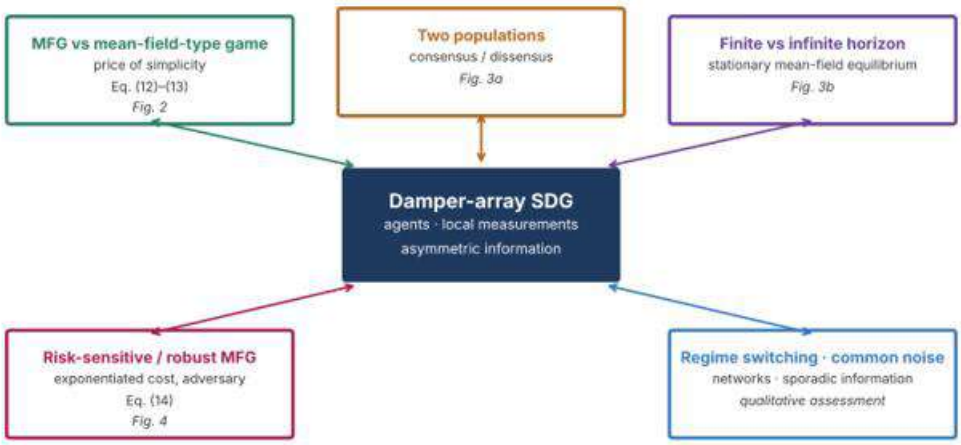


Figure 1. Mapping of additions to the damper-array stochastic dynamic game.

Stochastic Dynamic Games

Formal model

Let there be N agents, $\mathcal{N} = \{1,\ldots,N\}$, horizon T, state $x_t \in \mathcal{X}$, actions $u_t^i \in \mathcal{U}^i$, and joint action $u_t = (u_t^1,\ldots,u_t^N)$; the dynamics are

$$x_{t+1} = f(x_t, u_t, w_t), \qquad w_t \sim P_w(\cdot) \tag{1}$$

Agent i's information at time t is written $\mathcal{I}_t^i = \eta_t^i(x_{0:t}, u_{0:t-1}, \theta^i)$, where η_t^i is the information structure and θ^i is private information. In structural control, x_t represents the interstory drifts and velocities (and load-filter states), u_t^i the command of the i-th damper, and w_t the combined ground acceleration and wind fluctuation.

$$\min_{\gamma,\sigma} J(\gamma) \quad \text{s.t.} \quad \mathcal{I}_t^j \supseteq \sigma_t^i\left(\mathcal{I}_t^i\right), \ j \in \mathcal{N}_i \tag{2}$$

Here $\gamma = (\gamma^1,\ldots,\gamma^N)$ denotes the agents' decision rules, σ the information-sharing rule that determines which part of agent i's information $\mathcal{I}_{it}$ is passed to its neighbors $\mathcal{N}_i$, and J(γ) the expected common cost.

Team Problems and the Signaling–Optimization Tradeoff

Common-information formulation

Agent i's information is the union of the common information C_t, known to all agents, and private information $P_{i,t}$: $\mathcal{I}_{i,t} = (C_t, P_{i,t})$. In the approach of Nayyar et al. (2013), a fictitious coordinator who knows C_t selects for each agent a prescription $\varphi_{i,t}$ from $P_{i,t}$ to action: $u_{i,t} = \varphi_{i,t}(P_{i,t})$. The coordinator's state is the common belief over the state and *all private information*:

$$\Pi_t = P(x_t, P_{1,t}, \ldots, P_{N,t} \mid C_t) \tag{3}$$

$$V_t(\pi) = \min_{\varphi} \left\{ \mathbb{E}[g(x_t, u_t) \mid \pi, \varphi] + \mathbb{E}\left[V_{t+1}\left(F(\pi, \varphi, c_{t+1}) \right) \mid \pi, \varphi \right] \right\} \tag{4}$$

Here F is the belief-update operator driven by the new common information c_{t+1}. The key point for signaling is that the dynamic program is built not on a single agent's belief but on the common-information profile Π_t. The *signaling value* of an action is the change in the V_{t+1} term in (4) arising from that action's effect on Π_{t+1}:

$$\begin{aligned} \mathrm{Sig}_t(\varphi \mid \pi) = \mathbb{E}\left[V_{t+1}\left(F(\pi, \varphi, c_{t+1}) \right) \mid \pi, \varphi \right] \\ - \mathbb{E}\left[V_{t+1}\left(F(\pi, \varphi_0, c_{t+1}) \right) \mid \pi, \varphi \right] \end{aligned} \tag{5}$$

Here φ is the prescription selected by the coordinator, φ_0 the reference prescription that carries no information, F(π, φ, c) the belief update after new common information c, and Sig the signaling value of the prescription φ.

Mean-Field Games with Misaligned Objectives

Standard formulation

For exchangeable $N \to \infty$ agents, let the agent's dynamics be $dx = b(x,u,m_t)dt + \sigma\, dW$ and its cost $J(u; m) = E[\int_0^T \ell(x,u,m_t)dt + \ell_T(x_T, m_T)]$; $m_t = \lim_{N\to\infty} N^{-1}\Sigma\, \delta_{x_t\wedge i}$ is the empirical distribution. Since a single agent's influence on the aggregate behavior is O(1/N), each agent computes its best response by taking the flow m as *given*. Tractability rests on three properties: symmetry, weak interaction (O(1/N)), and the possibility of decoupling the HJB and FPK equations and joining them by fixed-point iteration.

Equilibrium conditions for heterogeneous agent types

Let the agents be divided into K types (proportions π_k, $\Sigma\pi_k = 1$; e.g., floor group or device capacity); for type k the dynamics are $dx = f_k(x,u,m)dt + \sigma_k\, dW$, where $m = (m_1,\ldots,m_K)$ is the vector of type-conditional distributions and the aggregate distribution is $\bar{m} = \Sigma_k\, \pi_k\, m_k$. The cost is $J_k(u; m) = E\int_0^T \ell_k(x,u,m)dt + E\, \ell_k{}^T(x_T, m_T)$. With $\nu_k = \sigma_k{}^2/2$ and the Hamiltonian $H_k(x,p,m) = \min_u \{ p\cdot f_k(x,u,m) + \ell_k(x,u,m) \}$, the equilibrium conditions are the jointly solved HJB–FPK system:

$$-\partial_t v_k - \nu_k \Delta v_k + H_k(x, \nabla v_k, m) = 0, \qquad v_k(T,x) = \ell_k^T(x, m_T) \tag{6}$$

$$\partial_t m_k - \nu_k \Delta m_k + \mathrm{div}\left(m_k\, \partial_p H_k(x, \nabla v_k, m) \right) = 0, \qquad m_k(0) = m_{k,0} \tag{7}$$

Here v_k is the value function and m_k the state density of type k; H_k and ν_k are as defined above.

The optimal feedback is $u_{k\star}(x,t) = \mathrm{argmin}_u \{ v_k\cdot f_k + \ell_k \}$. The *mean-field equilibrium* is a fixed point: each type's best response to m generates the same m. For finite N, under standard Lipschitz and monotonicity assumptions the mean-field feedback yields an ε_N-Nash equilibrium with $\varepsilon_N \to 0$ (Huang et al., 2006; Lasry and Lions, 2007). Under Lasry–Lions monotonicity the equilibrium is unique; otherwise several equilibria may coexist and this should be reported. In discrete time it is written $V_t^k(x) = \min_u \{ g^k(x,u,\mu_t) + E[V_{t+1}^k(x')|x,u,\mu_t] \}$ and $\mu_{t+1} = \Sigma_k\, \pi_k\, \mu_t^k\, P^{(k_\star)}$; here the flow μ is a given function of time, not an argument in the HJB.

Linear-quadratic mean-field game: closed-form forward–backward equilibrium

The HJB–FPK system is in general a forward–backward coupled system that is hard to solve in the state space. In the linear-quadratic (LQ) case the system reduces to a finite-dimensional pair of forward–backward equations and the equilibrium can be computed in closed form. Let each agent have the dynamics $x_{t+1} = a\,x_t + b\,u_t + c\,m_t + \sigma\,w_t$ and the cost $J = E[\Sigma_{t<T}\, q(x_t - \gamma\, m_t)^2 + r\,u_t^2 + q(x_T - \gamma\, m_T)^2]$; here $m_t = \lim N^{-1}\Sigma_j\, x_t^j$ is the population mean, c denotes the mean coupling in the dynamics and γ in the cost. For a given deterministic flow m the value function has the form $V_t(x) = P_t\,x^2 + 2\,s_t\,x + z_t$, and the coefficients are found backward by the following recursion ($\kappa_t = r/(r + b^2P_{t+1})$, $L_t = b/(r + b^2P_{t+1})$):

$$P_t = q + a^2\kappa_t P_{t+1}, \qquad P_T = q \tag{8}$$

$$s_t = -q\gamma m_t + a\kappa_t(cP_{t+1}m_t + s_{t+1}), \qquad s_T = -q\gamma m_T \tag{9}$$

$$u_t^\star(x) = -L_t[P_{t+1}(ax + cm_t) + s_{t+1}] \tag{10}$$

$$m_{t+1} = (a + c)\,m_t - bL_t[(a + c)P_{t+1}m_t + s_{t+1}], \qquad m_0 = \mathbb{E}\,x_0 \tag{11}$$

Here P_t is the quadratic and s_t the linear (feedforward) coefficient of the value function, L_t the feedback gain, and m_t the population-mean flow; the other symbols are as in the agent model above.

These three steps define a map Φ: m ↦ m′ (first backward by (8)–(9), then forward by (11)); the MFG equilibrium is a fixed point of Φ. Since the coefficients are linear in m, Φ is affine, Φ(m) = A m + d. Hence (i) the equilibrium is the solution of the linear system (I − A) m = d, and its existence and uniqueness depend on the invertibility of I − A; (ii) the fixed-point iteration $m^{(n+1)} = \Phi(m^{(n)})$ converges geometrically from every initial point if, and only if, the spectral radius of A satisfies ρ(A) < 1 (at rate ρ(A)); (iii) if ρ(A) ≥ 1 the iteration may diverge and a unique equilibrium may not exist; in that case damped iteration or the direct linear solution should be used.

Fixed-point algorithm and ε-Nash error for finite N

ε-Nash error. In the N-agent game let all agents apply the mean-field policy and let agent 1 deviate unilaterally. Since the other agents act according to their own states and the deterministic m⋆, agent 1's deviation problem is only a three-dimensional LQ problem with state $(x_1, S_t, 1)$; $S_t = \Sigma_{j\neq 1}\, x_t^j$. Thus, however large N is, the deviation gain is computed exactly: $\varepsilon_N = (J_1^{MF} - J_1^{BR}) / J_1^{MF}$, where J_1^{MF} is the expected cost of the mean-field policy and J_1^{BR} that of the exact best response (both via extended Riccati and Lyapunov recursions). Standard MFG theory (Huang et al., 2006; Carmona and Delarue, 2018) predicts $\varepsilon_N \to 0$ when the agent's effect on the population mean is O(1/N) and the noises are individual; the controlled LQ-MFG test checks this prediction by exact computation. If one of the assumptions is violated (common noise, strong coupling, non-identical agents) the error may not decrease

Mean-field games and mean-field-type games: the price of simplicity

In a mean-field game the population term m_t is exogenous: the generic agent minimizes its cost by taking the flow m as given, because its own influence on the aggregate is O(1/N). In a mean-field-type game (MFTG; Başar, Djehiche, and Tembine, 2026) the dynamics and cost depend on the law of the agent's own state and control, for example through E[x], Var(x), or E[u]; thus a decision maker's action changes the quantity that enters its own cost, and the aggregate is a controlled object, not a frozen one. In a finite group of I decision makers with state x and mean-field terms $\bar{x} = E[x]$, $\bar{u}_i = E[u_i]$, agent i solves:

$$\min_{u_i} \mathbb{E}\Big[\ \tfrac{1}{2}\, q_i x^2(T) + \tfrac{1}{2}\, \bar{q}_i \bar{x}^2(T) + \int_0^T \tfrac{1}{2}\left(q_i x^2 + \bar{q}_i \bar{x}^2 + r_i u_i^2 + \bar{r}_i \bar{u}_i^2\right)$$

$$dx\ = \left(b_1 x + \bar{b}_1 \bar{x} + \sum_j b_{2j}\, u_j + \sum_j \bar{b}_{2j}\, \bar{u}_j\right) dt + \sigma_x\, dB \qquad (12)$$

Here q_i, $\bar{q}_i$, r_i, and $\bar{r}_i$ weight the state, its mean, the control, and its mean in agent i's cost; b_1, $\bar{b}_1$, b_{2j}, and $\bar{b}_{2j}$ are the coefficients through which its own state, its mean, and the controls and means of agent j enter the dynamics; ε_{ij} couples the mean controls of agents i and j; $\bar{x} = E[x]$ and $\bar{u}_i = E[u_i]$.

The reference compares two ways of solving this problem in its price-of-simplicity chapter. The mean-field game approach freezes the mean terms (it approximates, with a population of K_j virtual agents per type, the value $\bar{y}_j = \lim K_j^{-1} \Sigma_k u_{jk} \approx E[u_j]$ and each virtual agent ignores its effect on $\bar{y}_j$); the mean-field-type approach solves the original problem exactly by keeping these terms controlled. The difference between the total costs is the price of simplicity:

$$\mathrm{PoS} = \sum_i \left[L_i^{\mathrm{MFG}} - L_i^{\mathrm{MFTG}}\right], \qquad \mathrm{PoS}^{\mathrm{MFTG}} = 0 \qquad (13)$$

Here L_i^{MFG} and L_i^{MFTG} are agent i's costs under the mean-field game (frozen mean) and mean-field-type (exact) solutions; the price of simplicity PoS is the difference of their totals.

In a variance-aware linear-quadratic example with jump-diffusion noise, the reference shows that the PoS is positive, and can be unbounded, when the noise-plus-jump intensity exceeds a threshold, whereas the price of simplicity of the mean-field-type solution is zero. We use this as a hypothesis for damper arrays: since a damper's force changes the response of neighboring floors, and hence their measurements and costs, by a first-order amount, that is, by a change that does not shrink as the number of dampers N grows, the frozen-flow premise does not hold; this is consistent with the non-vanishing ε-Nash gap in the damper-array experiments, that is, a unilateral deviation gain that does not decrease as the array grows. Two cautions are needed. First, the mean-field-type solution is the exact optimum of the stated problem and, in a team-like setting, a cooperative optimum; it is not a Nash equilibrium. The deviation gain can therefore be larger. Second, the examples in the reference are scalar; the price-of-simplicity experiment below gives a structural test within a fixed family of gains.

Risk-sensitive and robust mean-field formulations

The loading parameters in the earthquake–wind loading model (peak ground acceleration, wind speed, and force scale) are uncertain, and a controller tuned to expected values may be fragile. Robustness can be built into the mean-field game in two seemingly equivalent ways (Tembine, Zhu, and Başar, 2014; Moon and Başar, 2017; Başar, 2026): by minimizing the exponentiated cost $E \exp(\theta L)$ ($\theta > 0$ risk-averse), or by adding to the dynamics an adversarial disturbance v penalized by $-s v^2$ in the cost; this turns the best-response problem into a zero-sum stochastic game (min over u, max over v). In both cases the equilibrium is again a fixed point, $m(t) = E[\bar{x}(t)]$, but now generated by the risk-sensitive or worst-case best response. In the scalar linear-quadratic case with dynamics $dx = (a x + \bar{a} m + b u + c v)\, dt + \sigma\, dB$ and cost $\tfrac{1}{2}\int (q x^2 + \bar{q}(x - m)^2 + r u^2 - s v^2)\, dt$ (reference, Eq. 7.63), the coefficient $\beta(t)$ of the quadratic part of the value function satisfies:

$$\dot{\beta} + 2a\beta + (q + \bar{q}) + \left(-\frac{b^2}{r} + \frac{c^2}{s} + \theta\sigma^2\right)\beta^2 = 0, \qquad u^* = -\frac{b}{r}(\beta x + \alpha) \qquad (14)$$

Here α is the linear part of the value function, θ the risk parameter, s the penalty on the adversarial disturbance, σ the noise intensity, and a, b, c, q, q̄, r the dynamics and cost coefficients.

For θ = 0 and c = 0 this is the usual Riccati equation. Positive $\theta\sigma^2$ and c^2/s reduce the curvature supplied by b^2/r; consequently β and the feedback gain $b\,\beta/r$ increase: a risk-averse or robust controller behaves more strongly. In the scalar example $\theta\sigma^2/2$ and $c^2/(2s)$ enter in the same way; this is the known equivalence between risk-sensitive control and the disturbance-attenuation game. The numerical values are given by the risk-sensitive example below. A structural application would apply the same exponentiation to the composite cost in the experimental design or add the ground-motion scale as a zero-sum player; we show only the scalar mechanism.

Regime switching, common noise, and multiple populations

In practice the hazard regime θ ∈ {E, W, E+W} is a hidden label fixed within a realization. The natural counterpart in mean-field theory is a finite-state Markov chain S(t) whose transitions are slow relative to the individual dynamics; the mean-field limit is a switching stochastic differential equation in which S(t) is constant on the intervals [lk, (l+1)k): dm = f(m, u, S(t)) dt + σ(m, u, S(t)) dB, whose solution exists and is unique under linear growth and Lipschitz conditions, and the stability of a stationary point is defined in probability. The reference also treats regime-switching linear-quadratic games with semi-explicit equilibria, in several of its chapters, and decision makers who observe only their own signal and the switching regime, in its asymmetric-information chapter; this is the information pattern of dampers with local measurements. A building departs from the weak-interaction setting in that all floors see the same ground acceleration, that is, a common noise; the reference treats LQ mean-field-type games with common noise.

Multiple populations. In the multi-population mean-field game of Aydin and Başar (2026), as presented in Başar (2026), an infinite number of agents is divided into a few populations weakly coupled through state measures; each player knows its own state and the state measures of all populations, and its single-stage cost depends on its own state, its action, and all state measures. For damper arrays the populations are the K floor groups (types) in the heterogeneous-type formulation. In the LQ case, population i has the dynamics $x_{t+1} = a_i\, x_t + b_i\, u_t + c_i\, m^{it} + f_i + \sigma\, w_t$ and the cost $q\,(x - h^i)^2 + r\,u^2$, with the target $h^{it} = g_{ii}\, m^{it} + \Sigma_{j\neq i}\, k_{ij}\, m^{jt}$; the best-response–flow map is again affine on the stacked flow, Φ(m) = A m + d; the equilibrium is the solution of (I − A) m = d and can be computed by iteration when ρ(A) < 1. A positive cross coupling $k_{ij} > 0$ pulls a population toward the other's mean (consensus type), a negative one pushes it away (dissensus type); both may coexist for different pairs.

Consensus and Dissensus in Networks

A consensus protocol has a single population and a single target. In the multi-type linear-quadratic mean-field game, consensus and dissensus are produced not by the graph Laplacian but by the signs of the cross-coupling coefficients k_{ij} in the multi-population formulation. Attraction toward the means of the other populations reduces the difference between populations, repulsion increases it, and if the coupling is too strong the fixed-point map may lose contraction, as the two-population experiment below shows. For floors, this means that neighboring floor groups agree on, or deliberately disagree on, their control targets.

Delayed network coupling and sparse information exchange. Başar (2025) studies Nash equilibria of network games in which the coupling between agents is delayed according to neighborhoods, in the high-population regime; Aggarwal et al. (2026a) study mean-field games among teams that share information only sparingly, where semantic communication decides what is worth sending. Both are related to the damper findings: the weak response of the composite cost to common-information delay is consistent with slow structural dynamics;

that sharing only velocity or only acceleration recovers 81–87% of the full-sharing gain is a simple, time-invariant form of semantic selection. Event-triggered or information-value-based sharing and delays depending on the distance between floors have not been tested.

Multi-Agent Reinforcement Learning

When the model (f, g, P) is unknown or uncertain (damage, nonlinearity, soil–structure interaction), policies are learned from experience. In the CTDE paradigm a centralized critic can see the global state and joint actions during training; at execution each actor uses only $\mathcal{J}_t^i$. IQL applies the update $Q^i(x,u^i) \leftarrow Q^i + \alpha[r^i + \gamma \max_{u'} Q^i(x',u') - Q^i]$ by treating the other agents as part of the environment; since the environment is non-stationary there is no convergence guarantee and it may cycle. VDN/QMIX use $Q_{tot} = \Sigma_i Q_i$ (VDN) or a monotonic mixing network satisfying $\partial Q_{tot}/\partial Q_i \geq 0$ (QMIX); under the IGM (individual–global–max) condition, local greedy actions are the joint optimum. MADDPG uses centralized critics $Q^i(x,u)$ and deterministic decentralized actors μ^i, with

In the cooperative setup MARL at best converges to a locally optimal joint policy; in the mixed setup there is no general convergence guarantee to a Nash equilibrium. The fixed points found should be interpreted as approximate local equilibria and verified afterwards by *exploitability* (the gain from a single agent's unilateral re-optimization with the others frozen).

Robustness to the Decision Horizon

Proposition (game). Let the costs be bounded by $0 \leq g^i \leq L_{max}$, the strategy spaces and dynamics be the same in the two games, and $\beta \in (0,1)$. An ε-Nash profile of the truncated (T-stage) game, followed by any (bounded) policy after T, is an ε′-Nash profile of the long-horizon game:

$$\varepsilon' \leq \varepsilon + \frac{2\,\beta^T L_{\max}}{1-\beta} \tag{15}$$

Here $\beta \in (0,1)$ is the discount factor, T the truncation horizon, L_{max} the bound on the stage cost, ε the Nash gap of the truncated-game profile, and ε′ the Nash gap of the same profile in the long-horizon game.

Multi-Agent Structural Vibration Control Under Combined Earthquake–Wind Loading

Structural model and device agents

An N = 10-story shear-type building is considered: $M\ddot{q} + C\dot{q} + Kq = -M\,1\,a_g(t) + F_w(t) + B\,u(t)$, where q are the floor displacements, M = diag(m), K the tridiagonal stiffness matrix, C Rayleigh damping ($\zeta = 2\%$ in the first two modes), a_g the ground acceleration, F_w the wind force vector, B the placement matrix of the i-th damper (damper i between floor i−1 and floor i), and u_i the damper forces; see Figure 1. The system is discretized exactly with a zero-order hold (ZOH) at $\Delta t = 10$ ms, with 4 substeps per control step for the damper hysteresis. The state is $x = (q, \dot{q}) \in \mathbb{R}^{20}$; the load-filter states are generated as an exogenous input and are not reported to the controllers.

Damper–agent game. The i-th damper (between floor i−1 and floor i) is an agent of an N-agent SDG. The agent's *action* is the yield force $u_{i,t} = f_{y,i,t} \in [0, f_{max}]$ produced by the MR current command; the *state* is $x_t = (q_t, \dot{q}_t) \in \mathbb{R}^{20}$ and the (hidden) loading regime θ; the *local observation* is $y_{i,t} = H_i\,x_t + v_{i,t}$ (stroke velocity, floor acceleration, and neighboring-floor acceleration); and the *common information* C_t is the applied forces and delayed, packet-loss-prone common measurements. Agent i's policy is γ_i: $(y_{i,0:t}, C_t) \mapsto u_{i,t}$; thus the information is both asymmetric (each agent sees a different y_i) and, because forces affect neighboring measurements,

endogenous (a non-classical information structure, as defined in the formal model). The agent cost is defined through its own floor's *interstory drift* δ_i, *absolute acceleration* α_i, and force expenditure:

$$J_i = \mathbb{E}\sum_t \left[a_w \left(\frac{\delta_{i,t}}{\delta_0}\right)^2 + (1-a_w)\left(\frac{\alpha_{i,t}}{\alpha_0}\right)^2 + \rho\left(\frac{f_{y,i,t}}{F_0}\right)^2 \right] \tag{16}$$

$$J_{\text{team}} = \sum_{i=1}^{N} J_i, \qquad J_i \neq J_j \tag{17}$$

Here $\delta_{i,t}$ is the interstory drift, $\alpha_{i,t}$ the absolute floor acceleration, and $f_{y,i,t}$ agent i's damper force; δ_0, α_0, and F_0 are normalization scales, $a_w \in [0,1]$ the weight of drift relative to acceleration, and ρ the weight of force expenditure.

- Team (common cost, signaling). All dampers jointly minimize (17). Since a damper's force changes the measurements of the neighboring floors, an action is also a *signal*; the common-information approach, in the form given in the team-problems section, accounts for this value. In practice, in the linear-Gaussian structure the common information is realized as an augmented estimator with delayed common measurements.
- Stackelberg (hierarchical management). A building-level controller determines and broadcasts the hazard mode (earthquake/wind); the damper followers choose their own weights according to this mode.
- Coalitional (which dampers?). The value of a subset of dampers is measured by $v(S) = J(\emptyset) - J(S)$; the Shapley value gives a criterion for the device budget and placement.
- Mean field (large arrays). A large number of similar dampers is divided into K types corresponding to floor groups, and each damper reacts to the population mean (for example, the mean floor velocity); the validity limit of the approximation is measured by the ε-Nash error.
- Learning (CTDE). When the model is uncertain, a shared policy is trained centrally with the team reward, and each damper executes it using only local inputs.

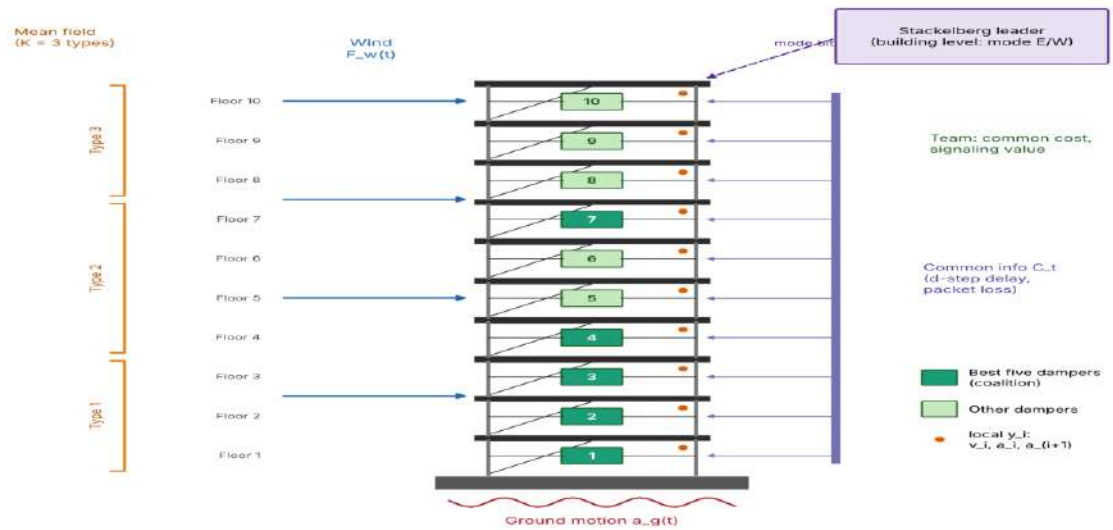


Figure 1. Building model and damper agents: the MR damper on each floor (agent i) decides with local measurements y_i and the (delayed, packet-loss-prone) common information C_t; the building-level Stackelberg leader broadcasts the

earthquake/wind mode; in the mean-field model the floors are divided into K = 3 types; the dark green dampers are the best five-damper coalition.

Price of simplicity in the damper array: frozen-mean versus joint mean-field-type gain design

Each type's three-parameter gain (own deviation, own velocity, population-mean velocity) is designed either by best-response iteration with the other types' gains frozen or jointly over the total cost of all agents; the reference is the centralized team LQR, and unless stated otherwise K = 3 types. The curves in Figure 2 give the result.

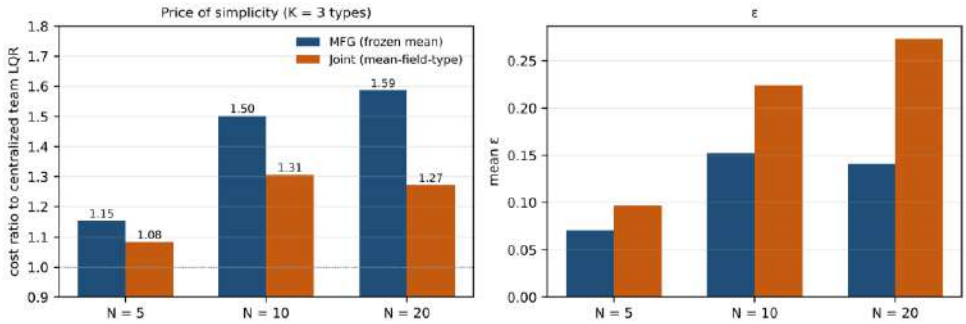


Figure 2. Price of simplicity in the damper array (K = 3): (a) cost ratio to the centralized team LQR for the frozen-mean (MFG) and joint (mean-field-type) designs; (b) mean deviation gain ε.

The joint design reduces the cost ratio from 1.15–1.59 to 1.08–1.31; the price of simplicity grows with array size (6.4% at N = 5, 14.9% at N = 10, 24.7% at N = 20). The price is paid in equilibrium quality: the deviation gain rises from 0.14 to 0.27 (N = 20, K = 3), that is, the joint design is a cooperative optimum, not a Nash equilibrium.

Two interacting populations and finite-horizon mean-field equilibrium

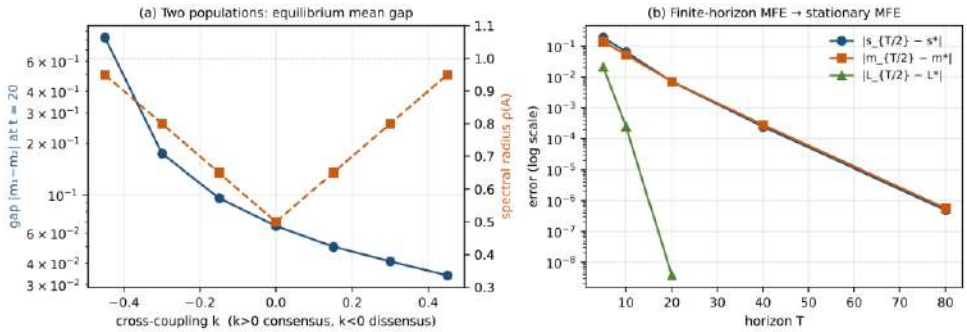


Figure 3. (a) Two-population LQ mean-field game: equilibrium difference between the population means at t = 20 (left axis) and spectral radius of the affine map (right axis), versus cross coupling k; (b) error of the finite-horizon mean-field equilibrium relative to the stationary one, versus horizon T.

Figure 3. (a) Attraction (k > 0) reduces the difference between population means and repulsion (k < 0) increases it (0.041 at k = +0.3, 0.066 without coupling, 0.174 at k = −0.3); since the spectral radius is approximately 0.5 + |k|, the map is a contraction only for |k| < 0.5, and beyond that the equilibrium is ill-conditioned. (b) The finite-horizon equilibrium approaches the stationary one geometrically (about 0.85 per step; 7×10^{-3} at T = 20, 5×10^{-7} at T = 80), whereas the fixed-point map has ρ(A) = 1.69 > 1 and requires a direct linear solution: contraction and convergence are separate properties that must be checked separately.

Risk-sensitive and robust scalar example

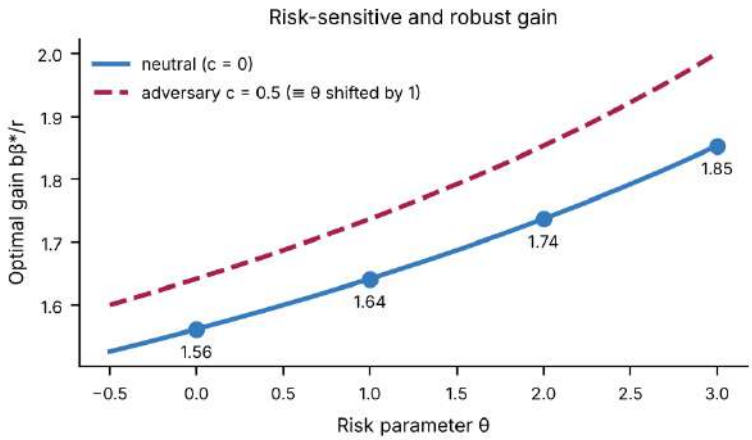


Figure 4. Risk-sensitive and robust gain versus risk parameter θ (scalar proxy a = −0.5, b = 1, q + q̄ = 2, r = 0.5, σ = 0.5, s = 1).

The optimal gain bβ*/r increases monotonically with the risk parameter (1.56, 1.64, 1.74, 1.85 for θ = 0, 1, 2, 3), a risk-seeking value lowers it, and an adversary with c = 0.5 gives exactly the gain of θ = 1. A larger gain means a stronger damper command that spends more energy.

Following the mean-field-type game theory of Başar (2026) and Başar, Djehiche, and Tembine (2026), the paper distinguishes mean-field from mean-field-type games (a 6–25% price of simplicity in the damper array, paid in equilibrium quality), extends the LQ mean-field equilibrium to interacting populations (consensus and dissensus) and to finite and stationary horizons, and adds a risk-sensitive and robust gain.

RESULTS

This paper formulates multi-damper structural vibration control under combined earthquake–wind loading as a stochastic dynamic game and shows how the team, Stackelberg, coalitional, mean-field, and learning formulations fit the information structure and scale of the damper array.

The following four findings rest on numbers read from the curves in the paper, and each gives a criterion for damper-array design.

(1) The price of simplicity grows with growing arrays (Figure 2). Compared with the frozen-mean design, the joint mean-field-type gain design lowers the cost ratio to the centralized team LQR from the range 1.15–1.59 to the range 1.08–1.31; the gap grows with array size and is 6.4%, 14.9%, and 24.7% for N = 5, 10, 20, respectively. Engineering meaning: as the number of dampers grows, the cost of ignoring the effect of each damper's own force on neighboring floors rises, so joint design cannot be neglected in arrays with N ≥ 10. This gain is paid in equilibrium quality: the deviation gain rises from 0.14 to 0.27 (N = 20, K = 3). The joint design is a cooperative optimum, not a Nash equilibrium; if the objectives are not truly shared, the agents' incentive to deviate unilaterally increases and the equilibrium must be checked separately.

(2) The sign and strength of the coupling between populations determine the equilibrium (Figure 3a). When neighboring floor groups are attracted to each other's means (consensus, k = +0.3), the equilibrium difference between population means falls to 0.041; it is 0.066 without coupling and rises to 0.174 under repulsion (dissensus, k = −0.3). Since the spectral radius of the affine map is approximately 0.5 + |k|, the map is a contraction only for |k| < 0.5; beyond this limit the equilibrium is ill-conditioned and fixed-point iteration becomes unreliable. Implication for design: the coupling strength between floor groups should be monitored as a design parameter and |k| kept below the contraction limit.

(3) The finite-horizon equilibrium approaches the stationary equilibrium quickly, but the solution method must be chosen separately (Figure 3b). The deviation of the finite-horizon equilibrium from the stationary one decreases at about 0.85 per step: 7×10^{-3} at T = 20, 5×10^{-7} at T = 80. In contrast, the spectral radius of the finite-horizon fixed-point map is 1.69 > 1 and plain iteration diverges; the equilibrium must be found by direct linear solution. That is, contraction and convergence are separate properties and must be checked separately. Practical conclusion: the short-horizon equilibrium is a good proxy for the long-horizon stationary equilibrium.

(4) Robustness can be translated into a risk setting (Figure 4). The optimal gain $b\beta^*/r$ increases monotonically with the risk parameter: 1.56, 1.64, 1.74, and 1.85 for θ = 0, 1, 2, 3. An adversary with c = 0.5 gives the same gain as θ = 1 (1.64); that is, the robust design with an adversarial disturbance and the risk-sensitive design reduce to the same setting. A larger gain means a stronger damper command that spends more energy; protection against load uncertainty is bought at this price.

DISCUSSION

What does the mean-field-type extension add? The talk by Başar (2026) and the reference give the study three missing tools: a name and a measure for the cost of freezing the aggregate (the price of simplicity), a route to protection against load uncertainty (risk-sensitive and robust best responses), and a place for the hidden hazard regime and multiple floor groups (regime-switching and multi-population mean-field games). The clearest new numerical result is that in the damper array the joint mean-field-type gain design is up to 25–30% cheaper than the frozen-mean design but farther from Nash; the two-population and horizon tests show that contraction of the fixed-point map and convergence of the finite-horizon equilibrium are separate properties; the risk-sensitive result is a mechanism, not yet a structural benefit.

CONCLUSION

Main conclusions. This study formulates multi-damper vibration control under combined earthquake–wind loading as a stochastic dynamic game of agents deciding with local measurements and asymmetric information, and relates the signaling value for cooperative teams, the Stackelberg and coalitional structures for misaligned objectives, and the mean-field and mean-field-type approaches for large arrays to the information structure and array scale. The numerical findings are summarized in four points: (i) the joint mean-field-type gain design lowers the cost ratio to the centralized team LQR from 1.15–1.59 to 1.08–1.31; the price of simplicity grows as the array grows (6.4%, 14.9%, 24.7% for N = 5, 10, 20) and is paid in equilibrium quality (deviation gain from 0.14 to 0.27); (ii) attraction (k = +0.3) reduces the difference between populations to 0.041 while repulsion (k = −0.3) raises it to 0.174, and the map is a contraction only for $|k| < 0.5$; (iii) the finite-horizon equilibrium approaches the stationary one quickly ($7\times10^{-3} \rightarrow 5\times10^{-7}$), yet a direct solution is required; (iv) the gain rises from 1.56 to1.85 with the risk parameter, and an adversary with c = 0.5 gives the same result as θ=1.

In future work, the results will be compared with those obtained by applying a multi-agent reinforcement learning (MARL) approach.

When the number of dampers is about ten or more, the gains should be designed jointly rather than with a frozen mean; however, since joint design is a cooperative optimum, the unilateral deviation gain (ε) should be reported alongside. The coupling strength between floor groups should be kept below the contraction limit by computing the spectral radius of the affine map; the finite-horizon equilibrium should be found by direct linear solution, and the short-horizon equilibrium used as a proxy for the long-horizon stationary equilibrium. The risk parameter θ should be chosen according to load uncertainty, and the force and energy expenditure brought by the larger gain should be evaluated together with the budget.

REFERENCES

Acemoglu, D., Ozdaglar, A., ParandehGheibi, A. (2010). Spread of (mis)information in social networks. *Games and Economic Behavior*, 70(2), 194–227.

Aggarwal, S., Zaman, M. A. uz, Bastopcu, M., Ulukus, S., Başar, T. (2026a). Semantic communication in multi-team dynamic games: A mean field perspective. IEEE Transactions on Automatic Control, 71(1), 49–64.

Aggarwal, S., Zaman, M. A. uz, Bastopcu, M., Ulukus, S., Başar, T. (2026b). Distributed offloading in multiaccess edge computing systems: A mean field perspective. IEEE Transactions on Mobile Computing, 25(6), 7592–7610.

Aydin, U., Başar, T., Saldi, N. (2025). Approximation of discrete-time infinite-horizon mean-field equilibria via finite-horizon mean-field equilibria. Proceedings of the IEEE Conference on Decision and Control.

Aydin, U., Başar, T. (2026). Variational contraction conditions for iterative algorithms in multi-population discrete-time regularized mean-field games. Proceedings of the IEEE Conference on Decision and Control (to appear); arXiv:2605.23906.

Başar, T. (2025). Nash equilibria of networked games with delayed coupling in the high population regime. Central European Journal of Operations Research, May 2025.

Başar, T. (2026). Multi-agent dynamical systems with asymmetric information and with elements of learning. Talk abstract, ITU Control and Automation Engineering, October 22, 2026.

Başar, T., Djehiche, B., Tembine, H. (2026). Mean-Field-Type Game Theory I: Foundations and New Directions. Birkhäuser/Springer, Static & Dynamic Game Theory: Foundations & Applications. https://doi.org/10.1007/978-3-032-07027-2.

Başar, T., Olsder, G. J. (1999). *Dynamic Noncooperative Game Theory* (2nd ed.). SIAM.

Carmona, R., Delarue, F. (2018). *Probabilistic Theory of Mean Field Games with Applications I–II*. Springer.

Huang, M., Malhamé, R. P., Caines, P. E. (2006). Large population stochastic dynamic games: closed-loop McKean–Vlasov systems and the Nash certainty equivalence principle. *Communications in Information and Systems*, 6(3), 221–252.

Lasry, J.-M., Lions, P.-L. (2007). Mean field games. *Japanese Journal of Mathematics*, 2(1), 229–260.

Moon, J., Başar, T. (2017). Linear quadratic risk-sensitive and robust mean field games. IEEE Transactions on Automatic Control, 62(3), 1062–1077.

Nayyar, A., Mahajan, A., Teneketzis, D. (2013). Decentralized stochastic control with partial history sharing: a common information approach. *IEEE Transactions on Automatic Control*, 58(7), 1644–1658.

Pandav, J., Chopra, M., Matsagar, V., Chakraborty, S. (2024). An iterative gradient descent-based reinforcement learning policy for active control of structural vibrations. *Computers and Structures*, 290, 107183.

Saldi, N., Başar, T., Raginsky, M. (2020). Approximate Markov–Nash equilibria for discrete-time risk-sensitive mean-field games. Mathematics of Operations Research, 45(4), 1596–1620.

Tembine, H., Zhu, Q., Başar, T. (2014). Risk-sensitive mean-field games. IEEE Transactions on Automatic Control, 59(4), 835–850.

Yu, C., Velu, A., Vinitsky, E., et al. (2022). The surprising effectiveness of PPO in cooperative multi-agent games. *Advances in Neural Information Processing Systems*, 35.

Yuan, R., Yang, Y., Su, C., Hu, S., Zhang, H., Cao, E. (2021). Research on vibration reduction control based on reinforcement learning. *Advances in Civil Engineering*, 2021.

Zhang, K., Yang, Z., Başar, T. (2021). Multi-agent reinforcement learning: a selective overview of theories and algorithms. In *Handbook of Reinforcement Learning and Control*, Springer, 321–384.

RADICALIZATION BETWEEN RELIGION AND SOCIAL REALITY: THE CASE OF BOKO HARAM

Mehmet Emin KALGI
Assoc. Prof. Dr. Department of Psychology of Religion, Ardahan University
Visiting Scholar, Indiana University Bloomington
ORCID ID: 0000-0001-6999-5059

Abstract

Although the relationship between religion and radicalization has long been widely recognized throughout history, it has re-emerged today within the context of new religious movements through the use of different dynamics. Concepts such as jihad, caliphate, war, and dar al-Islam occupy a central place within these movements, reflecting different perspectives according to the social and political dynamics of each country. However, the common characteristic of these movements is that they produce destructive consequences such as bloodshed, tears, death, and trauma. One of these movements is Boko Haram. Literally meaning "Western education is forbidden," this movement emerged with this slogan and became significantly more violent, particularly after the killing of its leaders in 2009. Operating in countries such as Nigeria, Cameroon, and Chad, the organization attracted greater international attention after pledging allegiance to ISIS in 2015.

Targeting schools, police stations, and civilian settlements, the emergence of this organization has been shaped primarily by Nigeria's socioeconomic conditions, including security weaknesses, drug trafficking, poverty, and unemployment. Nigeria's socioeconomic reality appears to be one of the main dynamics nourishing the organization. Today, with thousands of members, the group has transformed into a structure that is difficult to control and has become a major threat not only to Nigeria but also to neighboring countries through its violent activities.

Possessing messianic characteristics, Boko Haram is also regarded as a pan-Islamist and jihadist organization. Intellectually influenced by Ibn Taymiyyah, the group legitimizes violence through its core discourses.

The aim of this paper is to reveal the socio-psychological reality of this organization that emerged in Nigeria and to draw attention to the dynamics underlying recruitment and participation processes. The broader objective of the study is to highlight the potential threats that this organization—emerging within Nigeria's socioeconomic reality—may pose to regional countries in the future. The immediate objective, however, is to open an academic discussion on whether this organization, which draws upon Islamic concepts, can genuinely be considered Islamic.

Keywords: Psychology of Religion, Radicalization, Jihad, Boko Haram.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

REASONS FOR RELIGIOUS CONVERSION FROM CHRISTIANITY TO ISLAM: A FIELD STUDY

Mehmet Emin KALGI
Assoc. Prof. Dr. Department of Psychology of Religion, Ardahan University
Visiting Scholar, Indiana University Bloomington
ORCID ID: 0000-0001-6999-5059

This work was supported by the TÜBİTAK (The Scientific and Technological Research Council of Türkiye) through the 2219 International Postdoctoral Research Fellowship Program (Grant No. 1059B192400358). The study was conducted at Indiana University Bloomington under the supervision of Prof. Dr. M. Nazif Shahrani.

Abstract

The aim of this study is to identify the socio-psychological factors underlying the conversion of individuals from Christianity to Islam. A qualitative research design was employed, and data were collected through semi-structured interviews with twelve participants. In addition, participant observation was utilized to examine the religious rituals, traditions, customs, attitudes, and behaviors of the converts within their natural social settings. The interview protocol was structured around eight themes, including a concluding section, and data were collected by asking questions aligned with the objectives of the study under each theme. These themes consisted of: Biographical Background and Family Structure (General Framework), Previous Religious Experience and the Search for Meaning, The Conversion Process and Influencing Factors, The Meaning System of the New Faith (Cognitive and Emotional Dimensions), Religious Practices and Daily Life, Community, Belonging and Social Relationships, Influence and Dissemination, and Conclusion.
To provide an in-depth interpretation of the findings, the data were analyzed within the theoretical frameworks of Social Identity Theory, Deprivation Theory, Brainwashing Theory, and Process Theory.
In conclusion, for individuals who convert to Islam, the new religion represents not only an adopted system of belief but also a comprehensive way of life through which they deepen their spiritual lives, strengthen their religious identities, and develop a sense of responsibility to convey this identity to others. These findings demonstrate the transformative impact of a newly acquired religious identity on individuals' worldview, behaviors, and everyday religious practices.

Keywords: Psychology of Religion, Religion, Religiousness, Religious Conversion, Islam, Christianity.

INTRODUCTION

The issue of religious conversion represents a phenomenon rather than a mere topic. Historically, this phenomenon has arisen from interactions between people of different faiths, and the reasons behind it have been addressed academically. Scientific studies on religious conversion date back to the late nineteenth and early twentieth centuries. Çayır classifies these studies into five periods, beginning with William James and Edwin Diller Starbuck, followed by psychoanalytic approaches, brainwashing theories, research on new religious movements, and studies conducted outside Western cultures (Çayır 2008:9).
The factors influencing religious conversion can be grouped under sociological, psychological, and theological headings. Although the research touches upon the theological and sociological reasons for religious conversion, its main objective is to examine the psychological and social causes of this phenomenon.
This field study focuses on the phenomenon of religious conversion from Christianity to Islam. The aim of the research is to uncover the psychosocial reasons behind individuals' decisions to abandon their Christian identity and embrace Islam. In other words, the study seeks to answer the question: "Which psychosocial factors played a role in abandoning their Christian identity?"

Religious conversion is not merely a change in religious affiliation but also a process involving personal experiences, religious beliefs, social relationships, and individual identity. However, in today's world, where religious conversion is increasing, the question of how this affects the mental health and personality traits of converts remains unanswered (Paloutzian et al. 1999:1055). Therefore, further research is necessary to understand the psychological and social dimensions of religious conversion.

This research aims to reveal the psychosocial reasons underlying individuals' conversion from Christianity to Islam. Furthermore, the data obtained provides a basis for the development of a Religious Conversion Scale. By identifying the motives for religious conversion, the study seeks to contribute to the existing literature and provide insights for future research in the psychology of religion.

The main problem statement of our research is: What are the underlying psychosocial reasons why people belonging to the Christian religion later choose Islam? In other words, what psychosocial factors played a role in a person's abandonment of their Christian identity? In this context, the following research questions were addressed:

a. What role did childhood and adolescence experiences play in participants' conversion to another religion?

b. How did the participants become acquainted with Islam, and what factors played a role in their conversion (religious institutions, mystical experiences, and the general religious attitudes and behaviors of Christians, etc.)?

c. Did the attitudes of those around the participants change after they converted to Islam?

d. What changes occurred in the habits of the participants after they converted to Islam?

METHODOLOGY

A socio-psychological perspective allows for the examination of religious conversion through different methods and techniques. In this research, a qualitative research method was preferred, utilizing semi-structured interviews and participant observation techniques to investigate the psychosocial factors influencing conversion from Christianity to Islam.

First, the participants were identified, and their conversion experiences were examined through a questionnaire and semi-structured interviews. A questionnaire consisting of 15 questions was administered to determine the participants' socio-demographic characteristics and their individual and familial religious attitudes. The first seven questions focused on socio-demographic characteristics, while the remaining eight examined individual, familial, and religious factors that may have influenced the conversion process.

Following the questionnaire, semi-structured interviews were conducted with each participant to investigate the psychological and social motivations underlying their religious conversion. In addition, participant observation was employed to examine converts' religious rituals, traditions, customs, attitudes, and behaviors in their natural environments.

The findings obtained from the research were analyzed and interpreted within the framework of Social Identity Theory, Deprivation/Restriction Theories, Brainwashing Theories, and Process Theory, providing a theoretical foundation for understanding the psychosocial
dimensions of religious conversion.

CONCLUSION AND COMMENTS

Religious conversion is a complex and multidimensional phenomenon influenced by socio-demographic, psychological, cultural, and environmental factors. Although conversion may occur suddenly following a personal crisis, the findings of this research indicate that it is generally a gradual process shaped by various experiences and social interactions. The research findings were analyzed and interpreted within the framework of Social Identity Theory, Deprivation Theories, Brainwashing Theories, and Process Theory.

1. Results and Interpretations Regarding Life History, Family Background, and Religious Attitudes

The research findings indicate that a large majority of the participants grew up in religious family environments, with a significant number receiving strict Catholic education. Such religious upbringing may have contributed to questioning existing beliefs and developing resistance toward coercive religious practices. Within Process Theory, these experiences can be associated with the crisis stage of religious conversion.

Another important finding is that several participants grew up in broken family structures, which may have contributed to emotional and spiritual deprivation. Consequently, the search for love, belonging, security, and spiritual fulfillment played an important role in their conversion experiences. Furthermore, intellectual questioning of Christian doctrines, particularly the Trinity, encouraged some participants to explore Islam's monotheistic understanding of God. The shared historical and theological heritage of Christianity and Islam also facilitated this transition.

2. Factors Influencing Religious Conversion: Previous Religious Experiences and the Search for Meaning

The findings demonstrate that participants' previous religious experiences and their search for meaning significantly influenced their conversion to Islam. In particular, questions concerning the divinity of Jesus and dissatisfaction with the explanations provided within their previous religious environments encouraged participants to investigate alternative religious beliefs.

From the perspective of Process Theory, these experiences correspond to the quest stage, during which individuals seek religious explanations that they perceive as rational, consistent, and meaningful. Additionally, social support from Muslims played an important role in facilitating participants' transition to a new religious identity.

3. Factors Influencing Religious Conversion and Spiritual Experiences

The research identified several factors influencing conversion, including participants' investigations into Islam following the September 11 terrorist attacks, their questioning of Christian doctrines, their appreciation of the Quran's teachings, and their attraction to the concept of brotherhood in Islam.

According to Social Identity Theory, individuals evaluate their existing religious identity through social comparison and develop new identities based on perceived similarities and differences between religious groups. The participants compared Christianity and Islam, particularly regarding the nature of Jesus and the concept of God. Many considered Islam's understanding of monotheism and prophethood more rational and consistent, which contributed to their decision to embrace Islam.

4. Cognitive, Emotional, and Social Dimensions of Adaptation to the New Faith

The findings indicate that adaptation to Islam involves cognitive, emotional, and social dimensions and generally develops gradually. Although participants experienced difficulties during this transition, support from their new religious communities facilitated their adjustment.

The participants emphasized Islam's moral principles, social solidarity, and teachings concerning the protection of vulnerable individuals, including orphans, widows, and the poor. These values contributed to their identification with Islam. From the perspective of Social Identity Theory, the combination of cognitive consistency, emotional satisfaction, and social belonging strengthened participants' commitment to their new religious identity.

5. Changes in Daily Life, Religious Practices, and Lifestyle Following Conversion

Religious conversion brought significant changes to participants' daily lives, habits, and religious practices. Participants who previously consumed alcohol and pork reported abandoning these practices after embracing Islam and reorganizing their lifestyles according to Islamic principles.

The findings also suggest that individuals who had established close relationships with Muslims before conversion adapted more easily to their new religious environment. According to Social Identity Theory, adopting the values, norms, and practices of the new religious community strengthens group identification and reinforces religious belonging. Therefore, conversion represents not only a transformation of religious beliefs but also a change in everyday behavior and social identity.

6. Social Belonging, Social Relationships, and Environmental Responses After Conversion

The findings reveal that social support and acceptance from Muslim communities played an important role in strengthening participants' religious belonging. However, some participants experienced negative attitudes, exclusion, or criticism from their previous social environments. These experiences sometimes reinforced their identification with their new religious community.

Furthermore, participants reported encountering passive-aggressive attitudes, discrimination, and negative reactions to Islamic symbols in the United States. Nevertheless, some emphasized the advantages of religious freedom and the opportunity to practice Islam within a religiously diverse society. These findings demonstrate

that social acceptance, exclusion, and religious freedom influence the adaptation process and the development of a new religious identity.

7. Experiences and Approaches to Religious Communication Activities

The research revealed that participants who converted to Islam engaged in religious communication and missionary activities to introduce their beliefs to others. They considered these activities both a religious responsibility and a form of worship that contributed to their spiritual development.

These findings indicate that religious conversion extends beyond adopting a new belief system. It also involves developing a stronger religious identity, participating in religious activities, and sharing religious values with others. Thus, conversion can produce lasting transformations in individuals' beliefs, behaviors, social relationships, and daily lives.

Overall Conclusion

The findings demonstrate that conversion from Christianity to Islam is influenced by interconnected psychological, theological, and social factors. Religious questioning, the search for meaning, emotional needs, social support, and the desire for belonging emerged as important elements in the conversion process. Furthermore, adaptation to Islam involved transformations in religious identity, social relationships, and daily practices. Overall, the research contributes to understanding religious conversion as a gradual and multidimensional psychosocial process and provides a foundation for future studies in the psychology of religion.

A MODEL CURRICULUM FOR TEACHING RESPONSIBLE AI DEPLOYMENT: ACADEMIC INTEGRITY, CRITICAL THINKING, AND DOMAIN MASTERY

Thomas J. Bell III
Texas Wesleyan University, School of Business Administration, Fort Worth, Texas, USA.
Thomas J. Bell III, Ph.D.,

Abstract

The rapid adoption of generative artificial intelligence (AI) tools among students has outpaced most curricula's capacity to address the ethical and academic integrity implications of their use. This paper proposes a structured framework for embedding responsible and ethical AI use directly into course curricula, rather than treating it as a peripheral policy statement appended to a syllabus. The framework rests on three pillars: explicit instruction on the capabilities and limitations of AI systems, guided practice in evaluating AI-generated output against domain standards, and reflective exercises requiring students to justify when and how AI assistance is appropriate for a given task. Instead of prohibiting AI outright or leaving its use unaddressed, the approach positions AI literacy as a graded curricular outcome alongside domain competencies. Academic integrity is preserved through assessment design that separates AI-assisted exploration from independently demonstrated mastery, using process documentation, oral defense of submitted work, and staged deliverables that make each student's individual reasoning visible at every step. Critical thinking is cultivated by requiring students to interrogate AI outputs for bias, factual accuracy, and applicability to the domain context rather than accepting them at face value. The paper also examines how AI can support foundational domain knowledge by functioning as an on-demand tutor or Socratic questioning partner, while course design deliberately avoids configurations that would allow AI to fully automate assignment submission. Preliminary observations from piloting the framework across professional certification course settings suggest that students who engage with structured AI-integrity instruction demonstrate stronger conceptual understanding and more transparent reasoning than students given unrestricted or unaddressed access to AI tools. The paper concludes with practical recommendations for instructors seeking to integrate responsible AI use into existing syllabi without extensive redesign, along with a discussion of open challenges in scaling the approach across disciplines with differing assessment cultures.

Keywords: AI ethics, curriculum design, academic integrity, critical thinking.

FINANCING GREEN TRANSITION PROJECTS BY POLISH LOCAL GOVERNMENTS

Jacek Sierak
ORCID: 0000-0001-8968-133X, SGH
Warsaw School of Economics, Collegium of Business Administration and Finance; Department of Economics and Finance of Local Government, Warsaw, Poland

Abstract

The green transition is one of the most significant development challenges facing contemporary economies and a key component of the European Union's policy aimed at achieving climate neutrality. Local governments play a particularly important role in this process, as they are responsible for implementing numerous investments that directly affect environmental quality and the living conditions of local communities. The aim of this article is to assess the financing opportunities available to Polish local governments for green transition projects and to identify the main barriers limiting the implementation of such investments. The analysis focuses on key sources of financing, including local governments' own revenues, European Union funds, national support programmes, debt financing, and financial instruments dedicated to environmentally sustainable investments. Particular attention is paid to the importance of funding available under the EU Cohesion Policy and to financial instruments supporting the energy transition, improvements in energy efficiency, the development of renewable energy sources, sustainable transport, and climate change adaptation.
The study is based on an analysis of the relevant academic literature, strategic and programme documents, as well as data on local government finances and investments undertaken by local authorities. The analysis aims to determine the significance of individual financing sources and assess their accessibility from the perspective of local and regional public authorities. Particular attention is given to financial and institutional barriers, including limited investment capacity, rising investment costs, own-contribution requirements, and the complexity of procedures for obtaining external funding. The findings indicate that the effective implementation of the green transition requires diversification of financing sources, strengthening the institutional capacity of local governments, and more effective use of available financial instruments. A well-designed financing system can play a crucial role in accelerating the energy transition and fostering sustainable development across Polish municipalities, counties, and regions.

Keywords: Green transition, local government, investment financing, green investments, energy transition, local development.

INTENSIFICATION OF DROUGHTS IN THE RIVER BASIN DISTRICTS OF UKRAINE

Viktoriia SKYBA
https://orcid.org/0000-0003-2233-9438
Candidate of Agricultural Sciences, Associate Professor in the Department of Geoecology and Land Management, Dmytro Motornyi Tavria State Agrotechnological University, Ukraine.
WIRA Visiting Scholar, College of Agricultural Sciences, The Pennsylvania State University, United States of America

Abstract

According to the Water Code of Ukraine, water resources are managed on the river basin principle within nine river basin districts (604.7 thousand km²): the Dnipro, Dniester, Danube, Southern Bug, Don, Vistula, Black Sea Rivers, Azov Sea Rivers and Crimean Rivers districts. They contain 8 large and 87 medium-sized rivers. The Dnipro River Basin District (296.3 thousand km², 49% of the country's area) stretches from Polissia to the Steppe and comprises four management units: the Prypiat River sub-basin, the Upper Dnipro and Desna River sub-basin, and the Middle and Lower Dnipro sub-basins. Most large rivers are transboundary: Ukraine accounts for 58% and 73% of the Dnipro and Dniester basins, respectively.
Droughts in Ukraine are becoming more frequent. Most of the country lies in the Steppe and Forest-Steppe zones, where precipitation is lower than potential evapotranspiration (PET). The water balance is negative in seven of the nine districts; the precipitation-to-PET ratio ranges from 0.54 (Crimean Rivers) to 1.15 (Danube). Previous studies have compared ecological risks in steppe and forest river basins, but basin management plans still lack drought estimates for each district. Gridded data from the World Bank Climate Change Knowledge Portal (CCKP) were averaged within official district boundaries: ERA5 reanalysis (1950-2025), CRU TS v4.10 (1901-2025) and the CMIP6 multi-model ensemble under four SSP scenarios. Drought was assessed with the Standardized Precipitation Evapotranspiration Index (SPEI).
Over 1951-2025, the annual SPEI-12 for Ukraine decreased by 0.19 per decade ($p = 0.03$), with a shift to a drier regime in 1998-2007. The share of months with seasonal drought (SPEI-3 ≤ -1) rose from 9.4% in 1951-1988 to 19.8% in 1989-2025 and reached 31.9% in 2020-2025. Precipitation shows no significant trend, so the drying is driven by warming of 0.33-0.36 °C per decade. In the Dnipro district, SPEI-12 fell fastest in the Upper Dnipro and Desna River sub-basin (by 0.24 per decade) and in the Middle Dnipro sub-basin (by 0.22). By 2080-2099, SPEI-12 is projected to decrease by 0.50 (SSP1-2.6) to 1.85 (SSP5-8.5); under SSP5-8.5 drought is projected to occur in 45% of months in Ukraine and 51-52% in the southern districts. In the most exposed Lower Dnipro sub-basin, an average year is projected to become dry by around 2038.

Keywords: drought; SPEI; river basin district; CMIP6; Ukraine.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ENDOMETRIAL POLYPS AMONG WOMEN UNDERGOING HYSTEROSCOPY FOR ABNORMAL UTERINE BLEEDING IN ALBANIA

Edlira Bylykbashi
https://orcid.org/0009-0004-1157-8761
Ilta Bylykbashi
https://orcid.org/0009-0008-3100-8052
Albana Shahini
https://orcid.org/0009-0005-6179-0485
Faculty of Technical Medical Sciences, University of Medicine Tirana, Albania
University of Medicine Tirana, Albania

Abstract

Endometrial polyps are a common finding during investigation of abnormal uterine bleeding, but their frequency depends on referral patterns and diagnostic methods. This study aimed to estimate their prevalence and identify associated factors among women undergoing hysteroscopy at an Albanian university hospital. This multicentre retrospective cross-sectional study included 420 adult women who attended obstetrics and gynaecology clinics and hospitals in Tirana, Albania, between January 2023 and December 2025. One record per woman was analysed. Polyp diagnosis required histopathological confirmation. Prevalence was estimated with a Wilson 95% confidence interval (CI). Multivariable logistic regression included age, menopausal status, obesity, hypertension, diabetes and nulliparity.

Endometrial polyps were identified in 129 women (30.7%; 95% CI 26.5–35.3%). Median age was 46 years (interquartile range 39–53), and 131 women (31.2%) were postmenopausal. Older age was associated with greater prevalence odds per 10-year increase (adjusted odds ratio [aOR] 1.67; 95% CI 1.18–2.35; p=0.004). Obesity was also associated with polyps (aOR 3.13; 95% CI 1.95–5.03; p<0.001). The crude associations with postmenopausal status and hypertension attenuated after adjustment. Diabetes and nulliparity showed no clear adjusted associations.

Approximately three in ten women undergoing hysteroscopy for abnormal uterine bleeding had endometrial polyps. Older age and obesity were the principal associated factors. These characteristics may inform clinical assessment, while diagnosis requires appropriate cavity evaluation and tissue confirmation. The findings apply to the investigated hospital population and do not establish causal relationships.

Keywords: Endometrial polyps; Abnormal uterine bleeding; Hysteroscopy; Obesity; Albania.

INTRODUCTION

Abnormal uterine bleeding is a frequent reason for gynecologic assessment. In reproductive-age women, the International Federation of Gynecology and Obstetrics (FIGO) PALM–COEIN system distinguishes structural from non-structural causes and includes polyps among the structural categories (Munro et al., 2018). Endometrial polyps may coexist with other causes of bleeding, so their detection does not necessarily establish that they are the sole source of symptoms. Current guidance considers symptoms, malignancy risk and patient preferences when selecting management (Bougie et al., 2024).

The prevalence of polyps depends on the population and diagnostic pathway. A Danish population study reported histologically confirmed polyps in 7.8% of 619 evaluable women (Dreisler et al., 2009). A meta-analysis of diagnostic studies involving women with abnormal uterine bleeding reported a pooled prevalence of 38% (Kaveh et al., 2020). This difference illustrates the influence of symptom selection and referral for investigation. Ultrasound can identify suspected focal lesions, while hysteroscopy permits direct assessment and targeted removal; histopathology establishes the tissue diagnosis (Vitale et al., 2021).

Age and metabolic factors have been investigated, but adjusted findings are inconsistent. Serhat et al. (2014) reported an association with obesity, whereas Nappi et al. (2009) retained only age after adjustment. This study estimated polyp prevalence among women undergoing hysteroscopy for abnormal uterine bleeding in Tirana and assessed associated demographic, reproductive and metabolic factors to inform local service planning.

MATERIALS AND METHODS

Design and participants

This multicentre retrospective cross-sectional study was conducted at Bylykbashi Clinic, Multi Medical Center, and American Hospital in Tirana, Albania, covering the period from January 1, 2023, to December 31, 2025. Consecutive records of women aged ≥18 years who underwent hysteroscopy and endometrial tissue assessment for abnormal uterine bleeding were reviewed. The first assessment during the study period was retained for women with repeated procedures. Pregnancy-related bleeding, bleeding within six months after childbirth, an established cervical or vaginal bleeding source, previous endometrial polypectomy, known endometrial malignancy, and current tamoxifen or menopausal hormone therapy were exclusion criteria.

The bleeding indication comprised heavy, prolonged, irregular or intermenstrual bleeding before menopause, or bleeding after at least 12 months of spontaneous amenorrhoea. The FIGO terminology was used for reproductive-age symptoms (Munro et al., 2018); postmenopausal bleeding was recorded separately. Women referred solely for infertility or an incidental ultrasound finding without bleeding were excluded. Records required sufficient diagnostic documentation to classify polyp status and complete information for the prespecified covariates.

Outcome and covariates

The primary outcome was at least one endometrial polyp confirmed in tissue obtained during hysteroscopic removal or directed sampling. An ultrasound impression alone was insufficient. Women without polyps required a documented complete cavity examination and an adequate tissue report without a polyp. A normal blind biopsy alone did not establish absence of a focal lesion. This approach was consistent with guidance favouring visual assessment and histological confirmation of suspected polyps (Bougie et al., 2024; Vitale et al., 2021).

Age and body mass index (BMI) were recorded at the index assessment. Obesity was defined as BMI ≥30 kg/m². Hypertension and diabetes required a documented diagnosis or ongoing disease-specific treatment. Nulliparity indicated no previous birth at ≥24 weeks. Menopausal status was based on menstrual history, rather than age alone. Age was retained continuously in regression and expressed per 10-year increase; the <50/≥50-year categories were used only for descriptive presentation.

Statistical analysis

Analyses followed a plan using procedure available in IBM SPSS Statistics version 28.0; calculations were implemented in Python (NumPy, pandas and SciPy). Shapiro–Wilk tests supported describing age and BMI as medians and interquartile ranges (IQRs). Categorical variables were summarised as counts and percentages. Comparisons used Mann–Whitney U or Pearson's chi-square tests. Prevalence was estimated with a Wilson 95% confidence interval.

Univariable and multivariable logistic regression estimated crude and adjusted prevalence odds ratios (aORs) with Wald 95% confidence intervals and two-sided p-values. All six covariates were retained on clinical grounds, without stepwise selection. Diagnostics assessed convergence, variance inflation factors (VIFs), a quadratic age term and the Hosmer–Lemeshow test. Complete-case analysis was used without imputation. Statistical significance was set at $p<0.05$.

RESULTS

The deduplicated register contained 462 otherwise eligible women. Twenty-six records lacked adequate diagnostic documentation and 16 lacked one or more covariates, leaving 420 women for analysis. Endometrial

polyps were identified in 129 women and absent in 291, giving a prevalence of 30.7% (95% CI 26.5–35.3%). Median age was 46 years (IQR 39–53), and median BMI was 27.4 kg/m² (IQR 24.1–30.5). Table 1 describes the population and the proportion with polyps within each category.

Table 1. Patient characteristics and prevalence of endometrial polyps

Characteristic	Total n	Total %	Polyp n	Polyp %	p-value
Age					
<50 years	272	64.8	60	22.1	<0.001
≥50 years	148	35.2	69	46.6	
Menopausal status					
Premenopausal	289	68.8	69	23.9	<0.001
Postmenopausal	131	31.2	60	45.8	
Body mass index					
<30 kg/m²	302	71.9	72	23.8	<0.001
≥30 kg/m²	118	28.1	57	48.3	
Hypertension					
No	331	78.8	94	28.4	0.047
Yes	89	21.2	35	39.3	
Diabetes mellitus					
No	376	89.5	112	29.8	0.229
Yes	44	10.5	17	38.6	
Parity					
At least one previous birth	328	78.1	102	31.1	0.748
Nulliparous	92	21.9	27	29.3	

Total percentages use N=420; polyp percentages use the number of women in the corresponding row. Each p-value compares the two categories within a variable using Pearson's chi-square test. Categories are mutually exclusive within each variable. All 420 women had complete values for the listed variables.

Polyps were more frequent in women aged ≥50 years than in younger women (46.6% versus 22.1%) and in women with obesity than in those with BMI <30 kg/m² (48.3% versus 23.8%). Postmenopausal women also had a higher unadjusted proportion. The difference by hypertension was smaller, and diabetes and parity showed no clear unadjusted association. Women with polyps were older than those without polyps (median 51 versus 44 years; p<0.001) and had a higher median BMI (28.8 versus 26.9 kg/m²; p<0.001).

Factors associated with endometrial polyps

Table 2 presents the univariable and mutually adjusted estimates. All 420 women, including 129 with polyps, contributed to the multivariable analysis. Age and obesity retained associations after simultaneous adjustment for menopausal status, hypertension, diabetes and nulliparity.

Each 10-year increase in age was associated with 67% higher adjusted odds of a polyp (aOR 1.67; 95% CI 1.18–2.35; p=0.004). Women with obesity had approximately threefold higher odds (aOR 3.13; 95% CI 1.95–5.03; p<0.001). Both estimates remained above one across their confidence intervals, although the obesity estimate permitted a substantial range of effect sizes.

Postmenopausal status was associated with polyps in the univariable analysis (OR 2.69; 95% CI 1.74–4.17), but its adjusted estimate was smaller and imprecise (aOR 1.19; 95% CI 0.57–2.50; p=0.638). The corresponding hypertension estimate decreased from 1.63 to 1.07 after adjustment. Diabetes (aOR 1.05; 95%

CI 0.52–2.12) and nulliparity (aOR 1.38; 95% CI 0.80–2.39) also showed no clear adjusted associations. These intervals do not exclude clinically relevant differences.

The model converged, and VIFs ranged from 1.01 to 2.78. Addition of a quadratic age term did not improve model fit (likelihood-ratio p=0.787). The Hosmer–Lemeshow test did not identify lack of fit (p=0.933). The model was used to describe associations within the sample; its performance was not assessed in an external population.

Table 2. Logistic regression for factors associated with endometrial polyps

Factor and comparison	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Age, per 10-year increase	1.73 (1.42–2.12)	<0.001	1.67 (1.18–2.35)	0.004
Postmenopausal vs premenopausal	2.69 (1.74–4.17)	<0.001	1.19 (0.57–2.50)	0.638
BMI ≥30 vs <30 kg/m²	2.98 (1.91–4.67)	<0.001	3.13 (1.95–5.03)	<0.001
Hypertension, yes vs no	1.63 (1.00–2.66)	0.048	1.07 (0.61–1.87)	0.808
Diabetes, yes vs no	1.48 (0.78–2.83)	0.231	1.05 (0.52–2.12)	0.900
Nulliparous vs ≥1 birth	0.92 (0.55–1.53)	0.748	1.38 (0.80–2.39)	0.247

OR, odds ratio; CI, confidence interval; BMI, body mass index. The second category in each comparison is the reference. Adjusted estimates control simultaneously for all six listed factors. P-values are two-sided Wald tests. Analysis population: N=420. These estimates are prevalence odds ratios and should not be interpreted as prevalence ratios.

DISCUSSION

Endometrial polyps were identified in approximately three in ten women undergoing hysteroscopy for abnormal uterine bleeding. Older age and obesity were the principal factors associated with their presence. The crude associations with postmenopausal status and hypertension weakened after adjustment, showing the importance of accounting for differences in age and metabolic characteristics when interpreting hospital data.

The prevalence of 30.7% was below the pooled estimate of 38% in the diagnostic meta-analysis by Kaveh et al. (2020) and above the 7.8% reported in the Danish population study (Dreisler et al., 2009). These findings describe different denominators. Women referred for hysteroscopy have symptoms or clinical findings that increase the likelihood of an intrauterine lesion, whereas population sampling also includes women who have not sought care. Consequently, the present estimate describes the diagnostic yield within a selected service population and cannot be extrapolated to all Albanian women or all women with bleeding.

The age association is consistent with the adjusted results reported by Nappi et al. (2009). Older age may reflect cumulative hormonal and endometrial changes, but those pathways were not measured here. Menopausal status also correlated with age, and its confidence interval widened after both variables were entered into the model. The attenuation therefore indicates limited evidence for an additional association beyond the measured covariates, rather than proof that menopause has no relevance to polyp occurrence.

The obesity finding agrees with the association described by Serhat et al. (2014), although Nappi et al. (2009) did not retain an independent obesity association after adjustment. More recently, Weigel et al. (2025) identified polyps in 106 of 317 asymptomatic postmenopausal women undergoing hysterectomy for uterovaginal prolapse (33.4%). Higher BMI was associated with their presence (OR 1.06 per kg/m²; 95% CI 1.01–1.12). That study supports examining adiposity, but its asymptomatic surgical population and continuous BMI scale differ from the present population and obesity threshold.

Our data do not show that weight reduction prevents polyps or that obesity alone should determine access to hysteroscopy. Referral practices and unmeasured hormonal exposure may partly explain the observed association. The common outcome also affects interpretation: the crude obesity odds ratio was 2.98, whereas

the corresponding prevalence ratio calculated from Table 1 was approximately 2.03. The adjusted odds ratio of 3.13 should therefore not be described as a tripling of prevalence.

Hypertension and diabetes did not retain clear adjusted associations, a pattern broadly compatible with the uncertainty in previous studies (Nappi et al., 2009; Serhat et al., 2014). Only 44 women had diabetes, limiting precision. Nulliparity was also imprecisely estimated and should not be interpreted as either protective or harmful on the basis of this sample. Future studies should distinguish reproductive history, metabolic conditions and hormonal treatment exposure, while recording the clinical reasons for referral.

Polyp occurrence and malignant change within a polyp are separate outcomes. A 2025 systematic review of 20 studies involving 11,204 women examined premalignancy or malignancy among women with polyps and found an association with menopausal status (Al-Rayes et al., 2025). That result addresses a different question from the presence-versus-absence model used here. The present analysis cannot quantify malignancy risk or support excluding histological assessment on the basis of age, BMI or an apparently benign ultrasound finding.

The clinical implication is to maintain access to appropriate cavity evaluation and tissue diagnosis for women with persistent or otherwise concerning bleeding. Ultrasound has a useful initial role, but pooled diagnostic evidence indicates that it is less sensitive for polyps than hysteroscopy or saline infusion sonohysterography (Kaveh et al., 2020). Contemporary guidance supports individualised management and histological assessment of removed lesions (Bougie et al., 2024; Vitale et al., 2021). A 2025 prospective study of 180 women also demonstrated the feasibility of outpatient hysteroscopic treatment in selected patients (Martire et al., 2025). Our study did not compare treatment methods, symptom improvement or costs, so those outcomes require separate assessment.

Strengths and Limitations

Strengths include consecutive record selection, one observation per woman, histological confirmation and multivariable adjustment. The retrospective single-centre design, referral selection and exclusion of incompletely documented records limit generalisability. Unmeasured hormonal and metabolic factors may leave residual confounding. Diagnostic reports were not centrally reviewed, obesity was dichotomised, and small subgroups limited precision. The design does not establish temporal relationships or treatment benefit.

CONCLUSION

Endometrial polyps were present in approximately three in ten women undergoing hysteroscopy for abnormal uterine bleeding at the study hospital. Older age and obesity were associated with higher prevalence odds after adjustment. The findings support attention to these characteristics during assessment, while diagnostic decisions should remain based on the overall clinical presentation. Multicentre studies with standardised documentation are needed to assess the consistency and wider applicability of these associations.

Recommendations

Clinical services should document bleeding characteristics, BMI, menopausal status and relevant medication use consistently, and link hysteroscopy findings with pathology reports. Further research should include patients across different referral levels and measure symptom outcomes after treatment.

DECLARATIONS

Funding: No funding was received for this study.

Conflicts of interest: The authors declare no conflicts of interest.

Data availability: The data are not publicly available because of patient confidentiality. Requests for access may be directed to the corresponding author and considered subject to institutional approval and applicable data protection requirements.

REFERENCES

Al-Rayes S, Mohamed M, Suarthana E, Kigloo HN, Raina J, Tulandi T 2025. Risks of malignancy among 11,204 patients with endometrial polyp: a systematic review and meta-analysis. Gynecology and Minimally Invasive Therapy, 14(1): 40–50. doi: 10.4103/gmit.GMIT-D-24-00056.

Bougie O, Randle E, Thurston J, Magee B, Warshafsky C, Rittenberg D 2024. Guideline No. 447: Diagnosis and Management of Endometrial Polyps. Journal of Obstetrics and Gynaecology Canada, 46(3): 102402. doi: 10.1016/j.jogc.2024.102402.

Dreisler E, Stampe Sorensen S, Ibsen PH, Lose G 2009. Prevalence of endometrial polyps and abnormal uterine bleeding in a Danish population aged 20–74 years. Ultrasound in Obstetrics & Gynecology, 33(1): 102–108. doi:10.1002/uog.6259.

Kaveh M, Sadegi K, Salarzaei M, Parooei F 2020. Comparison of diagnostic accuracy of saline infusion sonohysterography, transvaginal sonography, and hysteroscopy in evaluating the endometrial polyps in women with abnormal uterine bleeding: a systematic review and meta-analysis. Videosurgery and Other Miniinvasive Techniques, 15(3): 403–415. doi:10.5114/wiitm.2020.93791.

Martire FG, Schettini G, Costantini E, d'Abate C, Sorrenti G, Centini G, et al. 2025. Approach to abnormal uterine bleeding in presence of endometrial polyps with new hysteroscopic devices. Archives of Gynecology and Obstetrics, 312(1): 257–265. doi:10.1007/s00404-025-08005-7.

Munro MG, Critchley HOD, Fraser IS; FIGO Menstrual Disorders Committee 2018. The two FIGO systems for normal and abnormal uterine bleeding symptoms and classification of causes of abnormal uterine bleeding in the reproductive years: 2018 revisions. International Journal of Gynecology & Obstetrics, 143(3): 393–408. doi:10.1002/ijgo.12666.

Nappi L, Indraccolo U, Di Spiezio Sardo A, Gentile G, Palombino K, Castaldi MA, et al. 2009. Are diabetes, hypertension, and obesity independent risk factors for endometrial polyps? Journal of Minimally Invasive Gynecology, 16(2): 157–162. doi: 10.1016/j.jmig.2008.11.004.

Serhat E, Cogendez E, Selcuk S, Asoglu MR, Arioglu PF, Eren S 2014. Is there a relationship between endometrial polyps and obesity, diabetes mellitus, hypertension? Archives of Gynecology and Obstetrics, 290(5): 937–941. doi:10.1007/s00404-014-3279-4.

Vitale SG, Haimovich S, Laganà AS, Alonso L, Di Spiezio Sardo A, Carugno J; Global Community of Hysteroscopy Guidelines Committee 2021. Endometrial polyps. An evidence-based diagnosis and management guide. European Journal of Obstetrics & Gynecology and Reproductive Biology, 260: 70–77. doi: 10.1016/j.ejogrb.2021.03.017.

Weigel GM, Baison GN, Mihalov L, Mupombwa T 2025. Prevalence of and risk factors for endometrial polyps among asymptomatic postmenopausal women with uterovaginal prolapse. American Journal of Obstetrics and Gynecology, 232(2): 196.e1–196.e6. doi: 10.1016/j.ajog.2024.08.001.

UNMASKING POSTPARTUM SYSTEMIC LUPUS ERYTHEMATOSUS THROUGH TRANSBRONCHIAL BIOPSY AND PLEURAL CYTOLOGY

Serxho Golgota
Eritjan Tashi
Marsel Broqi
Anxhela Papa
Emira Hysa
Alma Teferici
Kloedina Bratja
Ina Pojani
Kristi Reveli
Irida Ikonomi
Elona Hysenbelli
Ilir Peposhi
0009-0002-1848-4624 University Hospital Shefqet Ndroqi, Medicine University, Tirane, Albania, Pulmology Departament
Regional Hospital Shkoder Albania
Alexander Moisiu University Durres Albania

Abstract

Systemic lupus erythematosus (SLE) is a chronic autoimmune disease with heterogeneous multisystem manifestations. Pregnancy and the postpartum period are associated with immunological changes that may contribute to disease onset or exacerbation. Pleural involvement is among the most frequent pulmonary manifestations of SLE; however, bilateral pleural effusion as a prominent initial postpartum manifestation is uncommon and may pose a diagnostic challenge.
We report a 26-year-old postpartum woman presenting with bilateral pleural effusion and no typical cutaneous manifestations of SLE apart from Raynaud phenomenon. Diagnostic evaluation included pleural fluid analysis, cytological examination, and autoimmune testing.
Pleural fluid showed an inflammatory cellular profile, while cytological examination identified lupus erythematosus (LE) cells, defined as phagocytes containing engulfed denatured nuclear material. Transbronchial biopsy demonstrated inflammatory cell infiltration, providing evidence of concomitant pulmonary inflammation. Autoimmune evaluation demonstrated strongly positive antinuclear and anti-double-stranded DNA antibodies with complement consumption. The clinical, cytological, and immunological findings supported the diagnosis of postpartum-onset SLE presenting with lupus pleuritis. Treatment with corticosteroids and hydroxychloroquine was initiated.
This case highlights an uncommon postpartum presentation of SLE in which pleural effusion was a major initial manifestation despite the absence of typical mucocutaneous features. Detection of LE cells in pleural fluid, together with characteristic serological findings and hypocomplementemia, may provide valuable diagnostic evidence and facilitate timely recognition and treatment of lupus pleuritis.

Keywords: Systemic lupus erythematosus, lupus pleuritis, pleural effusion, postpartum period, LE cells, autoimmune disease.

LABORATORY RISK STRATIFICATION IN PEDIATRIC PARACETAMOL POISONING

Feride Imeraj
Numila Kuneshka-Maliqari
https://orcid.org/0009-0000-1349-3949, University Hospital Center "Mother Teresa", Faculty of Medicine, Department of Pediatrics, Tirana, Albania.
https://orcid.org/0000-0001-7001-1117, University of Medicine, Faculty of Medicine, Department of Pediatrics, Tirana, Albania.

Abstract

Paracetamol poisoning can cause substantial hepatic injury despite an initially asymptomatic presentation. Laboratory interpretation must distinguish circulating drug exposure from evolving organ damage. This review examines the contribution of timed paracetamol measurements and biochemical markers to risk stratification and treatment decisions in children and adolescents.

A focused narrative synthesis of pediatric clinical guidance and multidisciplinary consensus recommendations was conducted. The review examined sampling time, interpretation of serum paracetamol concentrations, biochemical evidence of hepatic injury, and laboratory criteria supporting antidote decisions.

Following a single acute ingestion with a reliable exposure time, serum paracetamol concentrations obtained between four and 24 hours can be interpreted using the Rumack–Matthew nomogram. Nomogram assessment is inappropriate when ingestion timing is unknown or exposure comprises repeated supratherapeutic dosing over a period exceeding 24 hours. Modified release preparations and coingestants that delay gastric emptying may necessitate serial concentrations. Early normal alanine aminotransferase and aspartate aminotransferase values do not exclude subsequent hepatotoxicity. These enzymes indicate hepatocellular injury, whereas international normalized ratio trends contribute to assessment of hepatic synthetic function. Glucose, creatinine, lactate, and acid–base status provide additional information in severe or delayed presentations. Results require interpretation alongside clinical findings, formulation, exposure history, and sampling time. Acetylcysteine should begin promptly when indicated, including before confirmatory results if waiting would delay treatment beyond eight hours after a potentially toxic ingestion. Decisions to discontinue treatment should integrate drug clearance, biochemical recovery, and clinical status. Persistent abnormalities require continued assessment and specialist consultation.

Timed drug measurements and serial biochemical assessment provide complementary information in pediatric paracetamol poisoning. Their integration supports appropriate antidote initiation, recognition of evolving liver injury, and individualized treatment duration. Reliable documentation of exposure and sampling times, accurate reporting of measurement units, and effective communication between clinicians and laboratory personnel are central to safe interpretation.

Keywords: Acetaminophen; Poisoning; Child; Liver Function Tests; Acetylcysteine.

SINONASAL DISEASE WITH ORBITAL EXTENSION

Tedi Minarolli
Birkena Qirjazi
University Hospital Center "Mother Theresa," Tirana, Albania

Abstract

Orbital extension is an important complication of acute rhinosinusitis and may lead to visual impairment, intracranial spread and severe systemic outcomes if not recognized early. Although most cases remain limited to the sinonasal cavities, infection may spread to the orbit through the lamina papyracea or ethmoid sinuses. Orbital complications have been reported in about 5.8% of hospitalized patients with rhinosinusitis.

This study aimed to describe the clinical presentation, diagnostic evaluation and management of patients with rhinosinusitis-related orbital involvement treated in the Otorhinolaryngology Service of University Hospital Center "Mother Teresa", Tirana.

A descriptive clinical study was conducted among patients evaluated for suspected orbital complications secondary to rhinosinusitis. Data included demographic characteristics, presenting symptoms, imaging findings, type of orbital involvement, treatment modality, need for surgical intervention and clinical outcome.

The study included 36 patients with orbital complications secondary to rhinosinusitis. Children and adolescents represented approximately 72.2% of cases. The most common manifestations were eyelid swelling, periorbital erythema, fever, ocular pain, headache and nasal obstruction or discharge. Severe cases presented with proptosis, restricted ocular movements, diplopia or reduced visual acuity. Preseptal cellulitis was the most frequent complication, accounting for 72.2% of cases, followed by orbital cellulitis in 22.2% and orbital abscess in 5.6%. Contrast-enhanced computed tomography was the main imaging modality used to assess sinonasal disease, orbital extension and possible abscess formation. All patients received systemic antibiotic therapy, while surgical drainage was indicated in selected cases with abscess formation, visual compromise, intracranial extension or poor response to medical treatment.

Rhinosinusitis-related orbital involvement requires early recognition, urgent imaging and coordinated otorhinolaryngologic and ophthalmologic management to prevent visual loss and severe complications.

Keywords: Rhinosinusitis; sinonasal disease; orbital extension; orbital cellulitis; otorhinolaryngology; QSUT.

TRADICIONAL USE OF MEDICINAL PLANTS IN THE PRESPA REGION

Rezana Pengu
Desareda Mero
Eva Kananllari
Tina Donefski
ORCID ID: https://orcid.org/0009-0003-1924-5868
Fan S. Noli University, Faculty of Natural and Human Science, Department of Biology and Chemistry, Korçë, Albania.
ORCID ID: https://orcid.org/0009-0006-0045-5955,
Fan S. Noli University, Faculty of Natural and Human Science, Department of Biology and Chemistry, Korçë, Albania.
Fan S. Noli University, Faculty of Natural and Human Science, Department of Biology and Chemistry, Korçë, Albania.
Center for conservation and protection of the natural environment in Albania
Korçë, Albania

Abstract

Medicinal plants have played an important role in the history of traditional medicine and continue to be a valuable resource for treating various health problems in many communities. The Prespa region, with its rich plant resources and unique biodiversity, represents an important area for studying traditional knowledge and practices in this field.
This study examines the traditional use of medicinal plants in the Prespa region, highlighting their cultural health-related, ecological and economic importance. The choice of this topic stems from the desire to study one of the richest and still relatively unexplored areas of Albanian flora, as well as to contribute to the conversation and scientific documentation of its biodiversity.
The study focuses on the biological and ecological aspects of medicinal plants, describing their uses in folk medicine and the traditional methods of collecting, processing and cultivating them. Particular attention is also given to the role of local communities in preserving and passing down traditional knowledge from one generation to another.
Through field research, interviews with local residents and a review of scientific literature the study aim to identify and analyze the main species of medicinal plants that grow naturally in this area. It also seeks to assess the possibilities for the sustainable use of these natural resources, with the aim of protecting native plant species, preserving natural heritage and promoting the economic development of the Prespa region.

Keywords: medicinal and aromatic plants, plant diversity, cultivation techniques, optimal growing conditions.

INTRODUCTION

Albania is characterized by rich natural resources and high biodiversity, with approximately 3,200 plant species, many of which have medicinal and aromatic properties. Medicinal plants have been used for centuries in traditional Albanian medicine to treat various health conditions and represent an important resource for rural communities, as well as for the pharmaceutical and cosmetic industries. This traditional knowledge has been preserved and transmitted across generations as an essential part of Albania's ethnobotanical heritage.
The Prespa region, located in southeastern Albania along the borders with North Macedonia and Greece, is distinguished by its diverse landscapes and habitats, including lakes, forests, mountains, alpine meadows, and Mediterranean vegetation. These conditions support a rich flora, including numerous medicinal and aromatic plant species, some of which are endemic or endangered. As part of Prespa National Park, the region has considerable ecological and cultural importance.

Several medicinal plants, such as Salvia officinalis, Sideritis raeseri, Hypericum perforatum, Matricaria chamomilla, and Papaver rhoeas, are traditionally used by local communities for various therapeutic purposes. Their collection and use depend on factors such as plant developmental stage, soil conditions, climate, and the concentration of active compounds.

Medicinal plants contain biologically active substances and can be used in different forms, including teas, extracts, oils, and pharmaceutical preparations. Their sustainable management and conservation are essential for protecting biodiversity, preserving traditional knowledge, and ensuring the continued availability of these valuable natural resources.

MATERIAL AND METHODS

1. Study Area

The study area for this research is the Prespa region, with particular focus on the villages of Liqenas, Zaroshkë, Gollomboç, and Lajthizë, located in the southeastern part of Albania, near Small Prespa Lake. These villages are characterized by a rich natural environment, including forests, meadows, and mountainous areas that provide favorable conditions for the spontaneous growth of numerous medicinal plants.

These villages were selected as study sites for several important reasons. First, the areas are characterized by high plant biodiversity. Second, the local inhabitants still preserve extensive and valuable knowledge regarding the use of medicinal plants. This knowledge has been passed down through generations and continues to be applied in everyday life.

2. Period of the Study

The data for this research were collected during May and June 2025 through a combination of qualitative field research methods. Interviews were conducted with residents of the Prespa region, including elderly people, women, and livestock breeders, who possess traditional knowledge of medicinal plant use.

The interviews were conducted individually in various settings, including participants' homes, on the streets, and in the fields where they were working.

3. Questionnaire and Interviews

For the purpose of this study, a questionnaire was designed and distributed among residents of the Prespa region to collect data on their knowledge and traditional uses of medicinal plants.

The questionnaire aimed to identify the most commonly used plant species, their methods of preparation, the plant parts used (leaves, roots, and flowers), their purposes of use, the diseases and health conditions for which they are traditionally used, as well as residents' opinions regarding the continuation of these practices in modern times. The questionnaire was created using Google Forms, and responses were recorded electronically.

4. Tools Used for Data Analysis

Following data collection through questionnaires and structured interviews, the information was processed using the Google Forms platform and subsequently analyzed through basic statistical and visual tools, such as bar charts and pie charts.

Quantitative data, including the percentages of plant parts used, locations where medicinal plants are collected, and perceived effectiveness, were analyzed statistically. The use of charts enables a clear visual interpretation and presentation of the results.

For the qualitative analysis, thematic analysis was employed as a simple yet effective technique for understanding the content and significance of the traditional knowledge preserved by local inhabitants.

5. Selection of Study Participants

A total of 30 residents of the Prespa region were interviewed for this study. Participants were selected randomly, regardless of age, gender, or place of residence. They represented different villages, including Zaroshkë, Lajthizë, Liqenas and Gollomboç in order to ensure the widest possible geographical and cultural coverage.

The participants' age groups ranged from under 18 to over 50 years, allowing for an assessment of how traditional knowledge is preserved and transmitted across generations.

6. Research Ethics

Throughout the research process, a careful ethical approach was followed. All interviewees were informed in advance about the purpose of the study and provided their consent to participate.
Their anonymity was respected, and the collected information was used exclusively for scientific purposes. Questions that could cause discomfort or raise sensitive issues were avoided, and a respectful attitude towards local culture, customs, and traditions was maintained throughout the research process.

RESULTS

Table 1. Summary of the study results on the use of medicinal plants in the Prespa region

Data category	Results
Number of participants	30 individuals from the Prespa region, randomly selected.
Gender composition	Male: 53.3%; Female: 46.7%.
Age groups	Under 18 years: 6.7%; 18–30 years: 20%; 31–50 years: 26.7%; Over 50 years: 46.7%.
Participating villages	Zaroshkë: 11; Liqenas: 8; Lajthizë: 6; Gollomboç: 5.
Most commonly used plants	Mountain tea (16 mentions), Chamomile (15), Nettle (9), Wild rose, Sage, and St. John's wort (5–6 mentions each).
Sources of medicinal plants	Wild harvesting: 73.3%; Market purchases: 16.7%; Home cultivation: 10%.
Plant parts used	Leaves: 75.9%; Flowers: 58.6%; Fruits: 20.7%; Roots: 6.9%; Whole plant: 24.1%.
Forms of use	Tea: 9.0%; Oils/Ointments: 10%.
Harvesting season	Summer: 76.7%; Spring: 26.7%; Autumn/Winter: 0%; Do not collect plants themselves: 10%.
Collection locations	Meadows: 16; Mountains: 11; Forests: 4; Do not collect plants: 5; Cultivate plants: 2.
Frequency of use	Regularly: 60%; Occasionally: 30%; Rarely: 10%; None of the participants reported not using medicinal plants.
Belief in the effectiveness of medicinal plants	Yes: 70%; To some extent: 30%; No: 0%.
Perceived risk of extinction	Yes: 50%; No: 30%; Do not know: 20%.
Current use compared to the past	Lower nowadays: 73.3%; Unchanged: 10%; Unsure: 16.7%.
Attitudes towards knowledge preservation	In favor of preservation and education: 96.6%; Against: 3.4%.
Willingness to participate in activities	Yes: 66.7%; Maybe: 33.3%; No: 0%.

DISCUSSION

The analysis of the interviews indicates that the use of medicinal plants in the Prespa region remains widespread, with the majority of residents using them to treat various health conditions. However, there is a growing tendency towards the loss of traditional knowledge due to the influence of modern medicine and the lack of interest among younger generations. These findings highlight the need for deeper consideration of the preservation and promotion of traditional knowledge.
The most active group in the use of medicinal plants consists of individuals over 50 years of age. This indicates that traditional knowledge regarding the use of medicinal plants is primarily preserved by older generations in the Prespa region.
Based on the data analysis, the majority of residents in the Prespa region consider medicinal plants effective in treating various health conditions, while some respondents perceive their effects as only partially effective. The medicinal plants most commonly used by local residents, which occupy a central place in traditional practices, are mountain tea (Sideritis raeseri), chamomile (Matricaria chamomilla), and nettle (Urtica dioica). These plants are traditionally known for their soothing and anti-inflammatory properties. Residents widely use them for purposes related to blood circulation, urinary system health, abdominal pain, relaxation, sore throat relief, improved digestion, and the treatment of flu symptoms and coughs.

Residents of the area obtain medicinal plants primarily through wild harvesting, particularly in meadows and mountainous areas, during spring and summer, when plants are at their peak stages of biological development. This indicates that the local community follows the natural growth cycles of plants and maintains traditional harvesting practices aimed at preserving their quality.

According to the data analysis, tea is the most common form of preparation and consumption of medicinal plants, while leaves and flowers are the most frequently used plant parts. This demonstrates the extensive traditional knowledge of local residents regarding the preparation and use of medicinal plants.

The findings indicate that the majority of residents support the preservation of medicinal plant knowledge and its inclusion in educational and informational activities within educational institutions and the local community. This result reflects a high level of community interest and awareness regarding the medicinal value of these culturally and naturally significant plants. Furthermore, a considerable proportion of residents expressed their willingness to actively participate in protecting the natural heritage of the region.

Only a very small percentage of respondents expressed disagreement with the inclusion of educational and awareness-raising activities concerning medicinal plant knowledge in educational institutions and the local community.

There is also growing concern about the gradual loss of traditional knowledge, particularly among younger generations, who increasingly rely primarily on pharmacies. This makes it essential to preserve, document, and revitalize these practices as part of the region's cultural and healthcare heritage through education and community awareness initiatives.

CONCLUSION

Based on the analysis of the data collected through interviews with residents of the Prespa region, as well as the assessment of the traditional use of medicinal plants, the following recommendations are proposed to preserve, develop, and further promote this valuable heritage:

Knowledge of medicinal plants is primarily concentrated among the older generation. To prevent the loss of this knowledge, it is recommended to encourage the involvement of younger generations in activities related to the collection, cultivation, use, and processing of medicinal plants. Such activities could include fieldwork, school projects, and community-based initiatives.

Some of the interviewed residents lacked comprehensive information regarding the correct medicinal use of certain plants. For this reason, it is recommended to organize educational and awareness-raising training sessions on the safe and informed use of medicinal plants, in collaboration with pharmacists, traditional medicine practitioners, and medicinal plant experts. Providing accurate information would help prevent the improper use of certain plants that may cause adverse effects.

In cooperation with local authorities and nature conservation agencies, it is recommended to develop a management plan for medicinal plants. This plan should include harvesting permits, authorized harvesting periods, and harvesting quotas in order to prevent the depletion and destruction of local flora.

Species such as Sideritis raeseri may be threatened by excessive harvesting from the wild. To ensure biodiversity conservation, it is recommended that the collection of these plants be carefully regulated and that their cultivation in designated plots be encouraged in accordance with sustainable agricultural practices.

The development of a local ethnobotanical database is recommended to document medicinal plant species, their traditional uses, and the experiences and knowledge of local inhabitants. Such a database would serve as a valuable resource for future scientific research and the preservation of the region's ethnobotanical heritage.

REFERENCES

1.Atlasi i bimëve mjekësore aromatike dhe i kërpudhave.
2.Barina, Z.Pifkó, D.& Somogyi, G. (2018). Contributions to the flora of Albania. Acta Botanica Hungarica.
3.Bernard Mongin -From total state to anarchic market: management of medical and aromatic plants in Albania.

4.https://doi.org/10.1038/nplants.2014.21
5.Kajno, K dhe Piperi, R (1990) Flora mjekësore e Korçës. Tiranë" Mihal Duri".
6.M.Xhulaj, L.Kashta, B. Ruci 2011. Sistematika e bimëve.
7.Pieroni, A., & Quave, C. L. (2014). Ethnobotany and biocultural diversities in the Balkans: perspectives on sustainable rural development and reconciliation. Springer.
8.Quave, C. L., & Pieroni, A. (2015). A reservoir of ethnobotanical knowledge informs resilient food security and health strategies in the Balkans. Nature Plants, 1(2), 14021.
9.Sustainability of the medicinal and aromatic plants sector-socio economoic value and policies for Albania.
10.Udhëzues teknik 2021. Vjelja dhe menaxhimi i bimëve mjekësore dhe aromatike pas vjeljes - |Nr. 1226.
11.Vangjeli, J., Ruci, B., & Mullaj, A. (2000). Flora e Shqipërisë, Vol. IV. Tiranë: Akademia e Shkencave e Shqipërisë.
12.Vangjeli, J. & al., 1997: Libri i Kuq - Red Book. Editors: Shoqata për Ruajtjen dhe Mbrojtjen e Natyrës.
13.https://iadk.org/Uploads/Documents/Pdf/AL/1034/Kultivimi%20i%20bimeve%20mjekesore%20aromatike%20-%20B5%20shqip.pdf

PREDICTING THE RISK OF CARDIOVASCULAR DISEASES IN THE ELDERLY BASED ON CLINICAL DATA AND HEART RATE VARIABILITY USING MACHINE LEARNING

Akbota Bugibayeva
Symbat Abzaliyeva
Kuat Abzaliyev
Madina Suleimenova
Tamara Abdirova
Irina Agababyan
0000-0003-1417-2711, Kazakhstan's Medical University "KSPH", Cardiology Course, Department of Residency, Almaty, Kazakhstan.
0009-0004-9802-0129, Al-Farabi Kazakh National University, Faculty of Information Technology, Department of Artificial Intelligence and Big Data, Almaty, Kazakhstan.
0000-0003-2452-854X, Al-Farabi Kazakh National University, Faculty of Information Technology, Department of Artificial Intelligence and Big Data, Almaty, Kazakhstan.
0009-0003-8553-5353, International Information Technology University, Department of Information Systems, Kazakhstan
0009-0004-9193-9378, Kazakhstan's Medical University "KSPH", Faculty of Public Health, Department of Public Health, Almaty, Kazakhstan.
0000-0003-1958-5718, Samarkand State Medical University, Faculty of Postgraduate Education, Department of Therapy, Cardiology and Functional Diagnostics, Samarkand, Uzbekistan.

Abstract
Cardiovascular diseases (CVD) remain a leading cause of morbidity and mortality among the older adults. Heart rate variability (HRV) derived from photoplethysmography (PPG) signals offers a non-invasive approach to assessing autonomic regulation of the cardiovascular system. Integrating PPG-derived HRV metrics into machine learning models may improve cardiovascular risk stratification.
To investigate the potential use of heart rate variability indices to predict the risk of developing cardiovascular diseases in individuals aged 65 years and older.
The study included 100 individuals aged 65 years and older, comprising 54 participants classified as being at cardiovascular risk and 46 classified as not being at risk. Date collection included questionnaires, anthropometric and hemodynamic measurements, and PPG recording obtained using the Eldar computer photoplethysmograph and Eldar-Vario software. Time-domain and frequency-domain HRV parameters were analyzed. Statistical analysis was performed using SPSS Statistics 22.0. Logistic regression and random forest with nested cross-validation were used for classification. Discrimination performance, calibration, Brier score, LogLoss, and feature contribution were evaluated using permutation importance and SHAP.
Participants with CVD exhibited reduced HRV indices, including SDNN (26 ms), pNN50 (4%), TINN (31 ms), and total HRV (6), as well as lower VLF, LF, and HF spectral components ($p<0.05$). The VLF/HF and LF/HF ratios were higer in this group. HRV indices showed statistically significant associations with age, physical activity, body mass index, and systolic blood pressure. Among the evaluated models, the random forest model combining clinical variables with HRV parameters, including HF and RMSSD, demonstrated the highest discriminatory performance with ROC-AUC of 0.9988.

Conclusion. PPG-derived HRV parameters are associated with the presence of cardiovascular disease and may improve disease classification when integrated into machine learning models. These results support further investigation of PPG-derived HRV as a potential tool for cardiovascular risk assessment in older adults.

EVALUATING FASCIAL MANIPULATION INTEGRATED WITH POSTURAL EXERCISES FOR CHRONIC LOW BACK PAIN MANAGEMENT: A PROSPECTIVE CONTROLLED CLINICAL TRIAL

Klejda Tani
Aisel Oseku
Surven Metolli
0000-0002-4060-4971, Department of Rehabilitation, Faculty of Rehabilitation Sciences, Sport University of Tirana, Tirana, Albania
0000-0003-2335-6272, Department of Biomedical Sciences, Faculty of Rehabilitation Sciences, Sport University of Tirana, Tirana, Albania
0000-0002-0373-8137, Department of of Movement and Health, Faculty of Physical Activity and Recreation, Sport University of Tirana, Tirana, Albania

Abstract

Non-specific low back pain (NSLBP) is a primary cause of global disability. This prospective controlled clinical trial evaluated the functional outcomes of combining Fascial Manipulation (FM) with Dynamic Neuromuscular Stabilization (DNS) in chronic NSLBP. Seventy-eight patients were allocated to either FM alone (FMTh; n=39) or FM combined with DNS (CTh; n=39) for 8 weeks. Primary outcome was the Oswestry Disability Index (ODI). Both groups improved significantly; however, the CTh group achieved greater functional disability reduction (10.74 ± 5.53 vs. 14.97 ± 5.84, p=0.001, Cohen's d=0.74) and a significantly higher proportion of patients reaching minimal disability (58.97% vs. 23.08%, p=0.005). Pain reduction was comparable between groups (p=0.36). Integrating DNS motor control training with FM structural treatment optimizes functional recovery in chronic NSLBP.

Keywords: Fascial Manipulation, Dynamic Neuromuscular Stabilization, Chronic Low Back Pain, Oswestry Disability Index, Myofascial Tissue, Motor Control.

INTRODUCTION

Low back pain (LBP) remains the leading cause of global physical disability. Most cases present as non-specific low back pain (NSLBP), lacking a defined structural anatomical lesion. Recent pathological models focus heavily on the thoracolumbar fascia (TLF). Rather than acting as a passive sheet, the TLF is an active structure rich in nociceptors and proprioceptors responsible for load transmission and trunk coordination. In NSLBP, fascial densification and restricted gliding alter sensory feedback and muscular mechanics. Simultaneously, chronic LBP features impaired neuromuscular control, such as dynamic diaphragm dysfunction and poor activation of the Integrated Stabilizing System of the Spine (ISSS).

Fascial Manipulation (FM) restores localized fascial gliding at specific Centers of Coordination (CCs) and Fusion (CFs). Dynamic Neuromuscular Stabilization (DNS), grounded in developmental kinesiology, restores intra-abdominal pressure (IAP) regulation and postural stabilization. While both interventions have documented efficacy independently, limited evidence exists regarding their combined impact. This prospective study evaluated whether combining FM with DNS yields superior functional recovery compared to FM alone in patients with chronic NSLBP.

MATERIALS AND METHODS

Participants & Ethics

Ethical approval was granted by the Sports University of Tirana (Protocol No. 3000/2). Seventy-eight participants aged 45–59 years with chronic NSLBP (>8 weeks duration) and baseline Oswestry Disability Index (ODI) scores >30% were recruited from Treka FIZIO Clinic. Exclusion criteria comprised prior spinal surgery, structural spinal pathologies (fractures, tumors, radiculopathy), systemic inflammatory conditions, pregnancy, or concurrent physiotherapy.

Interventions

Participants completed an 8-week protocol:

- FMTh Group (n=39): Received one weekly 30-minute session of Stecco FM targeting densified CCs and CFs in the lumbopelvic region.
- CTh Group (n=39): Received the identical 30-minute FM treatment, immediately followed by 30 minutes of supervised DNS exercise (Bear Position, Low Lateral Oblique Sit, Supine 3-month position, and DNS Squat) utilizing 6 sets of 10 diaphragmatic cycles per position. Patients also performed these DNS exercises daily at home (30 min/day).

Outcome Measures and Analysis

Primary functional disability was measured via the Oswestry Disability Index (ODI v2.0) pre- and post-treatment. Pain intensity was drawn from ODI Section 1. Data were analyzed using IBM SPSS v26.0 via independent sample t-tests, repeated-measures ANOVA, and Fisher's exact tests ($p < 0.05$).

RESULTS

Demographic and Baseline Clinical Profile

All 78 enrolled participants completed the study without dropouts. The overall mean age was 50.99 ± 3.98 years (range 45–59 years), with females representing 52.56% (n=41) of the sample. Baseline demographics and clinical parameters showed no significant between-group differences across most functional domains, total ODI (28.08 ± 9.58 vs. 29.28 ± 8.43, p=0.55), or baseline pain scores (3.36 ± 1.33 vs. 3.44 ±1.14, p=0.77). A baseline imbalance was present only in the Walking domain (2.61 ± 0.99 in CTh vs. 3.10 ± 1.02 in FMTh, p=0.03).

Table 1. Baseline Clinical Characteristics Between Groups

Characteristic	***CTh Group (n=39)***	***FMTh Group (n=39)***	***p-value***
Gender (Female/Male %)	51.28% / 48.72%	53.85% / 46.15%	N/A
Age (years)	50.71 ±4.15	51.26 ±3.84	p = 0.54
Total ODI Score (%)	28.08 ±9.58	29.28 ±8.43	p = 0.55
Pain Intensity Score	3.36 ±1.33	3.44 ±1.14	p = 0.77
Personal Care Score	2.59 ±1.18	2.46 ±1.17	p = 0.62

Lifting Score	3.02 ±1.27	3.15 ±1.20	p = 0.64
Walking Score	2.61 ±0.99	3.10 ±1.02	p = 0.03
Sitting Score	2.90 ±1.07	2.97 ±1.01	p = 0.76
Standing Score	3.33 ±0.95	3.54 ±0.99	p = 0.34
Sleeping Score	1.92 ±1.06	2.15 ±1.04	p = 0.33

Primary Outcome: Functional Disability

Both treatment groups demonstrated statistically significant intra-group reductions in functional disability following the 8-week intervention. However, between-group comparisons revealed a markedly superior functional recovery in the combined therapy group. The post-treatment mean ODI score dropped to 10.74 ±5.53 in the CTh group compared to 14.97 ±5.84 in the FMTh group (p = 0.001). The magnitude of this difference represented a moderate-to-large effect size (Cohen's d = 0.74) in favor of CTh.

Table 2. Comparison of Mean ODI and Pain Scores Before and After Therapy

Outcome Measure	Intervention Group	Pre-Therapy (Mean ± SD)	Post-Therapy (Mean ± SD)
ODI Total Score (%)	CTh Group (n=39)	28.07 ±9.57	10.74 ±5.53
	FMTh Group (n=39)	29.28 ±8.43	14.97 ±5.84
Pain Intensity Score (%)	CTh Group (n=39)	3.35 ±1.33	1.64 ±0.96
	FMTh Group (n=39)	3.43 ±1.14	1.82 ±0.76

Disability Category Redistribution

Categorical shift analysis showed clear functional transition differences post-intervention. At baseline, no patients in either group presented minimal disability. Post-treatment, 58.97% (n=23) of patients in the CTh group shifted into the minimal disability category (0–20% score) compared to only 23.08% (n=9) in the FMTh group (p = 0.003). Conversely, severe disability (41–60%) remained in 23.08% (n=9) of FMTh patients versus only 4.35% (n=1) in the CTh group (p = 0.014).

Table 3. Distribution of Patients Across ODI Disability Categories

Disability Category (ODI %)	Pre CTh (n=39)	Pre FMTh (n=39)	Post CTh (n=39)	Post FMTh (n=39)	Post p-value
Minimal (0–20%)	0 (0.0%)	0 (0.0%)	23 (58.97%)	9 (23.08%)	p = 0.003
Moderate (21–40%)	13 (33.33%)	5 (12.82%)	15 (38.46%)	21 (53.84%)	p = 0.250
Severe (41–60%)	14 (35.89%)	17 (43.59%)	1 (4.35%)	9 (23.08%)	p = 0.014
Crippled (61–80%)	6 (15.38%)	13 (33.33%)	0 (0.0%)	0 (0.0%)	p = 1.000
Exaggerated (81–100%)	6 (15.38%)	4 (10.26%)	0 (0.0%)	0 (0.0%)	p = 1.000

Pain Intensity Outcomes

Pain intensity scores decreased in both cohorts. Mean pain scores dropped from 3.35 ± 1.33 to 1.64 ± 0.96 in the CTh group and from 3.43 ± 1.14 to 1.82 ± 0.76 in the FMTh group. However, the between-group difference was not statistically significant ($p = 0.36$), yielding a small effect size (Cohen's $d = 0.21$).

DISCUSSION

The central finding of this trial is that integrating Dynamic Neuromuscular Stabilization (DNS) with Fascial Manipulation (FM) achieves significantly greater functional recovery than FM alone in patients with chronic NSLBP. Although both interventions provided meaningful symptom relief, the addition of motor control exercises yielded a moderate-to-large functional advantage (Cohen's $d = 0.74$) and enabled over twice as many patients to reach minimal disability status (58.97% vs. 23.08%).

Mechanistic Complementarity: Structural Release vs. Motor Re-education

A major observation in our trial is the physiological dissociation between pain reduction and functional disability improvement. Both treatment arms demonstrated comparable analgesic effects ($p = 0.36$), confirming that FM effectively mitigates nociceptive input by reducing hyaluronic acid densification, breaking fascial adhesions, and restoring tissue shear strain across thoracolumbar layers. However, pain relief alone did not fully restore daily functional movement capacity.

Functional activities (lifting, standing, sitting) require dynamic spinal stability and central motor coordination. DNS addresses these deficits by re-establishing developmental postural patterns. Through diaphragmatic breathing and coordinated activation of the pelvic floor, transverse abdominis, and deep spinal extensors, DNS restores intra-abdominal pressure (IAP) regulation. This creates a dual-phase recovery mechanism: FM eliminates structural peripheral restrictions and restores afferent proprioceptive signaling, enabling the patient to execute neuromuscular exercises without biomechanical interference; DNS then uses this restored mobility to rebuild motor control, joint centration, and core stabilization during functional tasks.

Comparison with Existing Literature

These findings align with international clinical practice guidelines recommending multimodal, active function-oriented rehabilitation over single passive modalities. While systematic reviews demonstrate that exercise and manual therapy both benefit chronic LBP, combining passive manual techniques with active stabilization exercises consistently yields superior functional outcomes. Our findings build upon prior research demonstrating that DNS improves core muscle contractility, diaphragm excursion, and postural sway, confirming that adding structured motor retraining to fascial release yields additive functional gains.

Clinical Dosage and Practical Limitations

The inclusion of a daily home-based DNS exercise program in the CTh group meant a higher overall intervention dose. In real-world rehabilitation, frequent, repeated activation is essential to drive central nervous system neuroplasticity and motor pattern learning. Weekly supervised sessions ensured correct diaphragmatic execution, while daily home practice reinforced neuromuscular motor learning.

Several limitations should be noted:

1. Blinding Constraints: Blinding practitioners and patients was not feasible due to the nature of manual therapy and active exercise, though outcome evaluators remained blinded to reduce detection bias.
2. Intervention Dose Variance: The CTh group received additional total therapy exposure via home practice, which may account for a portion of the functional improvement beyond the specific effects of DNS.

3. Follow-Up Duration: Outcomes were evaluated immediately post-intervention (8 weeks); future long-term studies are needed to determine whether functional gains persist over time.

CONCLUSION

Combining Dynamic Neuromuscular Stabilization with Fascial Manipulation leads to significantly greater functional recovery in chronic non-specific low back pain than FM alone. Rehabilitation protocols addressing both structural fascial densifications and central motor control systems offer a comprehensive, highly effective framework for clinical management.

REFERENCES

Bonaldi L, Berardo A, Stecco A, Fontanella CG 2025. Assessment of the Fascial System Thickness in Patients with and Without Low Back Pain: A Narrative Review. Diagnostics, 15: 2059.

Branchini M, Lopopolo F, Andreoli E, Loreti I, Marchand AM, Stecco A 2015. Fascial Manipulation® for chronic aspecific low back pain: a single blinded randomized controlled trial. F1000Research, 4: 1208.

Frank C, Kobesova A, Kolar P 2013. Dynamic neuromuscular stabilization & sports rehabilitation. International Journal of Sports Physical Therapy, 8: 62-73.

Huang H, Xie H, Zhang G, et al. 2025. Effects of dynamic neuromuscular stabilization training on core muscle contractility and standing postural control in CLBP: a randomized controlled trial. BMC Musculoskeletal Disorders, 26: 213.

Stecco A, Giordani F, Fede C, Pirri C, De Caro R, Stecco C 2023. From Muscle to the Myofascial Unit: Current Evidence and Future Perspectives. International Journal of Molecular Sciences, 24: 4527.

World Health Organization 2023. WHO guideline for non-surgical management of chronic primary low back pain in adults in primary and community care settings. Geneva: World Health Organization.

Pirri C, Pirri N, Guidolin D, et al. 2023. Ultrasound Imaging of Thoracolumbar Fascia Thickness: Chronic Non-Specific Lower Back Pain versus Healthy Subjects. Diagnostics, 13: 1436.

Sikdar S, Srbely J, Shah J, et al. 2023. A model for personalized diagnostics for non-specific low back pain: the role of the myofascial unit. Frontiers in Pain Research, 4: 1237802.

Sannasi R, Dakshinamurthy A, Dommerholt J, Desai V, Kumar A, Sugavanam T 2023. Diaphragm and core stabilization exercises in low back pain: A narrative review. Journal of Bodywork and Movement Therapies, 36: 221-227.

González-Gómez L, Moral-Munoz JA, Rosales-Tristancho A, et al. 2025. Exercise Therapy Versus Manual Therapy for the Management of Pain Intensity, Disability, and Physical Function in People With Chronic Low Back Pain: A Systematic Review. European Journal of Pain, 29: e70090.

Narenthiran P, Granville Smith I, Williams FMK 2025. Does the addition of manual therapy to exercise therapy improve pain and disability outcomes in chronic low back pain: A systematic review. Journal of Bodywork and Movement Therapies, 42: 146-152.

Cashin AG, Furlong B, et al. 2025. Analgesic effects of non-surgical and non-interventional treatments for low back pain: a systematic review and meta-analysis of placebo-controlled randomised trials. BMJ Evidence-Based Medicine, 30: 222-231.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ACCEPTABILITY OF SCHOOL MEAL PROVISION IN ALBANIA: STAKEHOLDER PREFERENCES, REGULATORY FRAMEWORK AND NUTRITIONAL CONSIDERATIONS

Jolanda Hyska
ORCID: 0000-0001-8598-8983
University of Medicine, Faculty of Medicine, Department of Public Health, Tirana, Albania

Abstract

Many Albanian children start the school day without breakfast and eat too few vegetables, and almost one in three 8-year-olds is overweight. Yet Albania still has no national school meal programme. This study explored whether such a programme would be accepted by the school community and what would be needed to make it work in nine-year (basic) schools. It combined a review of the legal framework, nutritional reference values and European school meal models with a national online survey run by the Ministry of Education and Sports in 2024, followed by a consultation with key stakeholders. The survey reached 79,080 respondents: 26,959 students in grades VI–IX, 41,068 parents and 11,053 school staff, almost all from public schools. Support for a meal at school was strong, with 88.0% of students, 92.9% of parents and 88.6% of staff in favour, and nearly everyone wanted the food to be healthy and controlled. A school canteen was clearly the preferred option (69.7–78.3%), while catering and vending machines drew much less support. Lunch was the favoured meal, although more than a quarter of students (28.0%) also wanted breakfast. Parents and staff were divided between food from home and food served at school; those who preferred home food did so mainly because they considered it safer. Those who favoured school meals valued food safety, the fact that every child receives the same meal, and healthier choices. Current legislation does not prevent school food provision, but nutritional standards for school meals, hygiene rules for collective catering, clear institutional responsibilities and monitoring tools are still missing. A school meal programme would therefore meet a real public health need and enjoy wide support. Whether it is feasible will depend on regulation, infrastructure and funding, which a phased and carefully evaluated pilot should test.

Keywords: school meals, acceptability, feasibility, child nutrition, school food policy, Albania.

INTRODUCTION

Childhood and adolescence are critical periods for health and development: nutrient needs are high, and the eating habits formed at these ages tend to persist into adulthood. A healthy diet in childhood reduces the risk of overweight, dental caries and, later in life, diet-related non-communicable diseases (NCDs) such as cardiovascular disease, type 2 diabetes and some cancers. Schools reach almost all children over many years and are therefore widely regarded as a key setting for nutrition interventions (WHO Regional Office for Europe, 2006; Oostindjer et al., 2017). In Europe, the main rationales for school meal provision include tackling obesity, teaching healthy eating, supporting learning, addressing food insecurity, creating a social space and, increasingly, environmental sustainability (European Commission, 2021). A systematic review found that universal free school meals including lunch were associated with better diet quality, food security and academic performance, with no adverse effect on body mass index (Cohen et al., 2021).

Albania faces a double burden of malnutrition. Stunting has declined, while childhood overweight has increased. In the most recent COSI round (2022–2023), 30.2% of children aged 8 years were overweight (including obesity) and 14.2% were obese; 42.3% had not eaten breakfast on the day of measurement, 67.1% ate fresh fruit daily but only 29.9% ate vegetables daily (Hyska et al., 2023). Breakfast skipping has been independently associated with obesity among Albanian children (Burazeri et al., 2016). Among adolescents, the Health Behaviour in School-aged Children (HBSC) survey of 2021/22 reported overweight (including obesity) in 27.5%, 21.5% and 16% of 11-, 13- and 15-year-olds, respectively (Faculty of Medicine and Institute

of Public Health, 2024). The national knowledge, attitudes and practices (KAP) survey of 2017–2018 found that about one in three children brought food from home to eat at school every day or almost every day, while 58% carried money to buy food or drinks (Hyska et al., 2018; Hyska et al., 2020).

Albania has made progress on the school food environment: two joint ministerial orders adopted in 2021 restrict the advertising of unhealthy foods in schools and set food standards for pre-university institutions (Ministry of Health and Social Protection et al., 2021a; 2021b), and COSI 2022–2023 found no marketing of energy-dense, nutrient-poor foods in any sampled school. However, the same survey found that access to fresh fruit, vegetables, milk or unsweetened juice on school premises was markedly lacking, and only about one in three schools offered drinking water (Hyska et al., 2023). Unlike most European countries, Albania has no national school meal programme. Within the "Schools for Health" project, implemented by Save the Children with the support of the Swiss Agency for Development and Cooperation, a feasibility study was therefore undertaken to inform policy decisions.

The aim of this paper is to assess the acceptability and feasibility of providing at least one meal per day in Albanian basic schools. Its specific objectives were: (i) to assess the views of students, parents and school staff on school meal provision, including meal preferences, delivery arrangements and eating conditions; (ii) to analyse the legal and regulatory framework governing school food; and (iii) to review nutritional requirements and international school meal models relevant to Albania.

MATERIALS AND METHODS

Study design and partners

The study combined three complementary methods: a desk review, a national survey and a stakeholder consultation. It was carried out jointly by the Ministry of Health and Social Protection, the Ministry of Education and Sports (MoES), the Agency for Quality Assurance in Pre-University Education (ASCAP) and the Institute of Public Health (IPH). It assessed perceptions, preferences and enabling conditions; it was not an evaluation of an existing programme.

Desk review

The review covered Albanian legislation and by-laws relevant to education, child rights, local government, social care, food, public procurement and sanitary inspection; national strategic documents on health, nutrition and education; national surveillance data (COSI, HBSC and the KAP survey); dietary reference values (EFSA, 2013; SINU, 2014); and school meal models from Sweden, Finland, Italy, Ireland, Denmark, Greece and the EU school fruit, vegetables and milk scheme (European Union, 2016; European Commission, 2021). Gaps were identified by comparing existing provisions with the requirements of a functioning school meal programme.

National survey

In 2024 the MoES distributed an online questionnaire (Google Forms) to all public and non-public pre-university institutions providing basic education. The same questionnaire was used for students, parents and school staff, with wording adapted to the age of child respondents (e.g. "I would like…" instead of "Students should…"). It contained closed and open questions on: whether students should eat a meal at school; the preferred source of food during the school day; the preferred delivery model (school canteen, catering, vending machines); the meal(s) to be served; reasons for the chosen options; and the characteristics of the eating environment. Most attitudinal items had three response options (agree, disagree, don't know); questions on the preferred source, meal timing and reasons allowed one answer. Parents and staff answered for basic education as a whole, while the student questionnaire was completed only by students in lower secondary education (grades VI–IX).

Ethics approval and consent to participate

Before data collection, class teachers informed parents about the survey and obtained their oral consent for their children's participation. Students were also informed about the survey and gave their oral assent before

completing the questionnaire. Participation was voluntary and anonymous, and no personally identifying information was collected.

No separate approval was obtained from an institutional research ethics committee. The survey was carried out in collaboration with schools and families, within the school–family partnership set out in Article 62 of Law No. 69/2012 on the pre-university education system, as amended (Republic of Albania, 2012). This article recognises parents as the main partners of the school in the upbringing of children and in the functioning of the institution, and gives them the right to be informed about, and to consent to, their children's school activities.

Stakeholder consultation and analysis

Preliminary findings were discussed with all partner institutions and stakeholders, and their comments were used to finalise the conclusions and recommendations. Survey data were analysed descriptively and are presented as percentages of respondents in each group. Because the survey used a self-selected online sample, no inferential statistics were applied.

RESULTS

Participants

A total of 79,080 respondents took part: 26,959 students (34.1%), 41,068 parents (51.9%) and 11,053 school staff (14.0%). Almost all (97.6%) were from public schools, the setting through which a national programme would be delivered. Compared with the national totals for the 2023–2024 school year (1,127 schools, 258,072 students and 24,109 teachers; Ministry of Education, 2025), student respondents correspond to approximately 10.4% of all students; because only grades VI–IX were surveyed, the actual response rate in these grades is higher, and staff respondents correspond to about 45.8% of the teaching workforce (an upper estimate, as the staff group may also include non-teaching staff). Parent responses equal about 15.9 per 100 students; an exact response rate cannot be calculated for parents because the number of families is not known. Public schools account for about 89% of students (88.7%), teachers (89.2%) and schools (90.0%) nationally, so private schools were under-represented among respondents (about 2.4%).

Acceptability of a meal at school

Support for students eating a meal at school was high in all three groups (Table 1). Almost all respondents agreed that the food should be healthy and controlled and should be eaten during the school break in a separate, dedicated space. Not eating any meal at school was supported by only 2.3–5.1% of respondents (Table 2).

Table 1. Agreement (%) with statements on school meal provision, delivery models and the eating environment among students, parents and school staff, Albania, 2024 (N = 79,080)

Statement / option	Students (%)	Parents (%)	Staff (%)
General acceptability			
Students should eat (would like to eat) a meal at school	88.0	92.9	88.6
The meal eaten at school should be healthy	88.6	98.0	97.5
Food at school should be controlled	93.2	97.5	97.6
Food should be eaten during the school break	91.1	96.3	95.8
Food should be eaten in a separate dedicated space	78.1	89.3	90.0
Delivery model			
Food at school should be provided by a school canteen	71.4	78.3	69.7
Food at school should be provided through catering	46.3	4.3	34.9
Food at school should be provided by vending machines	36.4	17.8	18.8
Eating environment			
The dining room should be spacious	95.8	97.3	96.6
The dining room should be clean	97.5	98.7	98.0

Statement / option	Students (%)	Parents (%)	Staff (%)
The dining room should have enough tables and chairs	96.3	97.6	97.0
A supervisor should be present to keep order	86.5	95.4	93.4
The dining room should be used in shifts by class	60.2	74.2	66.1
The classroom may be used for eating a quick snack	37.6	31.5	29.4

Percentages of respondents answering "agree"; the remaining respondents answered "disagree" or "don't know". Items for students were worded in the first person.

Preferred delivery model

The school canteen was the first choice in all groups, supported by around seven in ten respondents (Figure 1). Catering received mixed views: it was supported by 46.3% of students and 34.9% of staff but by only 4.3% of parents, 59.2% of whom disagreed and 36.5% of whom were unsure. Vending machines received the least support from adults (17.8–18.8%). Students more often answered "don't know" for catering (30.9%) and vending machines (28.9%).

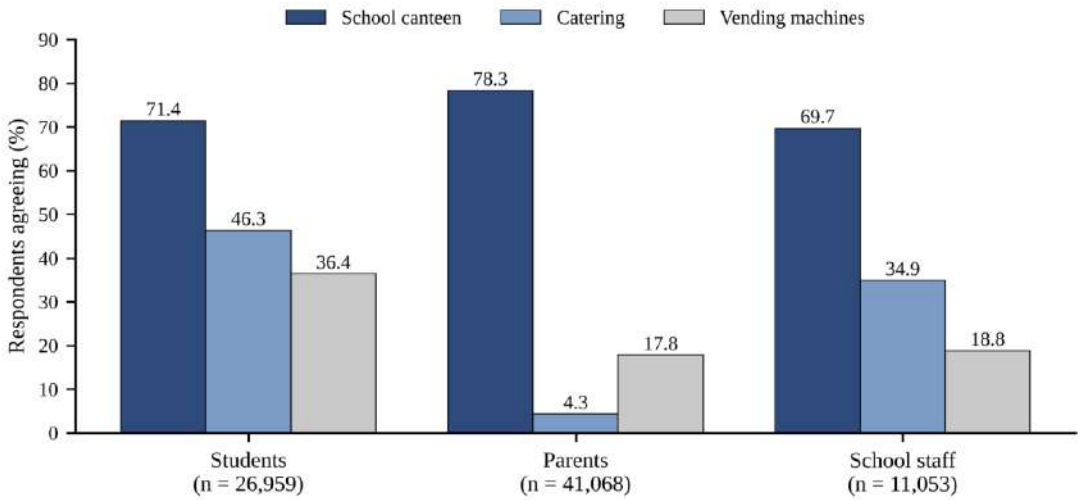


Figure 1. Respondents agreeing (%) with each model of food provision at school, by respondent group, Albania, 2024

Home or school, timing of the meal and reasons

When asked where children's food during the school day should come from, students most often chose food provided at school (48.3%), whereas staff more often chose a packed meal from home (55.3%); parents were almost evenly divided (50.0% home, 46.2% school) (Table 2). About one in six students (16.1%) preferred buying food from shops on the way to school, an option almost absent among adults. Among respondents who preferred home food, the main reason in every group was that home food was considered safer (60.7–70.7%). Among those who preferred school-provided food, students and staff most often cited safe and controlled food, while parents most often cited equality, i.e. that all children eat the same meal (38.6%). Respondents who chose buying food outside school mainly justified it by the absence of food at school (46.0–53.7%).

Lunch between lessons was the preferred meal in all groups, more so among staff (80.2%) and parents (74.2%) than among students (56.2%); 28.0% of students wanted both breakfast and lunch at school. As perceived benefits of a school meal, parents most often mentioned health (66.1%), while students mentioned learning healthy eating (33.1%) and eating together with friends (30.6%).

Table 2. Preferred source of food, preferred meal(s) and main reasons for preferring school-provided or home-packed food (%), by respondent group, Albania, 2024

Statement / option	Students (%)	Parents (%)	Staff (%)
Preferred source of food during the school day (single choice)			
Food provided and eaten at school	48.3	46.2	41.7
Packed meal brought from home	30.5	50.0	55.3
Food bought from shops on the way to school	16.1	1.4	0.8
No meal at school	5.1	2.4	2.3
Preferred meal(s) at school (single choice)			
Lunch, between lessons	56.2	74.2	80.2
Both breakfast and lunch	28.0	16.2	10.2
Breakfast, before lessons	9.6	7.4	6.7
No food at school	6.2	2.2	3.0
Main reason, among those preferring food provided at school			
Food is safe and controlled	36.5	28.5	35.5
All students eat the same food	27.4	38.6	29.1
Food is selected and healthy	24.5	18.3	23.6
The family thinks it is a good solution	11.6	14.8	11.8
Main reason, among those preferring a packed meal from home			
Home food is safer	60.7	70.7	65.6
Children can eat the food they like	23.0	16.0	14.1
It is simpler for / preferred by the family	10.7	6.6	9.3
It is cheaper	5.7	6.7	11.0

Reasons are shown only for respondents who chose the corresponding option; each block sums to approximately 100%.

Eating environment

More than 95% of respondents in every group wanted a spacious, clean dining room with enough tables and chairs, and most considered a supervisor necessary (Table 1). Using the dining room in shifts by class was preferred to a single time slot, particularly by parents (74.2%). Using the classroom for eating was rejected by about half of students and by most adults.

Regulatory framework

The desk review found that the law on pre-university education (Law No. 69/2012; Republic of Albania, 2012) is neutral towards school food: it neither prevents nor regulates it. Law No. 18/2017 on the rights and protection of the child provides a basis for including school food among measures that guarantee equal access to education, while the laws on local self-government (No. 139/2015), social care services (No. 121/2016), food (No. 9863/2008) and public procurement provide the framework for financing, service delivery, food safety and purchasing. The 2021 joint orders on food standards and on the ban of unhealthy food advertising in schools are already in force. Operational gaps remain, however: there is no regulation on the organisation and hygiene of collective catering, no hygiene and sanitary regulation for food preparation and eating areas in schools, no designated service for monitoring and verifying school menus, no tool for assessing compliance with standards and no guidance on preventing choking. Following the 2020 amendment of the law on sanitary inspection, the control of food in schools is the responsibility of the National Food Authority rather than the State Health Inspectorate.

Nutritional considerations

General food standards exist, but nutritional standards for school meals have not yet been established. Based on EFSA and Italian reference values (EFSA, 2013; SINU, 2014), mean daily energy needs were estimated at about 1,930 kcal for children aged 6–11 years and 2,640 kcal for those aged 11–15 years. If lunch provides 35–40% of daily energy, as recommended in European school catering guidelines (Ministero della Salute, 2010), a school lunch should supply approximately 680–770 kcal for children aged 6–11 years and 920–1,060 kcal for those aged 11–15 years; a breakfast providing 10–15% would supply 190–290 kcal and 260–400 kcal, respectively. These targets still need to be translated into menus, portion sizes and procurement specifications.

DISCUSSION

This assessment, based on a national consultation of almost 80,000 respondents, shows that a school meal programme would respond to a clear public health need and would be broadly accepted. Nearly nine in ten students, parents and staff support a meal at school, and only a small minority reject eating at school altogether. The strong demand that the food be healthy and controlled shows that acceptability is conditional: stakeholders accept school food provided that its quality and safety are guaranteed.

The central challenge is trust. Adults, and staff in particular, were divided between home and school food, and safety was by far the main reason for preferring food from home. Trust therefore appears to be the main obstacle, more than any rejection of school meals in principle. The clear preference for school canteens over catering and vending machines points in the same direction: respondents favour an organised, visible, on-site system in which quality and safety can be monitored. The very low support for catering among parents, together with a large proportion of undecided answers, suggests limited familiarity with this model; catering may nevertheless be needed where infrastructure does not allow a canteen, but it would require strict licensing, transparent controls and communication with families. European experience shows that low uptake, often linked to meals that children find unappealing, is a common barrier to school meal programmes (European Commission, 2021), which underlines the importance of involving children and families from the start.

Students' views deserve particular attention. Students were more likely than adults to favour food provided at school and to want both breakfast and lunch, and one in six preferred buying food from shops, mostly because no food is offered at school. Given that about two in five children skip breakfast and that breakfast skipping is associated with obesity in Albania (Burazeri et al., 2016; Hyska et al., 2023), the choice between lunch only and breakfast plus lunch should be guided by nutritional standards, the length of the school day, the needs of children and the resources available. Parents' emphasis on equality, i.e. all children receiving the same meal, indicates that school meals are also valued as a measure of social inclusion, in line with the rationales reported across the EU (European Commission, 2021) and with evidence on food security benefits (Cohen et al., 2021). The Nordic concept of the "pedagogical meal", in which children learn about food and eat together with teachers, matches students' wish to eat with their friends and suggests that school meals should be combined with food education (Oostindjer et al., 2017).

Acceptability is necessary but not sufficient for feasibility. The regulatory analysis shows that the existing framework is a solid starting point but lacks the operational rules (catering hygiene, menu verification, compliance tools, institutional responsibilities) that a programme needs in order to be safe and accountable. Equally important, this study did not estimate the costs of the different delivery models or assess the infrastructure of school buildings (space, running and drinking water, electricity, waste management), both of which are decisive for implementation. The findings therefore support moving towards implementation, but they do not yet show that a national programme is financially and operationally feasible.

The study has limitations. The survey was online and self-selected, so respondents may not be representative of all students, parents and staff, and those more interested in the topic may be over-represented. Student respondents corresponded to only about 10% of all basic school students, and private schools were under-represented, so the results mainly reflect the public school sector. Results are descriptive, and the questionnaire was not formally validated. Responses reflect stated preferences rather than actual behaviour, and because only students in grades VI–IX were surveyed, the views of younger primary school children (grades I–V) were not

captured directly. Finally, no approval from a research ethics committee was sought, although informed oral consent and assent were obtained. Strengths include the very large sample, the inclusion of all three groups involved in school life with a common instrument, and the triangulation of survey findings with legal, nutritional and international evidence.

CONCLUSION

The study confirms a clear public health need and strong social acceptability for a school food programme in Albania. Stakeholders converge on one healthy, controlled meal, preferably lunch, provided by a school canteen and eaten during the break, in shifts by class, in a clean, spacious and supervised dining room. Successful implementation will depend on clearly defined institutional responsibilities and coordination, adequate financial and operational resources, approved nutritional and food safety standards, and effective monitoring, with food safety control remaining within the mandate of the competent authority. A phased approach is recommended, starting with pilot schools, for example schools operating as community centres that already have adequate infrastructure, with four priority actions: (1) develop nutritional standards and translate them into age-appropriate menus and portion sizes; (2) strengthen the regulatory framework for food safety, hygiene, institutional responsibilities and monitoring; (3) assess school infrastructure, estimate the costs of each delivery model and establish sustainable financing, prioritising canteens while allowing other licensed models where necessary; and (4) build trust through transparent quality controls, nutrition education and the involvement of parents and school communities. Pilot implementation should be rigorously evaluated before the programme is extended.

ACKNOWLEDGEMENTS

This study was carried out within the “Schools for Health” project, funded by the Swiss Agency for Development and Cooperation (SDC) and implemented by Save the Children in Albania. The authors thank the Ministry of Health and Social Protection, the Ministry of Education and Sports, ASCAP and the Institute of Public Health, as well as all students, parents and school staff who took part in the survey.

REFERENCES

Burazeri G, Hyska J, Mone I, Roshi E 2016. Breakfast skipping is an independent predictor of obesity but not overweight among children in a Southeastern European population. International Journal for Vitamin and Nutrition Research, 86(5-6): [pages]. https://doi.org/10.1024/0300-9831/a000272

Cohen JFW, Hecht AA, McLoughlin GM, Turner L, Schwartz MB 2021. Universal school meals and associations with student participation, attendance, academic performance, diet quality, food security, and body mass index: a systematic review. Nutrients, 13(3): 911.

EFSA Panel on Dietetic Products, Nutrition and Allergies 2013. Scientific opinion on dietary reference values for energy. EFSA Journal, 11(1): 3005.

European Commission 2021. Provision of school meals across the EU: an overview of rationales, evidence, facilitators and barriers. European Platform for Investing in Children (EPIC). Luxembourg: Publications Office of the European Union.

European Union 2016. Regulation (EU) 2016/791 of the European Parliament and of the Council of 11 May 2016 amending Regulations (EU) No 1308/2013 and (EU) No 1306/2013 as regards the aid scheme for the supply of fruit and vegetables, bananas and milk in educational establishments. Official Journal of the European Union, L 135: 1–12.

Faculty of Medicine, Institute of Public Health 2024. Health Behaviour in School-aged Children – 11, 13 and 15 years old: national report from the 2021/22 survey in Albania. Tirana: UNICEF Albania.

Hyska J, Burazeri G, Menza V 2018. Assessment of nutritional status and nutrition-related knowledge, attitudes and practices among school-aged children in Albania: survey report 2017–2018. Tirana: Institute of Public Health.

Hyska J, Burazeri G, Menza V, Dupouy E 2020. Assessing nutritional status and nutrition-related knowledge, attitudes and practices of Albanian schoolchildren to support school food and nutrition policies and programmes. Food Policy, 96: 101888.

Hyska J, Toçi E, Tomini E 2023. Assessment of childhood obesity: impact of the COVID-19 pandemic on the daily routine and behaviours of school-age children in Albania. Tirana: Institute of Public Health.

Ministero della Salute 2010. Linee di indirizzo nazionale per la ristorazione scolastica. Rome: Ministero della Salute.

Ministry of Education 2025. Vjetari statistikor për arsimin 2023–2024 [Statistical yearbook of education 2023–2024]. Tirana: Ministry of Education. Available at: https://arsimi.gov.al/wp-content/uploads/2025/12/Vjetari-Statistikor-per-Arsimin-2023-2024.pdf [10.11.2026]

Ministry of Health and Social Protection, Ministry of Education and Sports 2021a. Joint Order No. 335, dated 14.07.2021, on the approval of the regulation on the ban of advertising of unhealthy foods in basic education institutions. Tirana.

Ministry of Health and Social Protection, Ministry of Education and Sports, Ministry of Agriculture and Rural Development 2021b. Joint Order No. 336, dated 14.07.2021, on the approval of the regulation on food standards in pre-university education institutions. Tirana.

Oostindjer M, Aschemann-Witzel J, Wang Q, Skuland SE, Egelandsdal B, Amdam GV, Schjøll A, Pachucki MC, Rozin P, Stein J, Lengard Almli V, Van Kleef E 2017. Are school meals a viable and sustainable tool to improve the healthiness and sustainability of children's diet and food consumption? A cross-national comparative perspective. Critical Reviews in Food Science and Nutrition, 57(18): 3942–3958.

Republic of Albania 2012. Law No. 69/2012, dated 21.6.2012, "On the pre-university education system in the Republic of Albania", as amended by Laws No. 56/2015, No. 48/2018 and No. 44/2023. Tirana: Official Journal of the Republic of Albania.

SINU (Società Italiana di Nutrizione Umana) 2014. LARN – Livelli di assunzione di riferimento di nutrienti ed energia per la popolazione italiana. IV revisione. Milano: SICS.

WHO Regional Office for Europe 2006. Food and nutrition policy for schools: a tool for the development of school nutrition programmes in the European Region. Copenhagen: WHO Regional Office for Europe.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

A STUDY ON THE USE OF *CERATONIA SILIQUA* L. AS A MEDICINAL PLANT IN TÜRKİYE

Güliz TÜRKMENOĞLU
Dr., Alanya Alaaddin Keykubat University, Antalya-Türkiye
ORCID: 0000-0003-3049-3216

Abstract

Within the scope of this study, it was aimed to determine the ethnobotanical use of *Ceratonia siliqua* L. based on data obtained through face-to-face interviews conducted with local people in Muğla (Türkiye) 2026. In this context, face-to-face interviews and survey studies were carried out with 184 participants in Muğla (Türkiye), and the data were subjected to statistical analysis after the completion of the surveys. Information regarding the plant parts used and the traditional usage patterns of *Ceratonia siliqua* L. in the region was recorded. It was documented that *Ceratonia siliqua* L. is used for molasses production and is considered a valuable medicinal species in Muğla. It was also determined that the vast majority of consumers using *Ceratonia siliqua* L. (%100) recommend the plants they use to their relatives and friends. *Ceratonia siliqua* L. has been widely used in traditional practices both as its fruit and especially in the form of molasses. Carob may help regulate the digestive system and support intestinal activity due to its high fiber content. Thanks to its natural antioxidant compounds, it may exert protective effects against free radicals in the body. In traditional use, it is preferred as a supportive remedy for respiratory complaints such as cough and phlegm. It is also consumed as an energy-giving food due to its natural sugar content. Carob molasses is one of the most valuable products obtained from this plant. It is particularly rich in minerals such as calcium, potassium, and iron. Therefore, it is commonly used to support bone health, help with anemia, and improve overall body resistance. Due to its natural sweetening properties, it is also preferred as an alternative to refined sugar. Overall, *Ceratonia siliqua* L. is widely consumed in Türkiye for its medicinal and health-related uses due to its nutritional and traditional value.

Keywords: *Ceratonia siliqua* L., Fabaceae, Medicinal plant, Ethnobotany, Carob molasses, Muğla-Türkiye.

Introduction

The carob tree (*Ceratonia siliqua* L.) and its various plant organs hold significant importance due to their wide range of applications in different sectors, including environmental and industrial fields such as food, medicine, health, and textiles. Studies on carob have shown that almost all parts of the tree including its leaves, wood, fruits, flowers, roots, and bark can be utilized in areas such as human and animal nutrition (Winer, 1980), landscape architecture (Makhzoumi, 2000), the food industry (Yousif & Alghzawi, 2000), furniture production (Hakim *et al*., 2010), beekeeping (Pehlivan and Gül, 2016), and healthcare (Zunft et al., 2001). The carob tree begins to bear fruit at the age of 5-10 years and reaches commercial maturity at around 15 years (Özkaya & Tunalıoğlu, 2003). One notable characteristic of the species is that both fruit yield and quality increase with age (Alexander & Shepperd, 1974). A carob tree can live for 300-400 years, with an average annual yield ranging between 90-115 kg; however, depending on climatic and soil conditions, this yield can increase up to 300 kg (Ghrabi, 2005). The Mediterranean basin, considered the cradle of world civilizations, is also a region where many plant species were first domesticated. The carob tree, known to have been used since approximately 4000-5000 BC and believed to have first been utilized in Egypt, is a plant that has held an important place throughout human history (Demirtaş, 2007).

Materials and Methods

In this study, a 25 item questionnaire developed by Korkmaz et al. (2011) was used. The questions and response options included in the questionnaire aimed to obtain information on: (1) the demographic and socio-economic characteristics of consumers, (2) consumers' purposes for using non-wood forest products (NWFPs), particularly medicinal plants, (3) consumption time, (4) consumption frequency, (5) procurement methods, (6) perceived benefits and side effects of the consumed plant products, (7) factors influencing the formation of consumption habits, and (8) evaluations of sales points. During the survey application, participants were encouraged to complete the questionnaire individually in order to ensure that their responses were not influenced by external factors. The evaluation of the questionnaires involved converting the responses into numerical values and presenting them as percentages.

Findings and Discussion

Demographic and Socioeconomic Characteristics of the Participants

Among the surveyed consumers, 54% were female and 46% were male. Some of the socio-economic and demographic characteristics of the respondents are presented. The income levels of the participants were examined across a wide range. The majority of the respondents belonged to the middle and upper-middle income groups.

Consumption Characteristics

When examining consumers purposes for using NWFPs (non-wood forest products), it is observed that use for general health purposes is predominant (Figure 1). In addition, there are also uses for treatment and recreational purposes. Of the respondents, 70% use these plants for general health, 25% for treatment, 1% for recreational purposes, and 4% for cosmetic and aesthetic purposes.

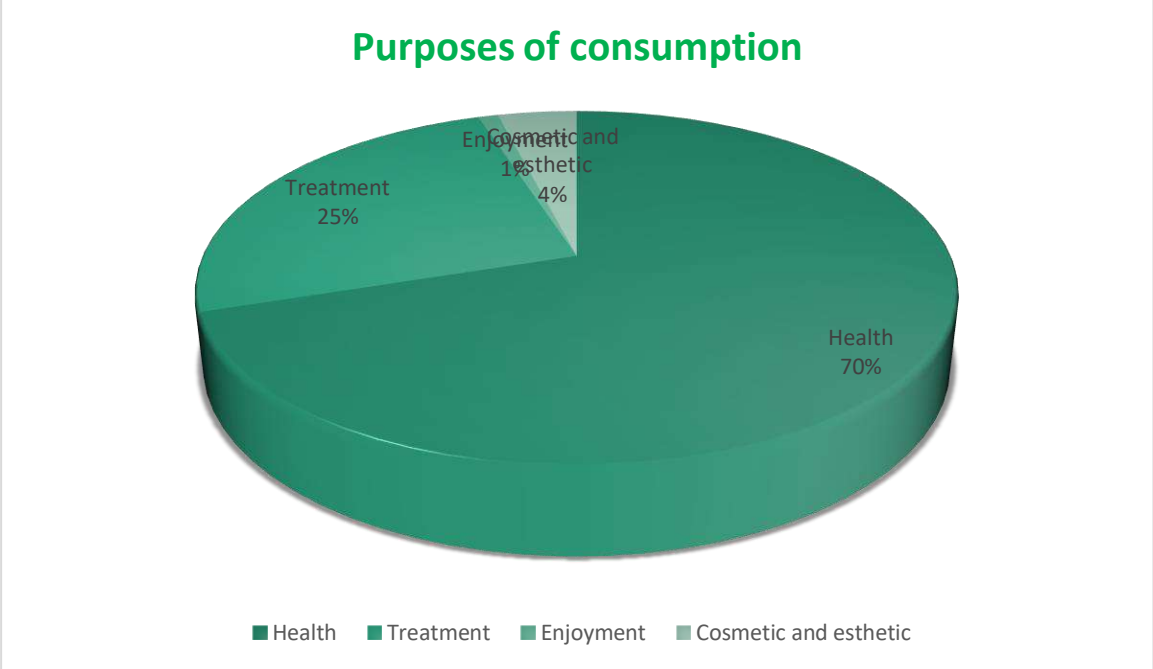


Figure 1. Purposes of consumption

The distribution of consumers' regular consumption habits in terms of time is presented in Figure 2. Of the respondents, 20% consume these products daily, 25% weekly, and 15% monthly, while 40% do not have a regular consumption habit.

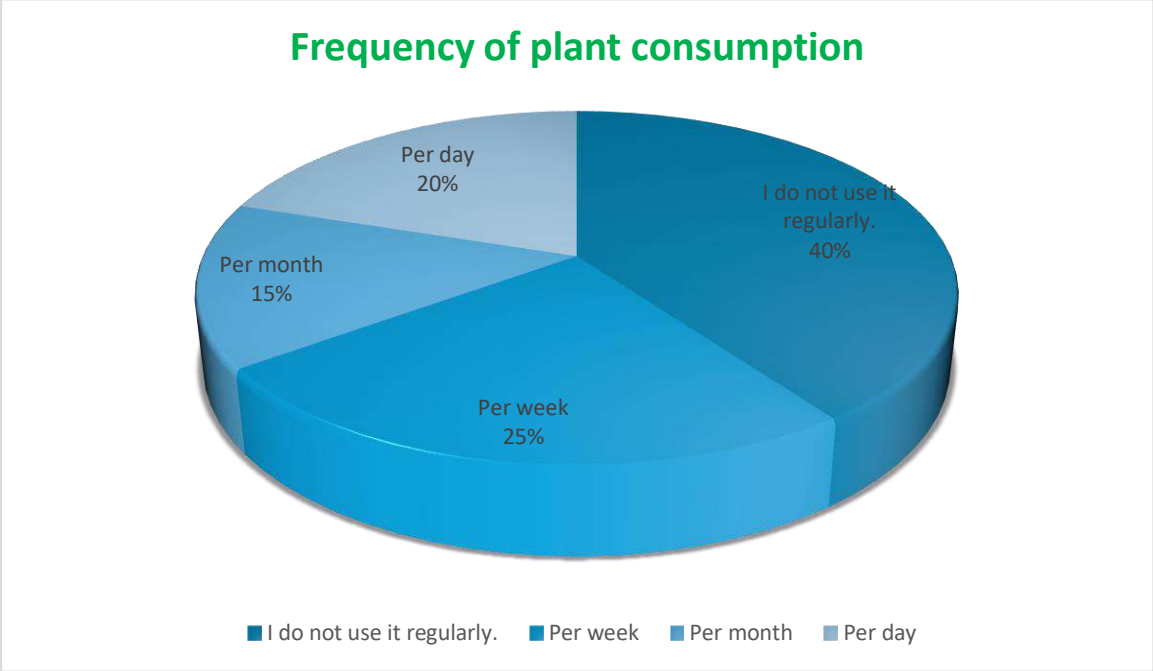


Figure 2. Frequency of plant consumption

In terms of continuous or alternating use of plants, most consumers reported using different plants intermittently. Of the respondents, 55% stated that they consistently use the same plants, 20% reported occasionally changing them, and 25% indicated that they use different plants (Figure 3).

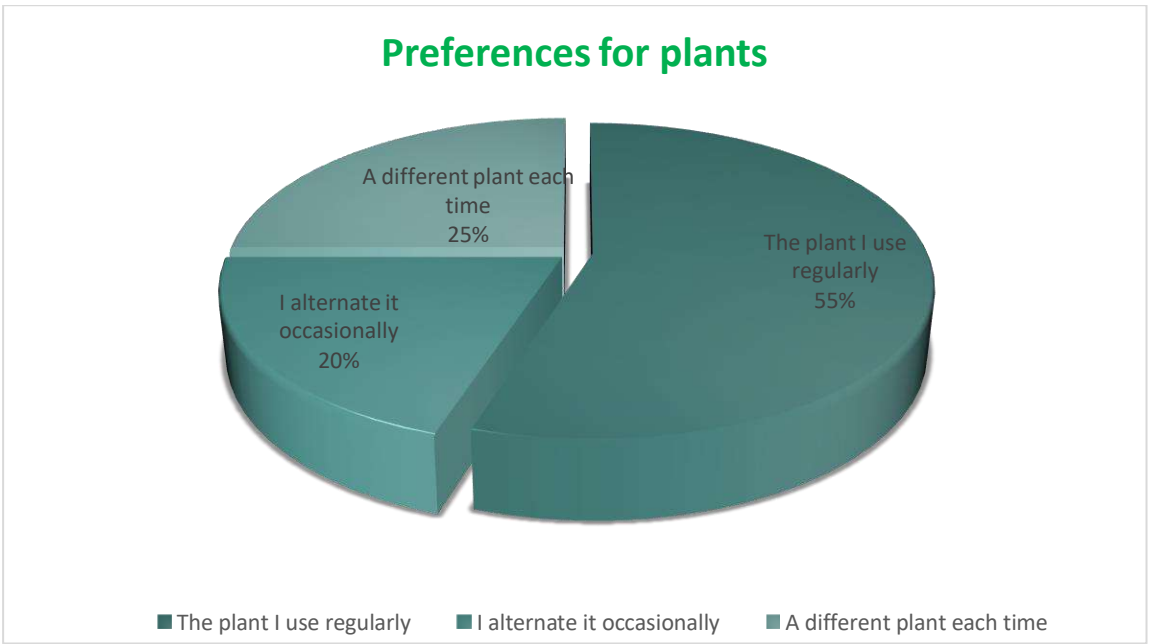


Figure 3. Preferences for plants

Consumers obtain these products from different sources. 55% collect them from nature, while procurement from markets (35%) and herbalists or supermarkets (10%) remains at a low level. This situation is attributed to the long-standing practice of collecting and consuming naturally growing species around rural areas (Figure 4).

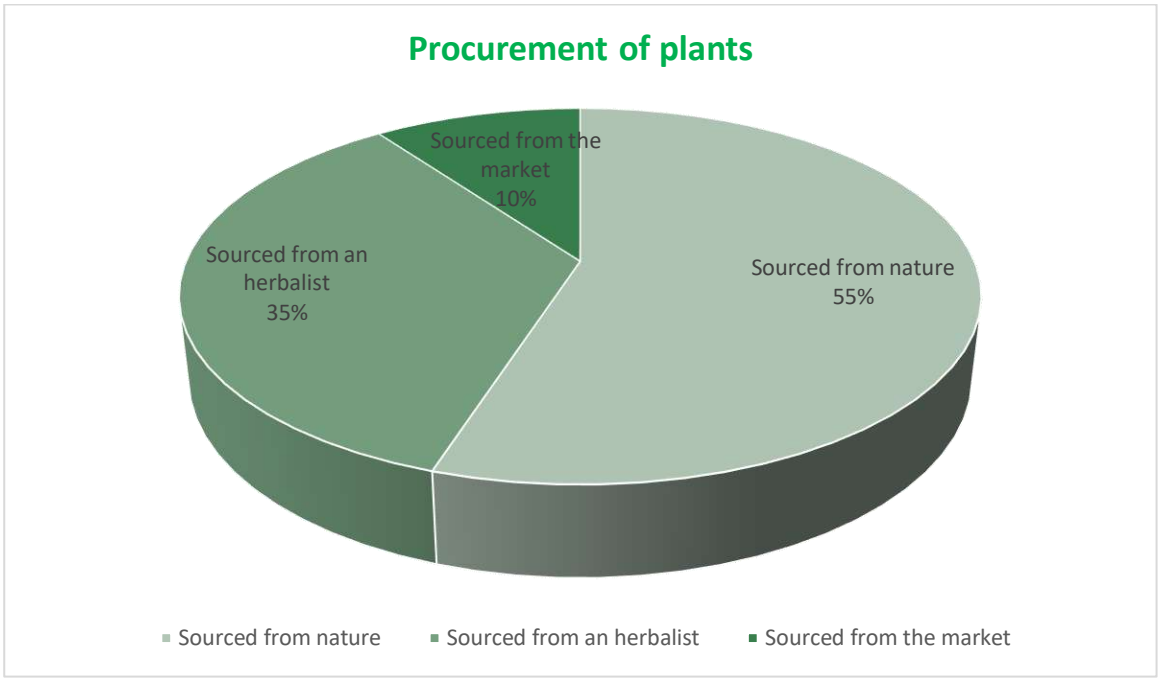


Figure 4. Procurement of plants

A large proportion of the products are consumed by boiling or infusion (65%). In addition, 20% of consumers use them by mixing them with foods, 10% as oil, 1% as ointment, 2% left the question unanswered, and 2% use them by extracting their juice (Figure 5).

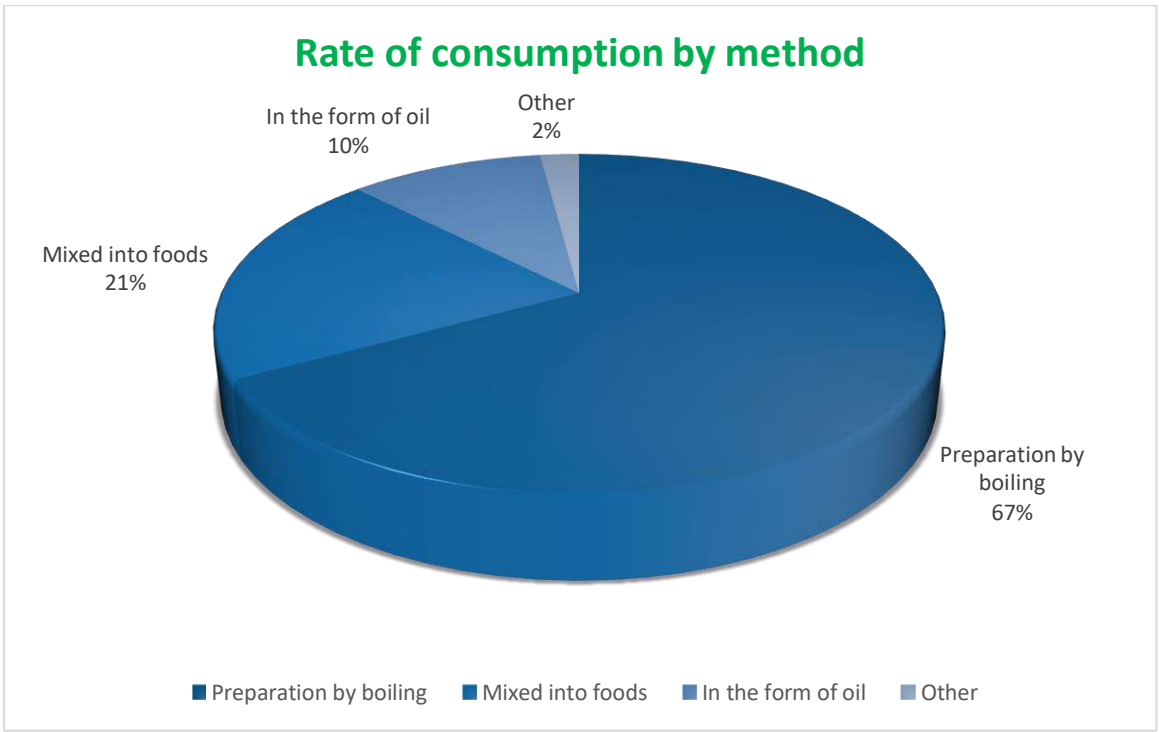


Figure 5. Rate of consumption by method

Of the consumers, 70% reported benefiting from these plants, 25% reported partial benefit, and 5% reported no benefit at all (Figure 6).

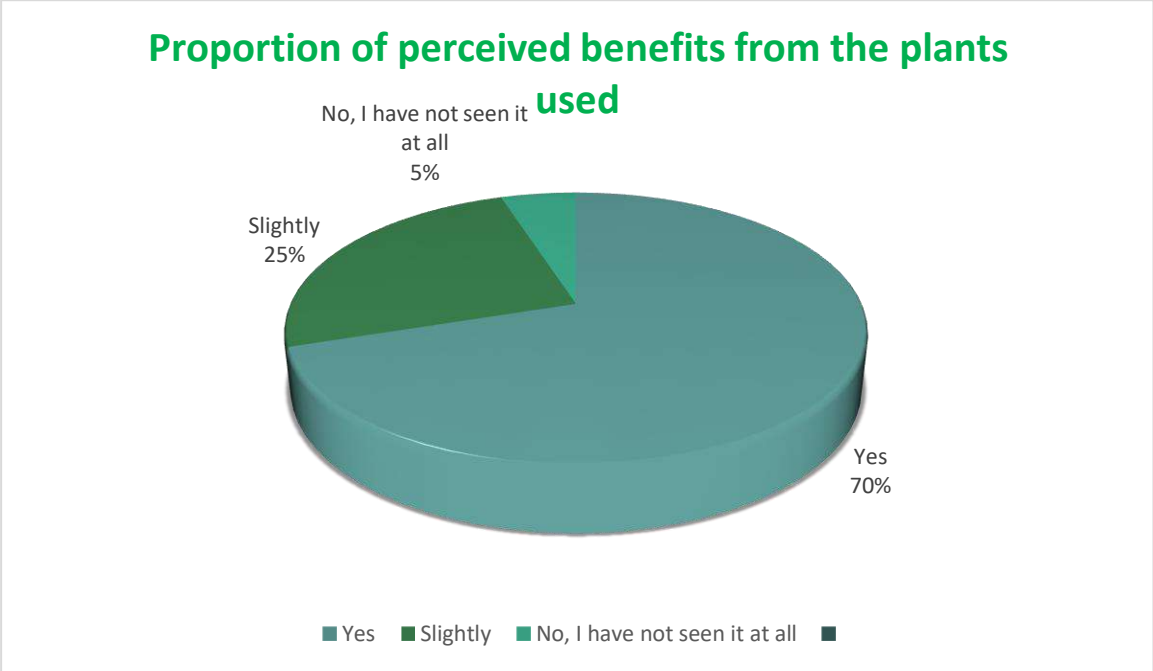


Figure 6. Proportion of perceived benefits from the plants used

65% of consumers stated that they obtained information before using the plants, 10% indicated that they sought information for some plants, 20% reported that they already had knowledge ("I know myself"), and 5% stated that they do not seek information because they already have sufficient knowledge (Figure 7).

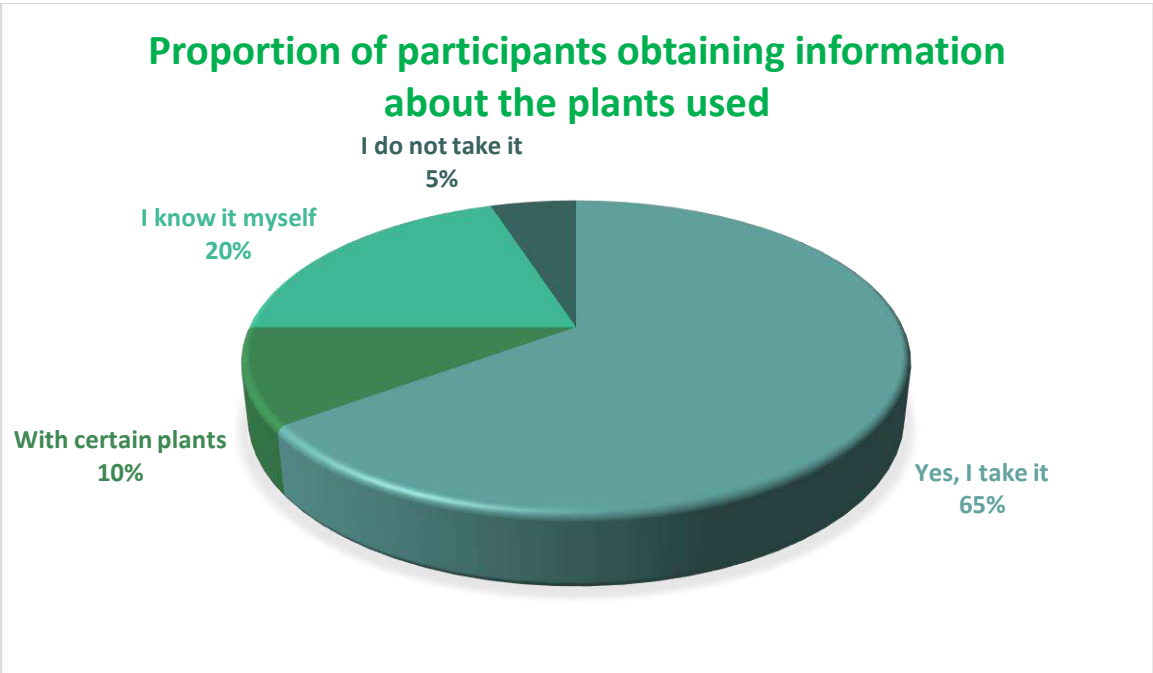


Figure 7. Proportion of participants obtaining information about the plantys used

In addition, the percentage distribution of consumers' opinions regarding product prices shows that 55% consider the products expensive, 20% consider them normal, 16% consider them cheap, and 14% have no opinion (Figure 8).

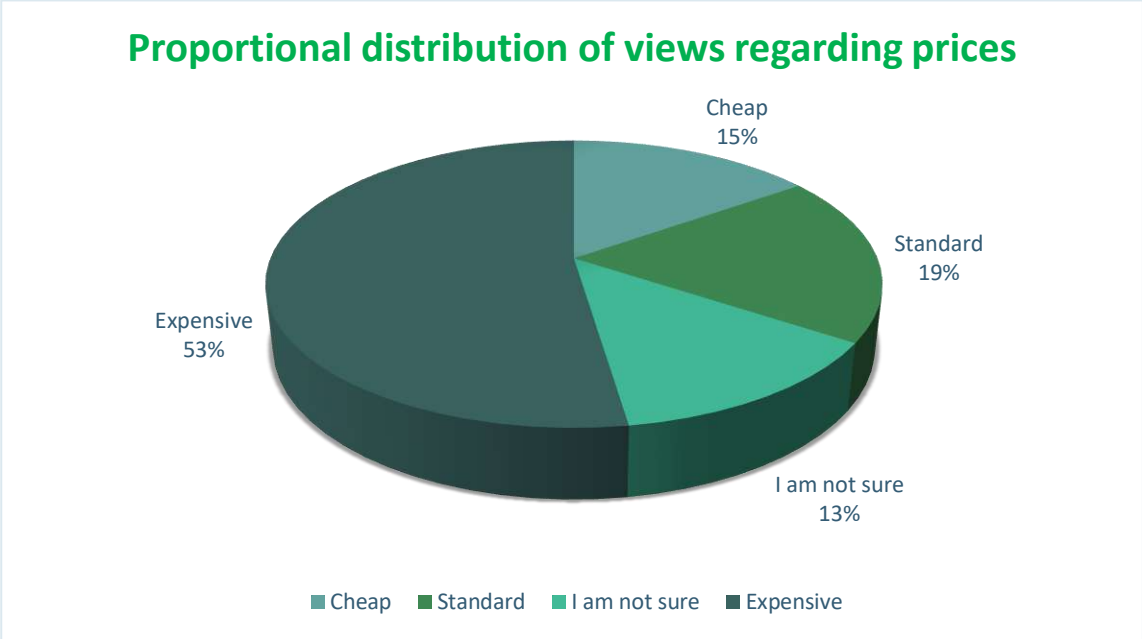


Figure 8. Proportional distribution of views regarding prices

The vast majority of consumers (100%) recommend the plants they use to their close circle and friends (Figure 9).

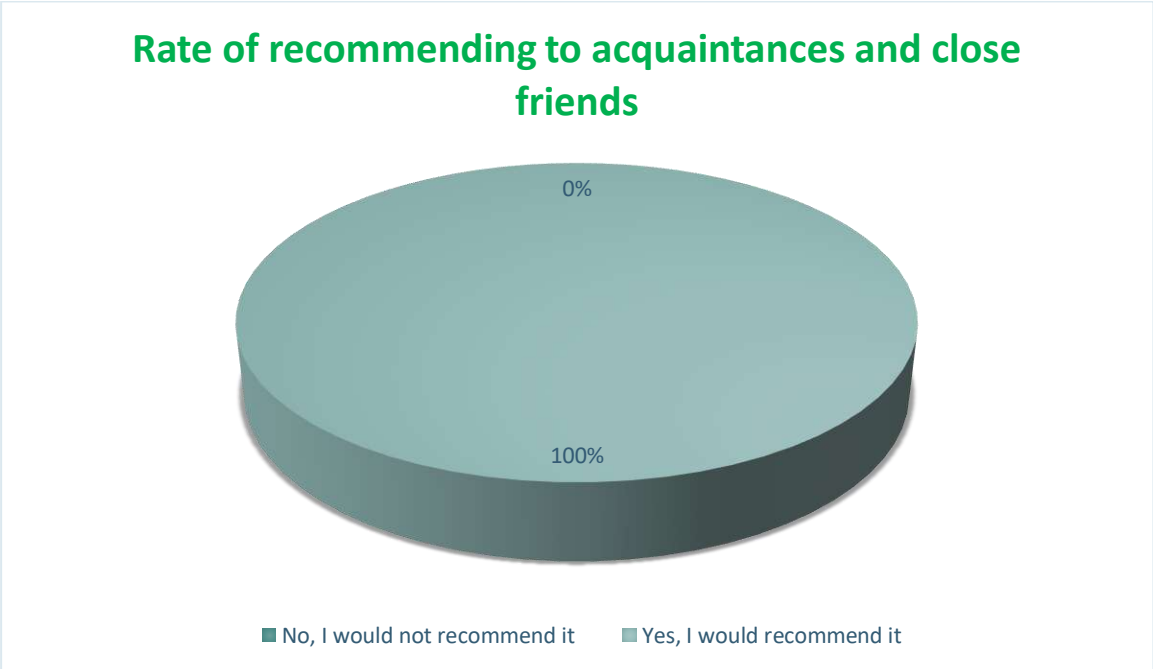


Figure 9. Rate of recommending to acquaintances and close friends

While 75% of consumers prefer using plants in their natural form, 15% prefer processed products, and 10% use them in both forms (Figure 10).

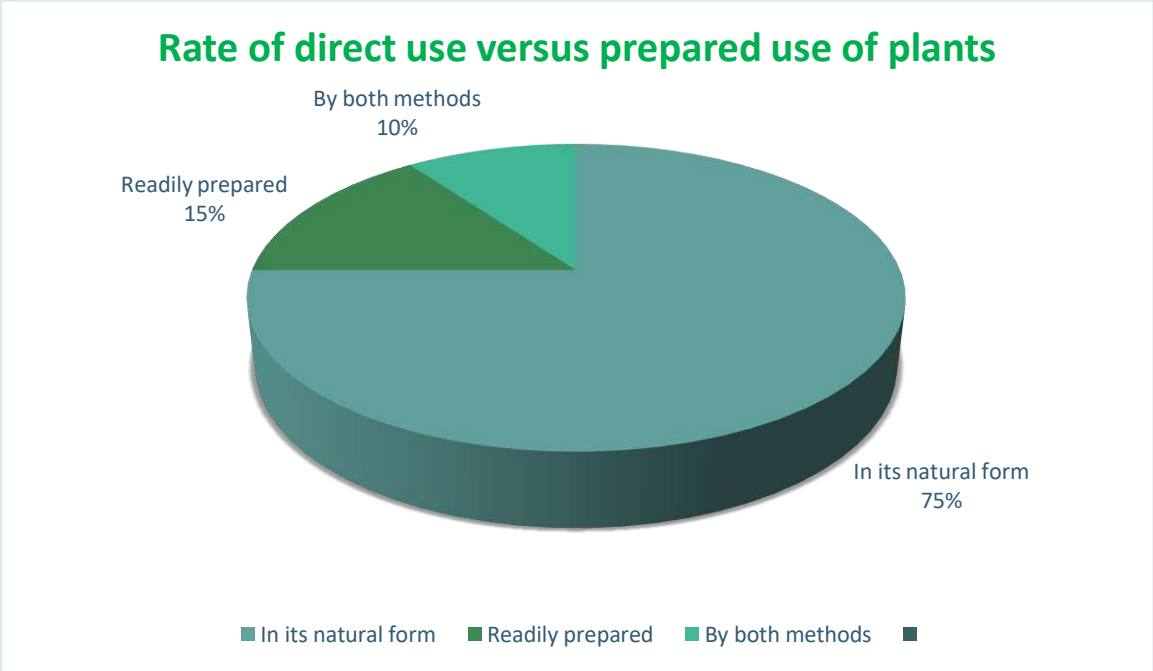


Figure 10. Rate of direct use versus prepared use of plants

Conclusion and Recommendations

Pazır and Alper (2016) and Christou *et al*. (2021) reported that the polyphenols in carob fruit (*Ceratonia siliqua* L.) have recently attracted considerable attention due to their wide range of health benefits. In a study conducted by Ayaz *et al*. (2007), the total phenolic content of carob molasses was found to be 13.51 mg GAE/g, whereas Tetik *et al*. (2010) reported a value of 1.62 mg GAE/g. The total phenolic content varies depending on production temperature, processing time, fruit composition, and growing conditions. It has also been reported that the maturity level of the fruit significantly influences its phenolic compound content (Christou *et al*., 2021).

The present study indicates that *Ceratonia siliqua* L. is a species with the potential to grow in many regions of the world. This taxon, which is currently found across all continents, has distribution areas particularly in Southwestern Europe, North and South America, and Oceania, largely associated with human activities and cultural interactions rather than purely ecological conditions. In Türkiye, its natural distribution area extends from the western regions, southward and eastward along the Taurus Mountains, reaching as far as Samandağ. The species is highly drought-resistant and, thanks to its deep root system, is capable of producing fruit even during severe drought periods. It does not require nutrient-rich soils for growth. Carob has been cultivated since ancient times and currently has a wide range of uses. In different cultures, it is utilized in various sectors including health, medicine, food (notably molasses), and the cosmetic industry. Consequently, global demand for carob has increased, while production has experienced fluctuations and declines. One of the main reasons for this is damage to shoots caused by harvesting methods involving beating branches, similar to olive harvesting, which reduces yield in the following year. As production is largely dependent on natural conditions, establishing plantation-type orchards in Türkiye, as in some other countries, could increase both production

areas and yield. This would contribute not only to local consumption (e.g., molasses and dried products) but also to the development of a new export commodity. Encouraging hand harvesting instead of stick-based methods would be an important strategy for reducing production fluctuations and ensuring sustainability. The production of carob molasses also reflects its economic importance and its use within health-related tourism. It has been identified as a highly valuable medicinal plant.

References

Alexander, R. R. & Shepperd, W. D. (1974). *Ceratonia siliqua* L., Carob, In: Schopmeyer CS, tech. coord. Seeds of woody plants in the United States, *Agricultural Handbook*, 450, Washington.

Ayaz, F.A., Torun, H., Ayaz, S., Correia, P.J., Alaiz, M., Sanz, C., Gruz, J. & Strnad, M. (2007). Determinatıon of chemical composition of anatolian carob pod (*Ceratonia siliqua* L.): sugars, amino and organic acids, minerals and phenolic compounds, *Journal of Food Quality*, 30, p.1040-1055.

Christou, A., Stavrou, I.J. & Kapnissi-Christodoulou, C.P. (2021). Continuous and pulsed ultrasound-assisted extraction of carob's antioxidants: Processing parameters optimization and identification of polyphenolic composition, *Ultrasonics Sonoch*emistry 76, p.105630.

Demirtaş, Ö. (2007). *Investigation of gum production methods from carob (Ceratonia siliqua) seeds*, Çukurova University, Adana, Türkiye.

Ghrabı, Z. (2005). A guide to medicinal plants in north africa, *IUCN Centre For Mediterranean, Cooperation Published*, p.79-81, Malaga, İspanya.

Hakim, L., Islam M.R., Mamun A.N.K., Ahmed, G. & Khan, R. (2010). Clonal propagation of carob (*Ceratonia siliqua* L., Fabaceae), *Bangladesh Journal of Botany*, 39 (1), p.15-19.

Makhzoumi, J.M. (2000). Landscape ecology as a foundation for landscape architecture: application in Malta, *Landscape and Urban Planning*, 50 (1), p.167-177.

Özkaya, M. T. & Tunalıoğlu, R. (2003). *Carob (Ceratonia siliqua)*. T.E.A.E. Bulletin, Issue 3, Issue 5, June, Ankara, Türkiye.

Pazır, F. & Alper, Y. (2016). Carob fruit (*Ceratonia siliqua*) and health, *Akademik Gıda*, 14(3), 302-306.

Pehlivan, T. & Gül, A. (2016). Chemical properties of carob, thyme, and milkweed honeys produced in Türkiye, *Mustafa Kemal University Journal of Agricultural Faculty*, 21(1), 48-56.

Tetik, N., Turhan, İ., Karhan, M. & Öziyci, H.R. (2010). Characterization and 5-hydroxymethylfurfural concentration in carob molasses (*Ceratonia siliqua*), *Gıda*, 35(6), 417-422.

Winer, N. (1980). The potential of the carob (*Ceratonia siliqua*), *International Tree Crops Journal*, 1, p.15-26.

Yousif, A.K. & Alghzawi H.M. (2000). Processing and characterization of carob powder, *Food Chemistry*, 69 (3), p.283-287.

Zunft, H.J., Lüder, W., Harde, A., Haber, B., Graubaum, H.J. & Gruenwald, J. (2001). Carob pulp preparation for treatment of hypercholesterolemia, *Advances in Therapy*, 18, p.230-236.

TIME-DEPENDENT EXPRESSION OF MSI1, NUMB AND ELAV IN IPSC-DERIVED BRAIN ORGANOIDS AND THEIR RELATIONSHIP WITH TAU PATHOLOGY IN ALZHEIMER'S DISEASE MODELING

Zeynep Pınar APAYDIN
Şenay GÖRÜCÜ YILMAZ
Sibel OĞUZKAN BALCI
0000-0002-0786-7593, Gaziantep University, Medical Faculty, Medical Biology, Gaziantep, Türkiye.
0000-0003-0523-7819, Gaziantep University, Health Science Faculty, Nutrition and Dietetics, Gaziantep, Türkiye.
0000-0003-0537-3028, Gaziantep University, Medical Faculty, Medical Biology, Gaziantep, Türkiye

Abstract

Alzheimer's disease (AD) is a progressive neurodegenerative disorder characterized by amyloid-beta plaques and hyperphosphorylated tau aggregates, leading to synaptic loss and neuronal death. Induced pluripotent stem cell (iPSC)-derived three-dimensional (3D) brain organoids offer a promising platform for modeling AD pathology in a human-relevant context. Musashi-1 (Msi1), an RNA-binding protein critical for neural stem cell maintenance, and its interacting partners NUMB and ELAV have been implicated in AD pathogenesis. Still, their developmental expression dynamics in human brain organoids remain unexplored. This study aimed to generate iPSC-derived brain organoids from healthy controls and AD patients, and to comparatively investigate the temporal expression profiles of Msi1, NUMB, and ELAV, as well as their relationship with tau pathology. Control and AD iPSC lines were differentiated into 3D brain organoids using an embryoid body-based protocol with neural and mesodermal induction, followed by long-term culture. Protein expression of Msi1, NUMB, ELAV, and phosphorylated tau (p-TAU) was assessed by immunohistochemistry and immunofluorescence, and quantified using ImageJ. Gene expression was analyzed by qRT-PCR. Statistical analyses included Mann-Whitney U, Friedman, Spearman correlation, and linear mixed models. AD organoids exhibited significantly lower *Msi1*, *ELAV*, and *NUMB* expression and higher p-TAU levels compared to controls at all time points ($p<0.001$). Control organoids showed a steady increase in *Msi1*, *ELAV*, and *NUMB* up to week 8, followed by a gradual decline, whereas AD organoids remained suppressed. p-TAU in AD organoids rose progressively, peaking at week 16. Strong negative correlations were found between Msi1 and p-TAU ($r = -0.892$), and between ELAV and p-TAU ($r = -0.854$), while Msi1 positively correlated with ELAV ($r = 0.918$) and NUMB ($r = 0.875$). Linear mixed models confirmed significant group × time interactions ($p<0.001$), indicating blunted Msi1/ELAV/NUMB trajectories and accelerated p-TAU accumulation in AD organoids. This study demonstrates that iPSC-derived brain organoids recapitulate key AD-related molecular alterations, including impaired Msi1/ELAV/NUMB expression and TAU hyperphosphorylation. The strong inverse relationship between Msi1 and p-TAU suggests that Msi1 deficiency may contribute to tau pathology. These findings highlight the utility of brain organoids for studying AD mechanisms and suggest Msi1 as a potential therapeutic target and biomarker.

Keywords: Alzheimer's disease; Brain organoids; ELAV; iPSC; Msi1; Tau pathology.

Introduction

Alzheimer's disease (AD) is the most common form of neurodegenerative disorder, characterized by progressive cognitive decline, memory impairment, and behavioral changes. The main pathological hallmarks of the disease are intracellular amyloid-beta (Aβ) accumulation and aggregation of hyperphosphorylated microtubule-associated protein TAU (Lo Vecchio et al., 2026). These two pathological processes threaten synaptic plasticity and neuronal viability, leading to irreversible neuronal loss.

Despite intensive research efforts, there is no definitive cure for AD. Current approaches generally focus on

slowing disease progression or early diagnosis. Recently, the FDA approved lecanemab (Leqembi), the first drug shown to reduce disease progression and slow cognitive and functional decline in adults (FDA, 2026). Additionally, clinical trials continue for new drug candidates such as donanemab (Rabinovici et al., 2025); a study of 257 individuals demonstrated that clinical progression was significantly slowed after 76 weeks (Mintun et al., 2021). However, these developments do not eliminate the need for a complete understanding of the molecular mechanisms underlying the disease.

Animal models, cell culture systems, and human postmortem tissue samples are widely used in AD research. Animal studies are conducted metabolically and transgenically. Metabolic models do not fully reflect the disease, and transgenic models cannot exhibit the same results as the human brain. Two-dimensional (2D) cell culture systems are insufficient to reflect the complex structure of the entire brain and intercellular interactions. These limitations prevent the pathophysiology of the disease from being fully elucidated and treatment targets from being accurately determined.

In recent years, advances in three-dimensional (3D) cell culture technologies have offered a new approach to simulating the human brain in neurodegenerative disease research. Brain organoids derived from human pluripotent stem cells (iPSCs) are 3D structures that mimic the cellular diversity and tissue organization of the human brain and organize when supported by the molecules required during organoid development (Kim et al., 2026). This technology offers an alternative or complementary approach to studying key features of AD pathology such as Aβ and TAU protein aggregation and neuroinflammation.

The greatest advantage of brain organoids is the ability to produce a model resembling the actual organ in a short time. By exploiting the intrinsic ability of iPSCs to form embryoid bodies (EBs) and differentiate into three germ layers in vitro, brain organoids mimicking key structural and functional features of the developing human cerebral cortex can be generated (Zhao et al., 2025). With developed protocols, cerebral organoids can replicate early in vivo human brain development up to a stage equivalent to the 13th week of gestation and can be maintained for up to 1 year after culture (Gordon et al., 2021).

Cerebral organoids derived from iPSCs modeling AD have been shown to represent the AD phenotype and exhibit significantly increased TAU protein levels and Aβ plaques (Gonzalez et al., 2018). Furthermore, these organoid platforms are recognized as valuable tools for drug screening and investigation of disease mechanisms (Gao et al., 2025).

In the adult mammalian brain, there are two main neurogenic regions: the ventricular-subventricular zone (V-SVZ) and the subgranular zone (SGZ) of the hippocampal dentate gyrus (DG) (Bond et al., 2015). Neural stem cells (NSCs) in these regions have the capacity to produce new neurons throughout life. However, in AD, this neurogenic capacity is impaired. Studies have shown that Musashi-1 and Ki-67-positive precursor cells in the hippocampus of AD patients can self-renew but reach senescence earlier compared to cells isolated from normal aged control subjects (Lovell et al., 2006). Furthermore, it has been reported that Musashi-1 immunoreactivity is significantly lower in the subgranular layer and granule cell layer in AD and decreases as Braak stages progress (Perry et al., 2012).

Musashi-1 (Msi1) is an evolutionarily conserved RNA-binding protein (RBP) with a critical role in regulating neural stem cell proliferation and self-renewal (Dobson et al., 2008; Forouzanfar et al., 2020). Msi1 contains two basic RNA recognition motifs (RRM1 and RRM2), and these regions have remarkably similar sequences in axolotl and human (Chernoff et al., 2018). Msi1 function involves binding to Numb, a negative regulator of the Notch signaling pathway, and suppressing its translation, thereby contributing to Notch-mediated proliferation (Imai et al., 2001).

Recent research sheds light on the role of Msi1 in AD pathology. It has been shown that MSI1 protein expression increases in parallel with the progression of TAU pathology and promotes TAU phosphorylation by activating the p38 MAPK signaling pathway (Li et al., 2025). Furthermore, it has been reported that pathogenic TAU oligomers alter the localization and function of MSI1 protein, causing cytoplasmic and nuclear aggregation and impairing MSI1's ability to bind RNA targets (Puangmalai et al., 2025). It has been determined that MSI1 and MSI2 proteins are present in oligomeric form in AD brains and that these large

aggregates colocalize with TAU, contributing to neurodegenerative pathogenesis (Sengupta et al., 2018).

Neuronal ELAV (embryonic lethal abnormal visual system) proteins (HuB, HuC, and HuD) are neuron-specific RNA-binding proteins that play important roles in post-transcriptional regulation and in the development and maintenance of the nervous system (Wutikeli et al., 2025). These proteins are the main inducers of neuronal differentiation through stabilization and/or translational enhancement of target transcripts carrying AU-rich elements (AREs) (Mirisis & Carew, 2019).

The relationship between MSI1 protein and neuronal ELAV proteins represents a critical regulatory mechanism during neural development. Neuronal ELAV proteins binding to ARE sequences in the 3'-UTR region of MSI1 mRNA stabilize the mRNA and promote its translation (Ratti et al., 2006). Through this mechanism, the continuity of MSI1 protein levels is ensured after MSI1 is transcriptionally inactivated during the transition of a proliferating neural stem cell to a differentiating neuron. Thus, a gradual transition of the stem/progenitor cell from proliferation to differentiation becomes possible.

In AD, the expression of neuronal ELAV proteins decreases. Decreased expression of ELAV4 (HuD) in the hippocampus has been associated with dementia and shown to play a role in Aβ plaque formation (Amadio et al., 2009). The relationship with TAU protein has been demonstrated by identifying the binding region of HuD protein to TAU mRNA (Atlas et al., 2004). Treatment with antisense oligonucleotides against HuD blocked induction of neurite outgrowth and reduced TAU mRNA levels (Aranda-Abreu et al., 1999). These findings indicate that ELAV-like proteins are required for neuronal differentiation.

Numb is an evolutionarily conserved endocytic adaptor protein involved in cell fate determination (Chi et al., 2024). Numb functions as a negative regulator of the Notch signaling pathway, and its interaction with MSI1 is critical in regulating neural stem cell proliferation (Imai et al., 2001). In the context of AD, it has been shown that altered expression of Numb isoforms increases Aβ production. Numb interacts with the carboxy-terminal region of amyloid precursor protein (APP) and regulates APP transport and processing (Kyriazis et al., 2008). Furthermore, Numb has also been identified as a regulator of intracellular TAU levels.

The current literature indicates critical roles of MSI1, neuronal ELAV proteins, and Numb in neural development and regeneration. It is known that impairments in the expression and function of these proteins occur in AD. However, the exact roles of these proteins in AD pathology and the dynamics of their interactions during the disease process have not been fully elucidated. In particular, the question of whether the association of MSI1 with TAU is the cause or a consequence of the disease remains unclear. Furthermore, the expression profile of this protein network in the human brain organoid model throughout the developmental stages of the disease and the timing of AD pathology onset have not yet been investigated.

The unique value of this project is that it examines for the first time comparatively the developmental expression dynamics of MSI1, neuronal ELAV proteins, and numb by generating AD and healthy brain organoids from iPSCs. Organoid technology will enable monitoring of these proteins from the early stages of the disease and provide temporal elucidation of their relationship with TAU pathology. This approach will provide mechanistic information in a human brain-specific context, overcoming the limitations of animal models and 2D cell cultures.

In the human brain organoid modeling process, the expression of MSI1, NUMB, and ELAV proteins and related genes shows tissue-specific changes according to developmental stages. In AD organoids derived from iPSCs, the expression profile of these proteins exhibits significant differences compared to healthy controls, and this difference is related to the development of TAU pathology. If MSI1 is a pathology, its staging during organoid formation and thus the activation of neuronal regeneration with endogenously produced neurons and potential mechanisms in the treatment of AD can be elucidated.

This research aims to generate normal and AD brain organoids from human iPSCs, to comparatively determine the developmental expression profiles of MSI1, NUMB, and ELAV proteins, to detect tissue-specific protein presence/absence, and to investigate the relationship of these proteins with TAU pathology.

Materials and Methods

Research Design

In this study, three-dimensional brain organoids were generated from control and Alzheimer's disease (AD)-derived human induced pluripotent stem cells (iPSCs). The developmental processes of organoids were monitored morphologically, and immunohistochemical expressions of Msi1, NUMB, and ELAV proteins were evaluated at different developmental time points.

The main objective of the study was to determine the time-dependent expression profiles of Msi1, NUMB, and ELAV proteins during brain organoid development and to reveal the differences between control and Alzheimer's iPSC-derived organoids. In the project, it was planned to evaluate Msi1, NUMB, and ELAV proteins in relation to the properties of neural progenitor cells, neural differentiation, and neuronal development.

Two experimental groups were formed: **Control iPSC group:** Brain organoids generated from healthy control-derived iPSCs. **Alzheimer iPSC group:** Brain organoids generated from Alzheimer's disease-derived iPSCs. Organoids from both groups were cultured under the same culture and differentiation conditions and evaluated at the same developmental time points.

Cell Culture

Human iPSCs were used in the study. Control and Alzheimer-derived iPSC lines were expanded under appropriate pluripotent stem cell culture conditions. StemMACS iPS-Brew medium, neural induction medium (NIM), NIM2, and neural differentiation medium (NDM) were used during cell culture stages. Media containing penicillin/streptomycin were used when necessary, during cell culture. It was considered that excessive confluence of iPSC cells could adversely affect differentiation behavior and experimental results; therefore, the culture status of cells was checked daily. Culture medium was renewed when necessary.

Generation of Neural and Mesodermal Organoids

For organoid generation, agarose-coated 96-well cell culture plates were prepared. iPSC cells were made into a single-cell suspension, and cell density was determined. Cells were seeded into agarose-coated 96-well plates in medium containing 10 µM ROCK inhibitor (Y-27632). Cells were cultured under 5% CO_2 and 20% O_2 conditions. ROCK inhibitor was used to reduce anoikis development in cells taken into cell suspension. After the first 24 hours of culture, the medium was replaced with NIM and incubated for 48 hours. Then NIM2 was used, and after 72 hours of culture, the medium was replaced with NDM and culture was continued for another 24 hours. At the end of this process, neural and mesodermal differentiation was achieved.

Assembly of Neural and Mesodermal Organoids

Organoids obtained on day 7 of neural induction and day 4 of mesodermal induction were brought together. At this stage, NDM in wells containing neural organoids was removed, and fresh NDM was added. A portion of the medium in wells containing mesodermal organoids was removed, and approximately 20 µL of medium was left to transfer organoids without damage. Then, one mesodermal organoid was transferred to the well containing the neural organoid. Organoid assembly was expected to be completed on **day 9**, and after this stage, BME was used to support the maturation of neural tissue.

Embedding in BME and Organoid Culture

BME was used to support the three-dimensional development of assembled organoids. BME was thawed on ice for 2 hours, and assembled organoids were placed into BME. Cultures containing BME were incubated at 37 °C to allow gel formation. Organoids were then transferred to appropriate culture vessels for long-term culture.

Long-Term Organoid Culture

Organoids were cultured at 37 °C, 5% CO_2, and 20% O_2 conditions. Culture medium was renewed depending on the size and number of organoids. Throughout organoid development, size, shape, integrity, and general morphological features were regularly evaluated microscopically.

Temporal Sampling

Organoid development was followed at different developmental time points. On day 4, mesodermal organoid formation; on day 7, neural organoid formation; on day 9, organoid assembly; and on day 10, transfer of assembled organoids to long-term culture were evaluated. On day 20, organoids were harvested for histological evaluation. The protocol specified that neural organoids should be cultured for at least 100 days, and long-term development was followed up to day 100.

Fixation of Organoids

For histological and immunohistochemical evaluation, selected organoids were taken from the culture medium and transferred to 2 mL reaction tubes. Organoids were washed with PBS and then fixed in +4 °C paraformaldehyde (PFA) overnight. After fixation, PFA was removed and samples were washed three times with PBS. To preserve the structural integrity of organoids, 1% agarose was prepared and cooled to an appropriate temperature, and then organoids were placed into agarose. Samples were transferred to tissue cassettes and stored in 70% ethanol until tissue processing.

Tissue Processing and Paraffin Embedding

Tissue processing of fixed organoids embedded in agarose was performed using a tissue processor. During tissue processing, samples were sequentially passed through 70% ethanol, 80% ethanol, 96% ethanol, 99% ethanol, 100% 2-propanol, 99.9% xylene, and paraffin. In the project protocol, it was planned to embed samples in paraffin after paraffin infiltration.

Preparation of Paraffin Sections

Sections of **3 µm thickness** were taken from paraffin blocks. Sections were transferred to microscope slides and dried in an incubator at 37 °C for approximately 17-20 hours. To preserve morphological details, the cryo-section method was not used; the paraffin section method was preferred.

Immunohistochemical Staining

Expression of Msi1, NUMB, and ELAV proteins was evaluated using the chromogenic immunohistochemistry method.

Deparaffinization and Rehydration

Paraffin sections were sequentially subjected to: 99.9% xylene for 2 × 10 minutes; 99% ethanol for 2 × 5 minutes; 96% ethanol for 5 minutes; 80% ethanol for 5 minutes; 70% ethanol for 5 minutes; distilled water for 5 minutes. As a result of this process, paraffin was removed, and tissues were re-adapted to an aqueous environment.

Antigen Retrieval

To reduce masking of antigens due to fixation, antigen retrieval was performed using **10 mM citrate buffer, pH 6**. After the procedure, sections were washed with distilled water and PBS.

Blocking of Endogenous Peroxidase Activity

Since the chromogenic HRP-DAB system was used, appropriate peroxidase blocking was applied to reduce non-specific signal that could arise from endogenous peroxidase activity. After this step, sections were washed with PBS.

Protein Blocking

To reduce non-specific antibody binding, sections were incubated in blocking solution. In the project protocol, it was envisaged that samples would be incubated in blocking buffer at 20-23 °C for 1 hour.

Immunohistochemical Staining with Primary Antibodies

Expression of the following proteins was evaluated in sections. **Msi1:** Msi1 was used to evaluate neural stem/progenitor cell properties. **NUMB:** NUMB was used to evaluate neural cell differentiation and cell fate.

ELAV: ELAV was used to evaluate neuronal differentiation and neural development. Within the project scope, these three proteins were determined as basic immunological markers. Manufacturer, clone, catalog number, and optimal dilution information of primary antibodies were recorded according to the commercial products used.

HRP-Conjugated Secondary Antibody and DAB Application

After primary antibody incubation, sections were washed with PBS. A HRP-conjugated secondary antibody was applied, and after incubation, sections were washed again with PBS. To visualize HRP activity, 3,3'-diaminobenzidine (DAB) chromogen was applied. Positive immunohistochemical reactions were evaluated as a brown-colored signal. When the DAB reaction reached appropriate staining intensity, the reaction was stopped.

Counterstaining and Coverslipping

After the DAB reaction, sections were washed, and light counterstaining with hematoxylin was performed for better evaluation of cellular morphology. Sections were washed with water, passed through dehydration processes, and cleared in xylene. Finally, slides were coverslipped using appropriate mounting medium.

Positive and Negative Controls

Positive and negative controls were used to evaluate the reliability of the immunohistochemical method. In negative controls, primary antibody was not applied, and all other staining steps were performed identically. Thus, non-specific staining that could arise from secondary antibody or chromogen system was evaluated. Appropriate positive control materials with known Msi1, NUMB, and ELAV expression were used to check the functionality of primary and secondary antibody systems.

Microscopic Evaluation

Immunohistochemically stained sections were examined under a microscope. The same microscope and imaging conditions were used for each sample. Distribution of Msi1, NUMB, and ELAV-positive cells, staining intensity, and positive cell ratio were evaluated. Staining characteristics were compared between control and Alzheimer's iPSC-derived organoids at the same developmental time points.

Immunohistochemical Image Analysis

Immunohistochemical images were analyzed using ImageJ software. An appropriate number of microscopic fields were evaluated in sections obtained from each organoid. Msi1, NUMB, and ELAV positivity were analyzed on coded images, and group codes were opened after statistical analysis was completed.

Molecular Analysis

To support immunohistochemical findings, Msi1, NUMB, and ELAV gene expressions were also evaluated at the molecular level. Total RNA was isolated from organoids, RNA quantity and purity were determined, and cDNA synthesis was performed using appropriate amounts of RNA. *ACTB* (β-actin) was used as an endogenous control gene in gene expression analyses. Relative expression levels of Msi1, NUMB, and ELAV genes were calculated relative to ACTB. In the project form, it was planned to evaluate these genes by qRT-PCR.

Statistical Analysis

Positive cell percentage, positive area percentage, and staining intensity data obtained from immunohistochemical analyses were statistically evaluated. Statistical analyses were performed using SPSS software. In the project form, it was planned to use the Kruskal-Wallis test for group comparisons and the Mann-Whitney U test for pairwise comparisons. Data were presented with mean and standard error values, and $p \leq 0.05$ was considered statistically significant. Since there were multiple time points during the 100-day development process, an appropriate multifactorial analysis approach was used when time and group effects needed to be evaluated together. If repeated measurements were made on the same organoid, the repeated

measurement structure was taken into account.

Findings and Discussion

A total of 12 organoids per group (control and Alzheimer's disease [AD]) were analyzed across the 0–20-week culture period; the day-20 harvest corresponded to week 3. Because the data were not normally distributed, Mann–Whitney U tests were used for between-group comparisons. At all time points, AD organoids showed significantly lower Msi1, ELAV, and NUMB expression and significantly higher p-TAU levels than controls ($p<0.001$). Representative week-20 values were as follows: Msi1 1.52±0.24 vs 2.68±0.32; ELAV 1.40±0.22 vs 2.60±0.30; NUMB 1.42±0.21 vs 2.65±0.31; and p-TAU 4.65±0.50 vs 1.15±0.18 (AD vs control, mean±SD, A.U.). In AD organoids, p-TAU increased progressively and peaked at week 16 (5.05±0.56 vs 1.20±0.20 in controls). Control organoids showed a steady increase in Msi1, ELAV, and NUMB up to week 8, followed by a gradual decline, whereas these proteins remained suppressed in AD organoids. Friedman tests confirmed significant time effects within groups for Msi1, ELAV, and NUMB ($p<0.001$); p-TAU also changed significantly over time in both groups (control $p=0.002$; AD $p<0.001$).

At week 20, Spearman correlation analysis showed a very strong negative correlation between Msi1 and p-TAU ($r=-0.892$, $p<0.001$) and between ELAV and p-TAU ($r=-0.854$, $p<0.001$), while Msi1 was strongly positively correlated with ELAV ($r=0.918$, $p<0.001$) and NUMB ($r=0.875$, $p<0.001$). Linear mixed-model analysis confirmed significant group×time interactions for Msi1 and p-TAU ($p<0.001$). For Msi1, the group effect was $\beta=-1.892$ (SE 0.124), the time effect was $\beta=+0.098$ (0.012), and the group×time interaction was $\beta=-0.087$ (0.015). For p-TAU, the group effect was $\beta=+2.985$ (0.210), the time effect was $\beta=+0.025$ (0.018; $p=0.165$), and the group×time interaction was $\beta=+0.195$ (0.025; $p<0.001$), indicating blunted Msi1 trajectories and accelerated p-TAU accumulation in AD organoids.

qRT-PCR findings supported the protein data. At week 16, MSI1, ELAVL4, and NUMB mRNA levels were lower in AD organoids than in controls (Msi1: 1.68±0.13 vs 3.20±0.25; ELAVL4: 1.55±0.14 vs 3.15±0.26; NUMB: 1.58±0.12 vs 3.10±0.24), whereas MAPT mRNA was higher (5.10±0.42 vs 1.20±0.10). Similar trends were observed at week 20. The Msi1/p-TAU ratio was approximately 2.5 in controls but decreased to 0.3–0.4 in AD organoids. Morphological tracking showed comparable organoid formation between groups, while immunofluorescence and immunohistochemistry showed reduced Msi1, NUMB, and ELAV signals and increased p-TAU immunoreactivity in AD organoids, consistent with the quantitative findings.

Alzheimer's disease (AD) is one of the most common causes of cognitive impairment and dementia in advanced ages, and it is predicted that the number of individuals affected by the disease will gradually increase with the aging of the population. The fact that AD shows a progressive process ranging from biological changes starting before the emergence of clinical symptoms to mild cognitive impairment and dementia stages makes it important to elucidate the cellular and molecular mechanisms underlying the disease. Although significant advances have been made in the development of disease-modifying treatments for AD in recent years, the complex pathophysiology of the disease and the limitations of existing treatment options maintain the need for research into new therapeutic targets and experimental models that better reflect the disease. In this direction, the use of human-derived induced pluripotent stem cells (iPSCs) and three-dimensional brain organoids developed from these cells stands out as one of the important experimental approaches that allow the cellular and molecular features of AD to be examined under conditions closer to human biology.

In this study, we generated 3D brain organoids from control and AD iPSCs and comparatively investigated the temporal expression profiles of Msi1, NUMB, and ELAV proteins and their relationship with TAU pathology. Our findings demonstrate that AD organoids exhibit significantly lower Msi1, ELAV, and NUMB expression and higher p-TAU levels compared to controls at all time points. Control organoids showed a steady increase in Msi1, ELAV, and NUMB up to week 8, followed by a gradual decline, whereas AD organoids remained suppressed. p-TAU in AD organoids rose progressively, peaking at week 16. Strong negative correlations were

found between Msi1 and p-TAU (r = -0.892), and between ELAV and p-TAU (r = -0.854), while Msi1 positively correlated with ELAV (r = 0.918) and NUMB (r = 0.875). Linear mixed models confirmed significant group × time interactions ($p<0.001$), indicating blunted Msi1/ELAV/NUMB trajectories and accelerated p-TAU accumulation in AD organoids.

Our finding that Msi1 expression is significantly reduced in AD organoids compared to controls is consistent with previous studies. Lovell and Markesbery (2005) reported that Msi1 is expressed in 83 ± 6% of neurofibrillary tangle-bearing neurons in the hippocampus of AD patients and in 94 ± 14% of Pick bodies in Pick disease, whereas almost no Msi1 immunoreactivity was observed in age-matched healthy control hippocampus. This finding suggests that ectopic expression of Msi1, which is normally specific to neural progenitor cells, in postmitotic neurons may contribute to the pathogenesis of pathological protein inclusions in these cells. Furthermore, Perry et al. (2012) reported that Musashi-1 immunoreactivity is significantly lower in the subgranular layer and granule cell layer in AD and decreases as Braak stages progress.

In our study, the observation that Msi1 expression in control organoids increased steadily until week 8 and then gradually declined is consistent with the physiological role of Msi1 in maintaining neural stem/progenitor cell proliferation and self-renewal (Dobson et al., 2008; Forouzanfar et al., 2020). The fact that Msi1 expression remained suppressed in AD organoids from the early stages suggests that the neurogenic capacity is impaired in AD from the very beginning.

Sengupta et al. (2018) demonstrated that Musashi family proteins (Msi1 and Msi2) form toxic oligomeric aggregates in AD, amyotrophic lateral sclerosis, and frontotemporal dementia brain tissues, and that this aggregation is directed through pathological interaction with tau protein. Furthermore, it has been shown that the interaction of Msi1 and Msi2 with soluble tau aggregates triggers the formation of pathological protein inclusions associated with age-related extracellular tau/Msi complex accumulations in AD, ALS, and FTD brain tissues and initiates nuclear dysfunction by causing disruptive effects on nuclear/cytoplasmic transport, chromatin remodeling, and nuclear lamina integrity (Montalbano et al., 2020). These findings support our observation that Msi1 deficiency may contribute to tau pathology.

Li et al. (2025) showed that MSI1 protein expression increases in parallel with the progression of TAU pathology and promotes TAU phosphorylation by activating the p38 MAPK signaling pathway. Furthermore, it has been reported that pathogenic TAU oligomers alter the localization and function of MSI1 protein, causing cytoplasmic and nuclear aggregation and impairing MSI1's ability to bind RNA targets (Puangmalai et al., 2025). These findings suggest a bidirectional relationship between Msi1 and TAU pathology. Our finding of a strong negative correlation between Msi1 and p-TAU (r = -0.892) suggests that Msi1 deficiency may trigger TAU hyperphosphorylation. This is consistent with the hypothesis that Msi1 is not only a marker of neural stem cells but also plays a protective role against TAU pathology.

Our finding that ELAV expression is significantly reduced in AD organoids compared to controls is consistent with previous studies. Amadio et al. (2009) reported that decreased expression of ELAV4 (HuD) in the hippocampus is associated with dementia and plays a role in Aβ plaque formation. The relationship with TAU protein has been demonstrated by identifying the binding region of HuD protein to TAU mRNA (Atlas et al., 2004). Treatment with antisense oligonucleotides against HuD blocked induction of neurite outgrowth and reduced TAU mRNA levels (Aranda-Abreu et al., 1999). These findings indicate that ELAV-like proteins are required for neuronal differentiation.

Ratti et al. (2006) demonstrated that neuronal ELAV proteins stabilize Msi1 mRNA by binding to ARE sequences in the 3'-UTR region, and that this mechanism ensures the continuity of MSI1 protein levels after MSI1 is transcriptionally inactivated during the transition of a proliferating neural stem cell to a differentiating neuron. Our finding of a very strong positive correlation between Msi1 and ELAV (r = 0.918) supports this mechanism. The fact that both Msi1 and ELAV expression remained suppressed in AD organoids suggests that the Msi1-ELAV axis, which is critical for neural development and regeneration, is impaired in AD.

Our finding that NUMB expression is significantly reduced in AD organoids compared to controls is consistent with previous studies. Numb functions as a negative regulator of the Notch signaling pathway, and its

interaction with MSI1 is critical in regulating neural stem cell proliferation (Imai et al., 2001). Kyriazis et al. (2008) demonstrated that Numb interacts with the carboxy-terminal region of amyloid precursor protein (APP) and regulates APP transport and processing. Furthermore, Numb has also been identified as a regulator of intracellular TAU levels.

Chi et al. (2024) reported that altered expression of Numb isoforms increases Aβ production. The fact that NUMB expression remained suppressed in AD organoids in our study suggests that Numb deficiency may contribute to Aβ pathology as well as TAU pathology.

Our finding that p-TAU levels in AD organoids rose progressively and peaked at week 16 is consistent with previous studies. Gonzalez et al. (2018) demonstrated that cerebral organoids derived from iPSCs modeling AD represent the AD phenotype and exhibit significantly increased TAU protein levels and Aβ plaques. In our study, the observation that p-TAU was above control levels from week 0 and peaked at week 16 suggests that TAU pathology develops early in AD organoids and progresses over time.

The strong negative correlation between Msi1 and p-TAU ($r = -0.892$) and between ELAV and p-TAU ($r = -0.854$) found in our study suggests that Msi1 and ELAV deficiency may contribute to TAU pathology. This is consistent with the hypothesis that Msi1 and ELAV play protective roles against TAU pathology.

Our finding that the Msi1/p-TAU ratio was around 2.5 in the Control group while this ratio dropped to 0.3-0.4 levels in the AD group suggests that this ratio could be a strong candidate biomarker for monitoring disease progression. This is consistent with the hypothesis that Msi1 and p-TAU could be used as biomarkers for AD diagnosis and monitoring.

Conclusion and Recommendations

In conclusion, this study demonstrates that iPSC-derived brain organoids recapitulate key AD-related molecular alterations, including impaired Msi1/ELAV/NUMB expression and TAU hyperphosphorylation. The strong inverse relationship between Msi1 and p-TAU suggests that Msi1 deficiency may contribute to tau pathology. These findings highlight the utility of brain organoids for studying AD mechanisms and suggest Msi1 as a potential therapeutic target and biomarker.

Thanks and Information Note

This study was supported by Gaziantep University Scientific Research Projects (BAP) Coordination Unit with project number SBF.DT.24.06. The authors thank Gaziantep University BAP for their support.

References

Amadio, M., Pascale, A., Wang, J., Ho, L., Quattrone, A., Gandy, S., Haroutunian, V., Racchi, M. & Pasinetti, G. M. (2009). nELAV proteins alteration in Alzheimer's disease brain: A novel putative target for amyloid-β reverberating on AβPP processing. Journal of Alzheimer's Disease, 16(2), 409-419.

Aranda-Abreu, G. E., Behar, L., Chung, S., Furneaux, H. & Ginzburg, I. (1999). Embryonic lethal abnormal vision-like RNA-binding proteins regulate neurite outgrowth and tau expression in PC12 cells. The Journal of Neuroscience, 19(16), 6907-6917.

Atlas, R., Behar, L., Elliott, E. & Ginzburg, I. (2004). The insulin-like growth factor mRNA binding-protein IMP-1 and the Ras-regulatory protein G3BP associate with tau mRNA and HuD protein in differentiated P19 neuronal cells. Journal of Neurochemistry, 89(3), 613-626.

Bond, A. M., Ming, G. L. & Song, H. (2015). Adult mammalian neural stem cells and neurogenesis: Five decades later. Cell Stem Cell, 17(4), 385-395.

Chernoff, E. A. G., Sato, K., Salfity, H. V. N., Sarria, D. A. & Belecky-Adams, T. (2018). Musashi and plasticity of Xenopus and axolotl spinal cord ependymal cells. Frontiers in Cellular Neuroscience, 12, 45. https://doi.org/10.3389/fncel.2018.00045

Chi, J., Chen, Y., Li, C., Liu, S., Che, K., Kong, Z., Guo, Z., Chu, Y., Huang, Y., Yang, L., Sun, C., Wang, Y., Lv, W., Zhang, Q., Guo, H., Zhao, H., Yang, Z., Xu, L., Wang, P., ... Cao, Y. (2024). NUMB dysfunction defines a novel mechanism underlying hyperuricemia and gout. Cell Discovery, 10(1), 106. https://doi.org/10.1038/s41421-024-00708-6

Dobson, N. R., Zhou, Y. X., Flint, N. C. & Armstrong, R. C. (2008). Musashi1 RNA-binding protein regulates oligodendrocyte lineage cell differentiation and survival. Glia, 56(3), 318-330.

Forouzanfar, M., Lachinani, L., Dormiani, K., Nasr-Esfahani, M. H., Gure, A. O. & Ghaedi, K. (2020). Intracellular functions of RNA-binding protein, Musashi1, in stem and cancer cells. Stem Cell Research & Therapy, 11(1), 193. https://doi.org/10.1186/s13287-020-01703-w

Gao, Q., Wu, Y., Mao, Y., Chen, X., Geng, Z. & Su, J. (2025). Organoids: A new frontier in precision medicine and engineering. Precision Medicine and Engineering, 2(4), 100049.

Gonzalez, C., Armijo, E., Bravo-Alegria, J., Becerra-Calixto, A., Mays, C. E. & Soto, C. (2018). Modeling amyloid beta and tau pathology in human cerebral organoids. Molecular Psychiatry, 23(12), 2363-2374.

Gordon, A., Yoon, S. J., Tran, S. S., Makinson, C. D., Park, J. Y., Andersen, J., Valencia, A. M., Horvath, S., Xiao, X., Huguenard, J. R., Pasca, S. P. & Geschwind, D. H. (2021). Long-term maturation of human cortical organoids matches key early postnatal transitions. Nature Neuroscience, 24(3), 331-342.

Imai, T., Tokunaga, A., Yoshida, T., Hashimoto, M., Mikoshiba, K., Weinmaster, G., Nakafuku, M. & Okano, H. (2001). The neural RNA-binding protein Musashi1 translationally regulates mammalian numb gene expression by interacting with its mRNA. Molecular and Cellular Biology, 21(12), 3888-3900.

Kim, H., Vasquez, F. J. A., Bello, A. B. & Lee, S.-H. (2026). Advances in cellular and structural engineering of brain organoids for disease modeling: A comprehensive review. Tissue and Cell, 101, 103401.

Kyriazis, G. A., Wei, Z., Vandermey, M., Jo, D. G., Xin, O., Mattson, M. P. & Chan, S. L. (2008). Numb endocytic adapter proteins regulate the transport and processing of the amyloid precursor protein in an isoform-dependent manner: Implications for Alzheimer disease pathogenesis. Journal of Biological Chemistry, 283(37), 25492-25502.

Li, J., Guo, L., Cai, W., Mei, J., Liu, J. & Liu, Y. (2026). Overcoming the blood-brain barrier: Nanomedicine strategies for targeted delivery and multimodal therapy in Alzheimer's disease. Drug Delivery, 33(1), 2645830. https://doi.org/10.1080/10717544.2026.2645830

Lo Vecchio, F., la Torre, A., Gravina, C., D'Onofrio, G. & Greco, A. (2026). Molecular mechanisms underlying Alzheimer's disease pathogenesis: Comprehensive overview. International Journal of Molecular Sciences, 27(10), 4651. https://doi.org/10.3390/ijms27104651

Lovell, M. A., Geiger, H., Van Zant, G. E., Lynn, B. C. & Markesbery, W. R. (2006). Isolation of neural precursor cells from Alzheimer's disease and aged control postmortem brain. Neurobiology of Aging, 27(7), 909-917.

Mintun, M. A., Lo, A. C., Duggan Evans, C., Wessels, A. M., Ardayfio, P. A., Andersen, S. W., Shcherbinin, S., Sparks, J., Sims, J. R., Brys, M., Apostolova, L. G., Salloway, S. P. & Skovronsky, D. M. (2021). Donanemab in early Alzheimer's disease. The New England Journal of Medicine, 384(18), 1691-1704.

Mirisis, A. A. & Carew, T. J. (2019). The ELAV family of RNA-binding proteins in synaptic plasticity and long-term memory. Neurobiology of Learning and Memory, 161, 143-148.

Montalbano, M., McAllen, S., Puangmalai, N., Sengupta, U., Bhatt, N., Johnson, O. D., Kharas, M. G. & Kayed, R. (2020). RNA-binding proteins Musashi and tau soluble aggregates initiate nuclear dysfunction. Nature Communications, 11(1), 4305.

Perry, E. K., Johnson, M., Ekonomou, A., Perry, R. H., Ballard, C. & Attems, J. (2012). Neurogenic abnormalities in Alzheimer's disease differ between stages of neurogenesis and are partly related to cholinergic pathology. Neurobiology of Disease, 47(2), 155-162.

Puangmalai, N., Aday, A. E., Samples, M., Bhatt, N., Lo Cascio, F., Marcatti, M., Park, S. J., Fung, L., Jerez, C., Penalva, L. O., Zhao, Y., Hao, H., Lugano, D., Kayed, R. & Montalbano, M. (2025). Pathogenic oligomeric tau alters neuronal RNA processes through the formation of nuclear heteromeric amyloids with RNA-binding protein Musashi1. Progress in Neurobiology, 247, 102742.

Rabinovici, G. D., Selkoe, D. J., Schindler, S. E., Aisen, P., Apostolova, L. G., Atri, A., Greenberg, S. M., Hendrix, S. B., Petersen, R. C., Weiner, M., Salloway, S. & Cummings, J. (2025). Donanemab: Appropriate use recommendations. The Journal of Prevention of Alzheimer's Disease, 12(5), 100150. https://doi.org/10.1016/j.tjpad.2025.100150

Ratti, A., Fallini, C., Cova, L., Fantozzi, R., Calzarossa, C., Zennaro, E., Pascale, A., Quattrone, A. & Silani, V. (2006). A role for the ELAV RNA-binding proteins in neural stem cells: Stabilization of Msi1 mRNA. Journal of Cell Science, 119(7), 1442-1452.

Sengupta, U., Montalbano, M., McAllen, S., Minuesa, G., Kharas, M. & Kayed, R. (2018). Formation of toxic oligomeric assemblies of RNA-binding protein: Musashi in Alzheimer's disease. Acta Neuropathologica Communications, 6(1), 113.

U.S. Food and Drug Administration (FDA). (2026). FDA approves first at-home starting dose for Alzheimer's disease treatment. Retrieved: August 25, 2026, from https://www.fda.gov/drugs/news-events-human-drugs/fda-approves-first-home-starting-dose-alzheimers-disease-treatment

Wutikeli, H., Xie, T., Xiong, W. & Shen, Y. (2025). ELAV/Hu RNA-binding protein family: Key regulators in neurological disorders, cancer, and other diseases. RNA Biology, 22(1), 1-11. https://doi.org/10.1080/15476286.2025.2471133

Zhao, Y., Wang, T., Liu, J., Wang, Z. & Lu, Y. (2025). Emerging brain organoids: 3D models to decipher, identify and revolutionize brain. Bioactive Materials, 47, 378-402. https://doi.org/10.1016/j.bioactmat.2025.01.025

OCULAR ALKALI INJURY IN A DOG FOLLOWING DISINFECTANT EXPOSURE: CLINICAL FINDINGS AND MANAGEMENT

Sumeyye SAİNKAPLAN
İrem ERGİN
Oytun Okan ŞENEL
Dr., 0000-0001-6335-2466, Ankara University, Graduate School Health Sciences, Ankara, Türkiye.
Assoc. Prof. Dr., 0000-0003-2373-5133; Assoc. Prof. Dr., 0000-0002-9008-9437, Ankara University, Veterinary Faculty, Surgery Department, Ankara, Türkiye.

Abstract

The cornea is a specialized ocular surface structure that plays a vital role in vision through its cellular organization and transparency. Maintaining corneal transparency is essential for normal visual function. Direct contact with chemical agents can disrupt corneal epithelial integrity and, depending on exposure severity, cause deeper tissue damage. Alkali agents are particularly harmful due to the destructive effects of hydroxyl ions and their rapid penetration into ocular tissues. By saponifying membrane fatty acids, these agents disrupt cell membrane integrity, potentially leading to cell lysis and tissue necrosis. The extent and severity of injury depend on factors such as pH, concentration, contact duration, and the timing of decontamination. A three-year-old female mixed-breed dog was referred to the Ophthalmology Clinic of Ankara University Faculty of Veterinary Medicine with severe blepharospasm and profuse serous ocular discharge in both eyes. According to the history, an alkaline hand disinfectant had accidentally been applied instead of an ocular antiseptic for eye cleaning, after which the eyes were thoroughly rinsed with water. Ophthalmic examination revealed severe bilateral blepharospasm and epiphora. A topical anesthetic was administered to facilitate examination. Fluorescein staining revealed intense positive staining in both eyes, particularly extending from the central cornea toward the distal regions, accompanied by corneal edema. Treatment included topical netilmicin, acetylcysteine, and cyclopentolate hydrochloride. An Elizabethan collar was also recommended to prevent self-trauma. At the one-week follow-up, fluorescein staining was negative in both eyes, although central corneal scarring was observed. At the two-week follow-up, the scarring persisted, but corneal transparency had improved. This case describes the clinical course and treatment outcome of bilateral chemical corneal injury caused by accidental exposure to an alkaline hand disinfectant, highlighting the potential ocular hazards of inappropriate disinfectant use.

Keywords: Alkali burn, corneal injury, dog.

Introduction

The cornea is a specialized tissue located in the anterior segment of the eye that plays a crucial role in transmitting light to the retina owing to its avascular structure and high optical transparency. Disruption of corneal integrity may lead to the development of various pathological processes that can directly impair visual function (Boyarinov, 2020). Chemical burns of the cornea are among the ophthalmic emergencies that can cause severe damage to the ocular surface and require immediate intervention. These injuries are classified as acid or alkali burns according to the chemical nature of the causative agent. The principal substances responsible for alkali burns include sodium hydroxide, ammonia, calcium hydroxide, and sodium hypochlorite. Alkali burns have been reported to occur more frequently than acid burns among chemical corneal injuries in dogs (Christmas, 1991; Saroyan, 2024).

The destructive effects of alkaline substances on ocular tissues are primarily attributed to the saponification of lipids within cell membranes, resulting in disruption of cellular integrity. Owing to their ability to penetrate ocular tissues rapidly, these substances can traverse the corneal epithelium and reach the underlying stromal layers. Furthermore, hydroxyl ions damage stromal collagen and proteoglycan structures, compromising tissue integrity and facilitating deeper penetration of the chemical agent (Dua, 2020).

The severity of tissue damage associated with alkali-induced corneal burns depends on the concentration, pH, duration of exposure, and quantity of the chemical agent, as well as its depth of penetration into the cornea. In severe cases, damage may extend beyond the corneal epithelium and stroma to involve the limbus and other structures of the anterior segment. In particular, damage to limbal stem cells can impair corneal epithelial regeneration, leading to persistent epithelial defects, conjunctivalization, corneal neovascularization, and fibrosis. These pathological changes may result in loss of corneal transparency and, in advanced cases, severe visual impairment. Early diagnosis and appropriate therapeutic intervention are therefore essential for preserving corneal tissue integrity and maintaining visual function following alkali-induced corneal burns (Busse, 2015; Boyarinov, 2020).

Alkali-induced corneal burns in dogs represent a significant clinical concern in veterinary ophthalmology due to their potential to cause rapidly progressive tissue damage and long-term ocular complications. This case report highlights the importance of appropriate therapeutic management and follow-up in cases of corneal alkali burns, demonstrating that successful restoration of ocular integrity and visual function can be achieved despite the potential for severe ocular complications.

Case Presentation

A three-year-old female mixed-breed dog was presented to the Ophthalmology Clinic of Ankara University Faculty of Veterinary Medicine Animal Hospital with severe bilateral blepharospasm and profuse serous ocular discharge. A detailed history obtained from the owner revealed that a hand disinfectant, reportedly alkaline in nature, had been inadvertently applied directly to both eyes instead of the ophthalmic antiseptic intended for cleaning the periocular region and ocular surface. Following exposure to the chemical agent, the dog developed marked signs of ocular irritation and discomfort, prompting the owner to immediately irrigate both eyes with copious amounts of water.

On ophthalmic examination, marked bilateral blepharospasm, profuse epiphora, and clinical signs consistent with ocular surface irritation were initially observed (Figure 1).

Figure 1. Severe bilateral blepharospasm.

To facilitate a thorough and comfortable examination of the cornea and alleviate blepharospasm, a topical anesthetic eye drop (Alcaine 0.5%, Alcon, USA) was initially administered to both eyes. Subsequently, fluorescein staining was performed to assess the extent of corneal damage. Both eyes exhibited extensive fluorescein-positive areas involving a large portion of the corneal surface, extending from the central cornea toward the peripheral regions (Figure 2). In addition, corneal edema was observed, particularly in the peripheral corneal regions.

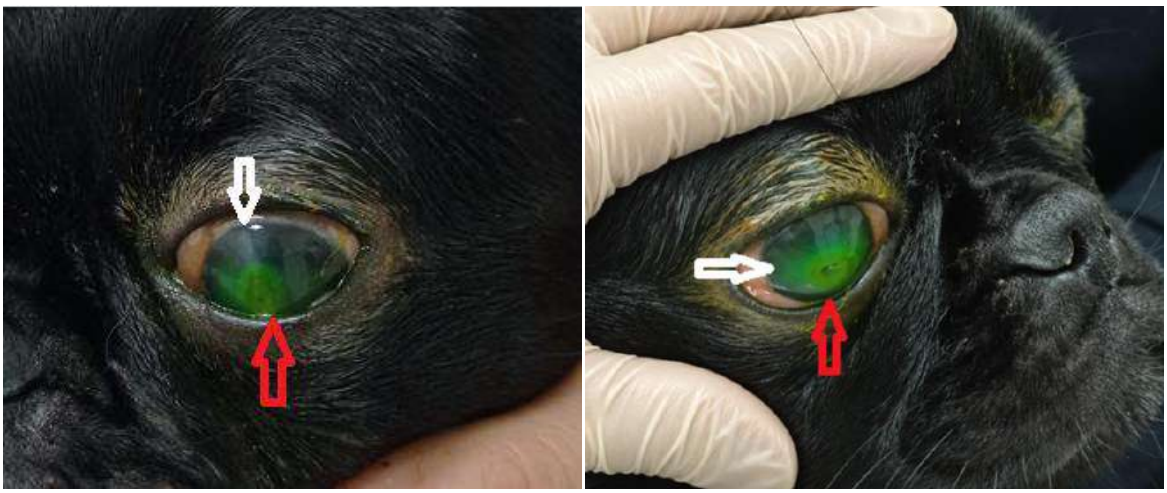


Figure 2. Fluorescein-positive staining (red arrows) and corneal edema (white arrows) in the left eye (left image) and right eye (right image).

Following the ophthalmic examination, the use of an Elizabethan collar was initially recommended to prevent self-inflicted ocular trauma from scratching. For topical antibiotic therapy, netilmicin ophthalmic drops (Netira 0.3%, SIFI, Italy) were prescribed three times daily. In addition, acetylcysteine ophthalmic drops were initiated three times daily to support corneal healing and limit collagen degradation associated with the extensive corneal damage. For pain management, cyclopentolate HCl ophthalmic drops (Siklopleji̇n 1%, Abdi İbrahim, Türkiye) were prescribed once daily for two days. To maintain corneal surface lubrication, a hyaluronic acid-based ocular lubricant (Dryex 0.15%, Abdi İbrahim, Türkiye) was recommended three times daily.

At the one-week follow-up examination, both corneas were negative for fluorescein staining, and a marked reduction in corneal edema was observed. However, central corneal opacity was noted, consistent with the history of extensive corneal injury (Figure 3). At the end of the first week, netilmicin ophthalmic drops were discontinued, while acetylcysteine and hyaluronic acid ophthalmic drops were continued twice and three times daily, respectively. At the two-week follow-up examination, a further improvement in corneal transparency was observed, accompanied by a reduction in central corneal opacity (Figure 4).

Figure 3. Ophthalmic appearance at the one-week follow-up examination following treatment, showing central corneal opacity (red arrow).

Figure 4. Ophthalmic appearance at the two-week follow-up examination following treatment, demonstrating a marked improvement in corneal transparency.

Discussion and Conclusion

Alkali-induced chemical injuries of the cornea are considered significant ophthalmic emergencies in veterinary medicine due to their potential to cause rapidly progressive epithelial and stromal damage and, in severe cases, permanent vision loss (Boyarinov, 2020). Previous studies evaluating chemical corneal burns have reported that alkali-induced injuries are more frequently encountered in dogs and are associated with clinical manifestations such as blepharospasm, loss of corneal epithelial integrity, corneal ulceration, neovascularization, stromal opacity, and corneal edema (Christmas, 1991; Busse, 2015).

The destructive effects of alkaline substances on the cornea are associated with disruption of the corneal epithelial barrier and subsequent penetration of the chemical agent into the stromal tissue. The inflammatory response and increased proteolytic enzyme activity following injury may lead to degradation of the corneal extracellular matrix and loss of stromal collagen. Consequently, it has been reported that corneal healing following chemical ocular injuries is influenced not only by the initial tissue damage caused by the chemical agent but also by subsequent inflammatory and proteolytic processes (Dua, 2020). Therefore, therapeutic management should focus not only on restoring epithelial integrity but also on preserving stromal tissue and

preventing secondary complications. In the present case, acetylcysteine ophthalmic drops were incorporated into the treatment protocol to utilize their anticollagenase properties due to the presence of extensive corneal epithelial defects (Yogo, 2026). The ability of acetylcysteine to inhibit the activity of proteolytic enzymes involved in corneal collagen degradation provides the rationale for its use as an adjunctive treatment in cases of corneal ulceration.

Disruption of the corneal epithelial barrier following chemical injury may increase the susceptibility of corneal tissue to secondary bacterial infections. Therefore, topical antimicrobial therapy is frequently employed in cases of corneal ulceration to prevent infectious complications (Bircan Akkartal, 2020). In the present case, topical netilmicin was administered to minimize the risk of secondary bacterial infection until corneal epithelial integrity was restored. Additionally, a short course of cyclopentolate HCl was used to alleviate ocular discomfort and pain associated with chemical injury, while a hyaluronic acid-based ocular lubricant was incorporated into the treatment protocol to maintain ocular surface hydration. The ability of hyaluronic acid to enhance ocular surface lubrication and contribute to tear film stability supports its use as an adjunctive therapy during corneal epithelial healing. Accordingly, the multimodal medical treatment protocol was designed to protect the corneal surface, minimize potential complications, and provide a favorable ocular environment for tissue healing.

Fluorescein staining is an important diagnostic method for evaluating corneal wound healing, particularly for identifying the presence and persistence of epithelial defects. In the present case, negative fluorescein staining in both eyes at the one-week follow-up examination indicated complete closure of the extensive epithelial defects observed at initial presentation. The marked reduction in corneal edema observed during the same examination was considered a favorable clinical finding, indicating progressive restoration of corneal transparency. Busse et al. (2015) reported that corneal surface healing following alkali-induced injuries may take several weeks and that long-term complications, including corneal edema, vascularization, and fibrosis, may develop in some cases. In this context, the achievement of negative fluorescein staining by the end of the first week, despite the initially extensive bilateral epithelial damage, represents a noteworthy clinical outcome in terms of early corneal re-epithelialization.

Despite the restoration of corneal epithelial integrity, stromal damage and the subsequent healing response may result in corneal opacity and scar formation. In chemical ocular injuries, activation of stromal keratocytes, remodeling of the extracellular matrix, and alterations in collagen organization may lead to a temporary or permanent reduction in corneal transparency. Dua et al. (2020) emphasized that corneal fibrosis and opacity are among the major factors influencing long-term visual prognosis following chemical ocular injuries. In the present case, although corneal epithelial integrity had been restored at the one-week follow-up examination, central corneal opacity was still evident. However, the continued improvement in corneal transparency and reduction in central opacity observed at the two-week follow-up examination suggest that the healing process was not limited to epithelial regeneration but also involved favorable changes within the corneal stroma.

Busse et al. (2015) reported that long-term complications following alkali-induced ocular injuries may include corneal fibrosis, conjunctivalization, neovascularization, and persistent corneal edema. Nevertheless, they also demonstrated that corneal transparency may gradually be restored over time, with favorable visual outcomes achieved in some cases despite marked corneal alterations at initial presentation. In the present case, the reduction in central corneal opacity and progressive improvement in corneal transparency observed at the two-week follow-up examination are consistent with the potential for corneal recovery described in their study.

The prognosis of chemical ocular injuries is influenced by several factors, including the properties of the chemical agent, duration of exposure, extent of initial tissue damage, and nature of the immediate intervention. Previous studies have emphasized that prompt and thorough ocular irrigation is essential for removing the chemical agent and limiting ongoing tissue damage (Dua, 2020). In the present case, irrigation of both eyes

with copious amounts of water by the owner immediately following chemical exposure was considered a potential contributing factor in limiting the severity of tissue damage.

In conclusion, this case report demonstrates that extensive bilateral corneal epithelial damage resulting from the accidental application of a disinfectant reportedly alkaline in nature to the ocular surface showed marked clinical improvement within a relatively short period following medical treatment. Negative fluorescein staining in both eyes and a reduction in corneal edema at the end of the first week, followed by improved corneal transparency and decreased central corneal opacity at the end of the second week, support a favorable early therapeutic response. These findings highlight the importance of timely intervention, supportive medical therapy aimed at preserving the corneal surface, and regular ophthalmic follow-up in the management of chemical corneal injuries.

References

Bircan Akkartal, M., & Haydardedeoğlu, A. E. (2020). A case of chemical/alkali burn in the eye of a dog. *Journal of Istanbul Veterinary Sciences*, 61–61. https://dergipark.org.tr/en/pub/http-www-jivs-net/article/687696

Boyarinov, S. A. (2020). *Atlas of corneal diseases in dogs and cats*. Ophthalmology Publishing House.

Busse, C., Hartley, C., Kafarnik, C., & Pivetta, M. (2015). Ocular alkaline injury in four dogs – Presentation, treatment, and follow-up – A case series. *Veterinary Ophthalmology, 18*(2), 127–134. https://doi.org/10.1111/vop.12171

Christmas, R. (1991). Management of chemical burns of the canine cornea. *Canadian Veterinary Journal, 32*(10), 608–612. https://pmc.ncbi.nlm.nih.gov/articles/PMC1481081/

Dua, H. S., Ting, D. S. J., Al Saadi, A., & Said, D. G. (2020). Chemical eye injury: Pathophysiology, assessment and management. *Eye, 34*(11), 2001–2019. https://doi.org/10.1038/s41433-020-1026-6

Saroyan, S., Goncharova, A., & Shtaufen, A. (2024). Differential diagnostic criteria for chemical corneal burn in dogs and cats and methods of their treatment. *E3S Web of Conferences, 510*, Article 01035. https://doi.org/10.1051/e3sconf/202451001035

Yogo, T. (2026). Anticollagenase therapy for canine corneal ulcers: A narrative review of mechanisms, efficacy, and clinical implementation. *Veterinary Ophthalmology, 29*(2), Article e70154. https://doi.org/10.1111/vop.70154

PERIOCULAR MALIGNANT FIBROUS HISTIOCYTOMA IN A CAT: SURGICAL APPROACH AND CLINICAL FOLLOW-UP

Batuhan Umut ÇAKIL
İrem ERGİN
PhD., 0009-0004-0633-5458, Ankara University, Graduate School Health Sciences, Ankara, Türkiye.
Assoc. Prof. Dr., 0000-0003-2373-5133, Ankara University, Veterinary Faculty, Surgery Department, Ankara, Türkiye.

Abstract

Ocular and periocular tumors in cats may be benign or malignant and compromise ocular function and surrounding tissues. Treatment planning depends on lesion location, extent, and histopathological characteristics. A four-year-old, 4-kg, neutered male mixed-breed cat was presented to the Ophthalmology Clinic of Ankara University Faculty of Veterinary Medicine Animal Hospital with a rapidly growing, hemorrhagic, painful mass near the left medial canthus, developing over one month. Ophthalmic examination identified a mass originating from the left lower eyelid conjunctiva, extending over the cornea to the medial canthus. Computed tomography revealed a heterogeneously contrast-enhancing, trilobulated mass measuring approximately 40 × 30 × 33 mm, extending from the left orbitonasal region into the maxillofacial area. The mass contacted the globe without apparent invasion. Thoracic imaging showed no findings suspicious for metastasis. The mass was excised en bloc with surrounding skin, including the medial canthus and part of the lower eyelid, followed by primary closure. Histopathological examination revealed ulcerated, moderately differentiated malignant fibrous histiocytoma of the storiform type, with neoplastic areas within dermal collagen extending to the surgical margin. Postoperative medical treatment was administered. Initial follow-up examinations confirmed preserved vision without significant corneal irritation or ectropion. At six months, two rapidly growing, hemorrhagic masses appeared at the same site and were considered local recurrence. At seven months, following the onset of dyspnea, thoracic radiographs revealed areas suspicious for metastasis. Before further investigations, euthanasia was elected based on the cat's clinical condition and owner consent. This case highlights the potential for local recurrence of periocular malignant fibrous histiocytoma after surgical excision in cats and emphasizes the importance of histopathological assessment of surgical margins and long-term follow-up.

Keywords: Cat, malignant fibrous histiocytoma, periocular tumor.

Introduction

Although eyelid and periocular tumors are less frequently encountered in cats than in dogs, they are of considerable clinical importance because of their tendency to exhibit malignant behavior. The most commonly reported neoplasms in this region include squamous cell carcinoma, mast cell tumor, hemangiosarcoma, adenocarcinoma, lymphoma, and peripheral nerve sheath tumors (Newkirk & Rohrbach, 2009). Depending on their anatomical location, size, and biological behavior, periocular tumors may cause complications such as impaired eyelid function, involvement of the ocular surface, and extension into surrounding tissues. In particular, in tumors with malignant features and infiltrative growth patterns, balancing the preservation of ocular structures against the achievement of adequate surgical margins complicates treatment planning (Hoffman et al., 2005; Foster et al., 2025).

Malignant mesenchymal tumors of the periocular region in cats have been described in a relatively limited number of case reports and case series. Peripheral nerve sheath tumors and fibrosarcomas within this group

may be characterized by locally infiltrative growth and recurrence following surgical excision. In a study evaluating periocular peripheral nerve sheath tumors, repeated recurrences were reported in cases managed with limited local treatment, whereas wide surgical excision was suggested to provide more effective local control (Hoffman et al., 2005). Similarly, in a cat diagnosed with periocular fibrosarcoma, rapid tumor growth was observed following surgical debulking, and local recurrence was reported despite orbital exenteration (Foster et al., 2025). Malignant fibrous histiocytoma is another malignant mesenchymal tumor that may exhibit pleomorphic and spindle-cell features histopathologically and requires careful consideration in the differential diagnosis. Therefore, histopathological examination is essential for diagnosing such periocular masses, while assessment of the tumor's anatomical extent is important for surgical planning.

This presentation aims to describe the clinical characteristics, diagnostic evaluation, and surgical management of periocular malignant mesenchymal tumors in cats. It also discusses the potential outcomes of globe-preserving surgical approaches, the risk of local recurrence, and the importance of long-term follow-up.

Case Presentation

A four-year-old, 4-kg, neutered male mixed-breed cat (*Felis catus*) was presented to the Ophthalmology Clinic of Ankara University Animal Hospital with a rapidly enlarging mass in the medial canthal region of the left eye. According to the medical history, the mass had first been noticed approximately one month earlier and had progressively increased in size since then.

Ophthalmic examination revealed a mass extending from the left lower eyelid toward the medial canthus and partially covering the cornea, with the overlying skin remaining intact (Figure 1). The mass was found to be fixed and painful on palpation. No obvious enlargement of the regional lymph nodes was detected.

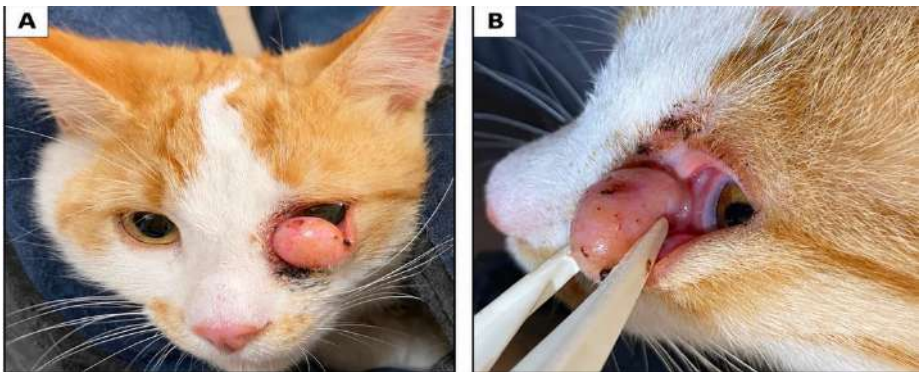


Figure 1. Gross appearance of the mass in the left periocular region at the initial clinical examination. (**A**) Frontal view showing the mass involving the left medial canthus and lower eyelid and partially covering the cornea. (**B**) Lateral view illustrating the smooth surface of the mass and its anatomical relationship with the medial canthus and lower eyelid.

Computed tomography (CT) was performed to assess the anatomical extent of the mass and its relationship with the globe and surrounding tissues. The examination revealed a mass located in the left orbitonasal region, extending toward the maxillofacial area, measuring approximately 40 × 30 × 33 mm, with lobulated margins and heterogeneous soft-tissue attenuation (Figure 2). On transverse images, the mass exhibited prominent outward growth and was observed to be in close proximity to the globe. No evidence of overt globe invasion was identified on imaging. Thoracic imaging revealed no findings suggestive of metastasis. Based on the clinical and imaging findings, surgical excision of the mass was planned with preservation of the globe.

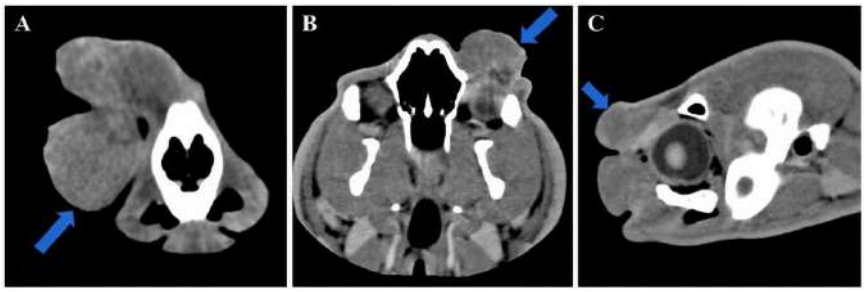


Figure 2. Preoperative computed tomography images of the mass located in the left periocular region. (**A**) Transverse image showing a lobulated mass located in the left orbitonasal region, with prominent outward growth. (**B**) Coronal reconstruction illustrating the location of the mass in the medial periocular region and its relationship with the surrounding anatomical structures. (**C**) Transverse image showing the close proximity of the mass to the globe and its outward extension..

Based on the clinical and computed tomography findings, surgical excision of the mass was elected. Under general anesthesia, the mass was removed en bloc along with the surrounding tissues, including the medial canthus and a portion of the left lower eyelid. Following excision, the resulting tissue defect in the medial canthal and lower eyelid regions was assessed, and the globe was found to be preserved (Figure 3A). The defect was primarily closed by approximating the surrounding tissues, thereby restoring the anatomical integrity of the eyelid (Figure 3B). No intraoperative complications were encountered. The excised mass was submitted for histopathological examination.

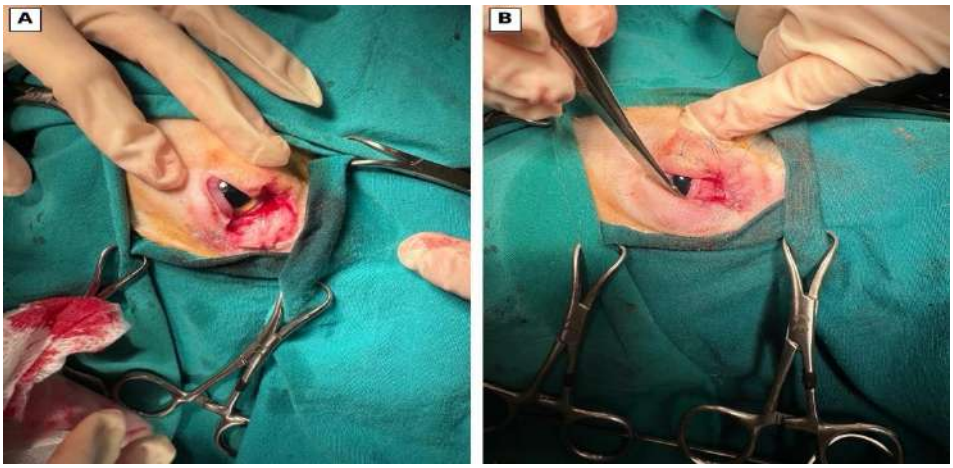


Figure 3. Intraoperative images showing surgical excision of the periocular mass and eyelid reconstruction. (**A**) Tissue defect in the medial canthal and lower eyelid regions following en bloc excision of the mass, with preservation of the globe. (**B)** Primary closure of the surgical defect by approximation of the surrounding tissues and suturing.

The surgically excised mass was submitted for histopathological examination. Hematoxylin and eosin (H&E)-stained sections revealed a dense neoplastic proliferation associated with the dermal connective tissue and composed of cells with oval to spindle-shaped morphology. The neoplastic cells were arranged in intersecting bundles and whorled patterns in some areas, extending in different directions within a collagenous stroma (Figure 4). In some sections, the neoplastic tissue was observed in close proximity to striated muscle fibers, with an accompanying inflammatory cell infiltrate in the neoplastic areas (Figures 4D–E). Based on the histopathological findings, the mass was diagnosed as a moderately differentiated malignant fibrous

histiocytoma (storiform type). The pathology report also indicated that, in some areas, the surgical margins were continuous with dermal collagenous tissue containing neoplastic foci.

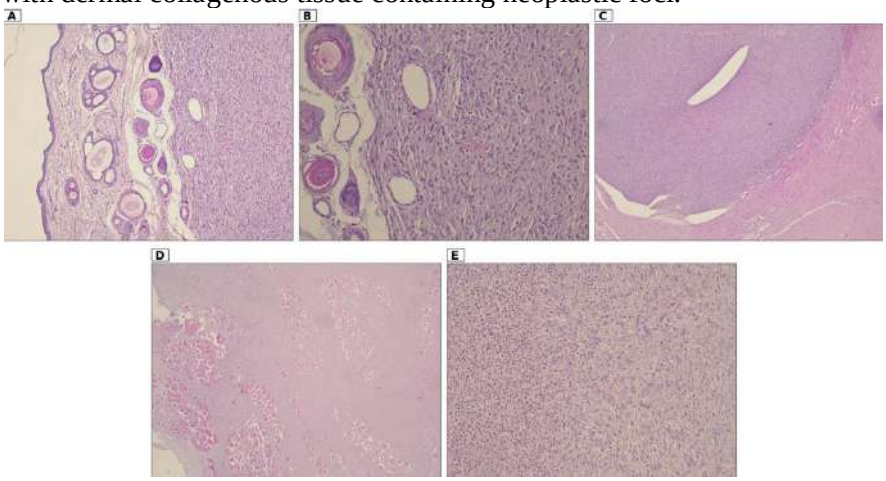


Figure 4. Histopathological appearance of periocular malignant fibrous histiocytoma. (A) Relationship between the skin tissue and the neoplastic proliferation (H&E, ×10). (B) Neoplastic proliferation composed of spindle-shaped and oval cells within the dermal collagenous stroma (H&E, ×20). (C) Overall appearance of the neoplastic focus, showing focal arrangement of the cells in bundles (H&E, ×4). (D) Relationship between the neoplastic tissue and striated muscle fibers (H&E, ×4). (E) Inflammatory cell infiltration accompanying the neoplastic tissue (H&E, ×20).

During the postoperative period, amoxicillin–clavulanic acid, meloxicam, and famotidine were administered systemically for one week. Topical treatment consisted of eye drops containing netilmicin and sodium hyaluronate during the first week, while sodium hyaluronate administration was continued for an additional two weeks. The sutures were removed on postoperative day 10. At the first-week follow-up examination, mild notching was observed in the central portion of the lower eyelid; however, no apparent ectropion had developed, and eyelid closure function remained intact. At the one-month postoperative examination, healing of the surgical site was largely complete, the anatomical integrity of the globe was preserved, and no apparent functional impairment was observed despite mild irregularity of the lower eyelid (Figure 5).

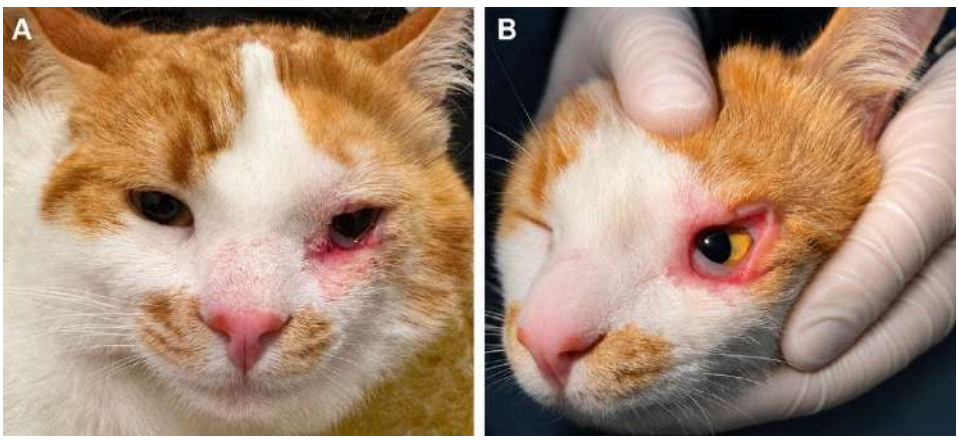


Figure 5. Clinical appearance of the cat at the one-month postoperative follow-up examination. (A) Frontal view showing healing of the surgical site, preservation of the left globe, and mild anatomical irregularity of the lower eyelid. (B) Lateral view showing the postoperative appearance of the medial canthus and lower eyelid, with preservation of the anatomical integrity of the globe.

During the postoperative period, the patient was monitored through monthly follow-up examinations. At the six-month evaluation, two distinct nodular masses were identified in the left periocular region, located dorsal and ventral to the medial canthus (Figure 6). The masses were pink, markedly protruding, and had irregular surfaces with areas of ulceration and crusting. Given their development in the same anatomical region as the primary tumor and their similar clinical appearance, local recurrence was suspected. However, recurrence could not be histopathologically confirmed because no repeat biopsy was performed. Thoracic radiographs revealed findings raising suspicion of metastatic spread; however, further imaging studies and histopathological confirmation could not be obtained. In view of the development of respiratory distress and deterioration in the patient's general clinical condition, euthanasia was performed with the owner's consent.

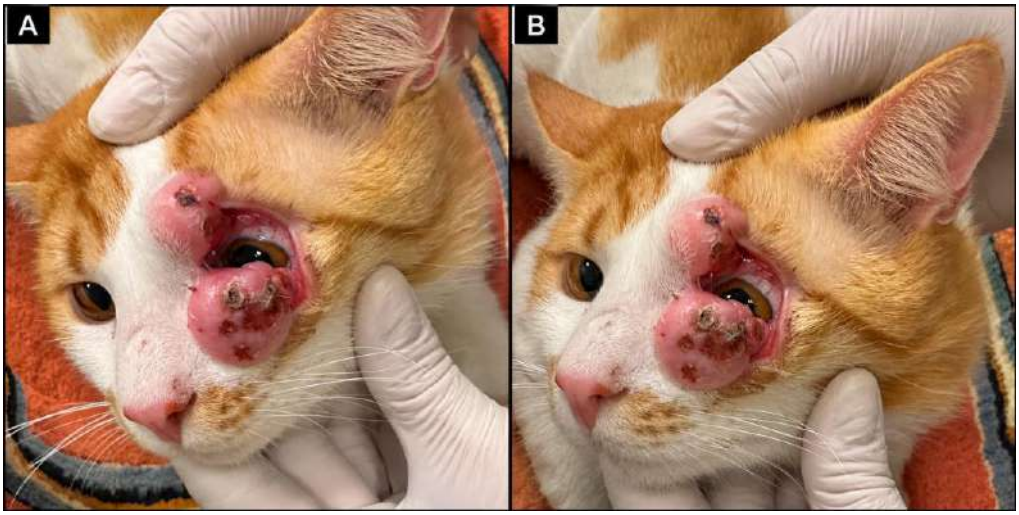


Figure 6. Clinical appearance of the periocular lesions raising suspicion of local recurrence at the six-month postoperative follow-up examination. (A) Two distinct nodular masses showing outward growth and located dorsal and ventral to the medial canthus of the left eye. (B) View from a different angle, showing ulcerated and crusted areas on the surfaces of the masses and their close anatomical relationship with the globe.

Discussion

Periocular tumors in cats are of clinical importance because of their tendency to exhibit malignant behavior and the surgical challenges associated with their anatomical location. In a retrospective study of 43 cats, Newkirk and Rohrbach (2009) reported that the majority of eyelid tumors were malignant or potentially malignant, with squamous cell carcinoma, mast cell tumor, and hemangiosarcoma being the most frequently encountered neoplasms. The mean age of cats diagnosed with tumors in that study was 10.4 years, whereas the tumor in the present case was identified in a four-year-old cat, which is noteworthy. Nevertheless, malignant mesenchymal tumors arising in the periocular region of cats have been reported in only a limited number of case reports and case series, and information regarding the clinical behavior of malignant fibrous histiocytoma at this anatomical site remains scarce. In this respect, the present case contributes to the literature by describing the clinical and histopathological features of periocular malignant fibrous histiocytoma in a young cat.

Assessment of the anatomical extent of periocular tumors and their relationship with the globe and surrounding tissues is of major importance in surgical management. Infiltrative tumors arising in this region may compromise the preservation of eyelid function and make it difficult to achieve adequate surgical margins. Foster et al. (2025) reported orbital exenteration in a cat diagnosed with periocular fibrosarcoma because of rapid tumor growth and regrowth following the initial surgical intervention. In the present case, computed

tomography revealed a mass measuring approximately 40 × 30 × 33 mm, extending from the left orbitonasal region toward the maxillofacial area. Despite its close proximity to the globe, no evidence of overt invasion was identified. This imaging finding was a key factor in planning surgical excision with globe preservation. Indeed, following en bloc excision of the mass along with the surrounding tissues, the surgical defect was closed primarily, and eyelid closure function was maintained during the early postoperative period.

Malignant fibrous histiocytoma (MFH) is among the malignant mesenchymal tumors that are challenging to classify histopathologically because of their marked cellular pleomorphism and diverse morphological patterns. Immunohistochemical studies in cats have demonstrated that some tumors previously classified as MFH may share immunophenotypic features with other mesenchymal neoplasms, making it difficult to establish their precise cellular origin based solely on morphological evaluation (Pace et al., 1994). In more recent veterinary pathology literature, some of these tumors have been classified within the framework of pleomorphic sarcoma terminology (de Cecco et al., 2021).

In the present case, histopathological examination led to a diagnosis of moderately differentiated malignant fibrous histiocytoma (storiform type). Nevertheless, fibrosarcoma, peripheral nerve sheath tumors, and other pleomorphic mesenchymal neoplasms should also be considered in the differential diagnosis. In such cases, immunohistochemical analyses may help support the morphological findings and facilitate differential diagnosis.

One of the major challenges in the treatment of periocular malignant mesenchymal tumors is achieving a balance between adequate surgical excision and preservation of ocular structures. Hoffman et al. (2005) reported repeated recurrences following limited local treatments in six cats with periocular peripheral nerve sheath tumors, whereas local control could be achieved in some cases following wide surgical excision. Similarly, Foster et al. (2025) described rapid tumor regrowth following surgical debulking and subsequent local recurrence after orbital exenteration in a cat with periocular fibrosarcoma.

In the present case, the mass was excised en bloc, including the medial canthus and a portion of the lower eyelid, and the globe and eyelid closure function were preserved during the early postoperative period. Histopathological examination indicated that, in some areas, the surgical margins were continuous with dermal collagenous tissue containing neoplastic foci. Although this finding raises the possibility of neoplastic tissue being present near the resection margins, it could not be conclusively determined whether tumor cells actually extended to the true surgical margins. The development of two distinct masses at the surgical site six months postoperatively raises the possibility that residual neoplastic tissue may have contributed to local recurrence. However, this relationship could not be established conclusively because the newly developed lesions were not histopathologically examined. These findings highlight the importance of surgical margin assessment and long-term postoperative follow-up in periocular malignant mesenchymal tumors.

The absence of repeat biopsy of the lesions identified at the six-month postoperative examination limits the possibility of histopathological confirmation of local recurrence. Nevertheless, their development in the same anatomical region as the primary tumor and their similar clinical appearance support the possibility of local recurrence. Although no findings suggestive of metastasis were detected on thoracic imaging at the initial evaluation, suspicious areas were identified on radiographic examinations performed during the follow-up period. However, metastatic spread could not be definitively established because further imaging and histopathological confirmation were not obtained. In view of the respiratory distress and deterioration in the patient's general clinical condition that developed later, euthanasia was performed with the owner's consent.

This case demonstrates that, although anatomical and functional integrity may be preserved during the early postoperative period following surgical excision of periocular malignant mesenchymal tumors, long-term oncological control may not necessarily be achieved. Therefore, histopathological assessment of surgical

margins, regular local examinations, and systemic screening for metastasis are considered important components of long-term follow-up in such cases.

Conclusion

This case demonstrates that periocular malignant fibrous histiocytoma in cats can be excised while preserving the globe, despite its close anatomical relationship with the eye, through appropriate surgical planning. Preoperative computed tomography played an important role in determining the surgical approach by allowing assessment of the anatomical extent of the mass and its relationship with the surrounding tissues. Although eyelid closure function was preserved during the early postoperative period following surgical excision, the development of lesions raising suspicion of local recurrence at six months postoperatively highlights the potential difficulty of achieving long-term local control in these tumors. The inability to determine the surgical margin status definitively on histopathological examination limited the assessment of the possible role of residual neoplastic tissue in the development of recurrence. In conclusion, preoperative imaging, appropriate surgical excision, histopathological assessment of surgical margins, and regular postoperative oncological follow-up are important in the management of periocular malignant mesenchymal tumors in cats, both for preserving ocular function and for evaluating long-term tumor control.

References

Foster, T. M., Newbold, G. M., Miller, E. J., Jeong, Y. J., Premanandan, C., & Husbands, B. D. (2025). Periocular fibrosarcoma with lipogranulomatous conjunctivitis in a cat. *Veterinary Ophthalmology, 28*(3), 646–650. https://doi.org/10.1111/vop.13249

Hoffman, A., Blocker, T., Dubielzig, R., & Ehrhart, E. J. (2005). Feline periocular peripheral nerve sheath tumor: A case series. *Veterinary Ophthalmology, 8*(3), 153–158. https://doi.org/10.1111/j.1463-5224.2005.00341.x

Newkirk, K. M., & Rohrbach, B. W. (2009). A retrospective study of eyelid tumors from 43 cats. *Veterinary Pathology, 46*(5), 916–927. https://doi.org/10.1354/vp.08-VP-0205-N-FL

de Cecco, B. S., Argenta, F. F., Bianchi, R. M., De Lorenzo, C., Wronski, J. G., Bandinelli, M. B., da Costa, F. V. A., Driemeier, D., Pavarini, S. P., & Sonne, L. (2021). Feline giant-cell pleomorphic sarcoma: Cytologic, histologic and immunohistochemical characterization. *Journal of Feline Medicine and Surgery, 23*(8), 738–744. https://doi.org/10.1177/1098612X20972667

Pace, L. W., Kreeger, J. M., Miller, M. A., Turk, J. R., & Fischer, J. R. (1994). Immunohistochemical staining of feline malignant fibrous histiocytomas. *Veterinary Pathology, 31*(2), 168–172. https://doi.org/10.1177/030098589403100202

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

IDENTIFYING JOB SATISFACTION AND JOB-RELATED EMOTIONAL EXHAUSTION PROFILES AMONG HEALTHCARE WORKERS: A LATENT PROFILE ANALYSIS

Hafize Boyacı
Selma Söyük
Dr. Hafize Boyacı, Istanbul University-Cerrahpasa, Cerrahpasa Medical Faculty, Fikret Biyal Central Laboratory, İstanbul, Türkiye. ORCID: https://orcid.org/0000-0003-2362-7845.
Prof. Dr. Selma Söyük, Department of Health Management, Faculty of Health Sciences, Istanbul University-Cerrahpasa, Istanbul, Türkiye. ORCID: https://orcid.org/0000-0001-9822-9417.

Abstract

This study aimed to identify the latent profiles that healthcare workers form according to their levels of job satisfaction and job-related emotional exhaustion, and to describe the characteristics of these profiles. Examining the relationship between these variables through their means cannot account for subgroup differences within the sample; latent profile analysis (LPA) was therefore used to identify the distinct employee profiles and risk groups that mean values cannot detect.

This quantitative study used a cross-sectional survey design. Data were collected through convenience sampling from 264 healthcare workers at a private hospital in Istanbul, using the Job-Related Emotional Exhaustion Scale and the Job Satisfaction Scale. One- to five-profile solutions were compared on information criteria (AIC, BIC, sample-size adjusted BIC), classification precision (entropy), profile sizes and theoretical interpretability. Analyses were performed with IBM SPSS 31 and Mplus.

Cronbach's alpha was .865 for the Job Satisfaction Scale and .886 for the Job-Related Emotional Exhaustion Scale. Job satisfaction and job-related emotional exhaustion were strongly and negatively correlated ($r = -.640$, $p < .001$). A three-profile solution was accepted (entropy = .712): Exhausted (at-risk) workers (n = 65; 24.6%; job satisfaction M = 2.43, exhaustion M = 4.28), Moderate workers (n = 134; 50.8%; M = 3.54 and 3.22) and Positive workers (n = 65; 24.6%; M = 4.23 and 2.00).

Healthcare workers exhibit three distinct profiles in terms of job satisfaction and emotional exhaustion. A quarter of the sample falls into the at-risk profile of low satisfaction and high exhaustion, while half falls into the moderate profile, a transitional zone between the two extremes and the priority target for preventive interventions. In combating job-related emotional exhaustion in healthcare institutions, an approach based on regular monitoring and profile-based intervention planning would be more appropriate.

Keywords: job-related emotional exhaustion, job satisfaction, latent profile analysis, healthcare workers.

1. Introduction

The healthcare sector differs from other service sectors in certain respects. In the delivery of healthcare services, employees are expected to perform at a level that involves a high degree of emotional labour and requires them to make error-free, unhesitating and urgent decisions. Irregular working conditions, working hours, shift work, intensive interaction with patients and their relatives, and the risk associated with the losses experienced and the responsibilities undertaken place healthcare workers in a distinctive position. In this respect, the burnout experienced by healthcare workers is one of the foremost topics addressed in the literature. Beyond being an individual health problem, burnout is a problem of service quality and patient safety. For healthcare institutions, it materialises in the form of turnover, absenteeism and re-employment costs (West et al., 2018).

Freudenberger (1974) described burnout as a decline in energy and motivation that emerges over time among employees who are intensely committed to their work, and also defined it as the development of distance towards the people they serve. The conceptualisation of burnout was achieved through the work of Maslach and Jackson (1981).

According to the Maslach model, burnout is described as a psychological response to chronic job stress with three dimensions: emotional exhaustion, depersonalisation and reduced personal accomplishment. Burnout is described not as a single state of fatigue but as a syndrome consisting of separable components (Maslach et al., 2001). Emotional exhaustion, the dimension within the scope of our study, refers to a state in which the individual's emotional resources are depleted and the individual feels extremely tired.

One of the most widely used frameworks explaining the emergence of burnout is the Job Demands–Resources (JD-R) Model (Demerouti et al., 2001). The model proposes that high job demands and insufficient job resources trigger a health-impairment process that leads to burnout. This approach treats burnout as a consequence of working conditions rather than as a personal characteristic.

Another of the most frequently studied topics in the field of organisational behaviour is job satisfaction. According to Locke's (1976) definition, job satisfaction is "a pleasurable or positive emotional state resulting from the appraisal of one's job or job experiences". This definition comprises an appraisal and the emotional reaction that accompanies this appraisal. In fact, job satisfaction is not merely an emotional state but rather the individual's attitude towards his or her job.

Burnout and job satisfaction are conceptually distinct. Whereas burnout is a wear-out response to ongoing job stress, job satisfaction is an attitude reflecting the individual's evaluation of his or her job (Demerouti et al., 2001; Schaufeli & Taris, 2014). Nevertheless, the two variables are strongly related. The reason for this is that insufficient job resources increase burnout and, at the same time, reduce job satisfaction (Demerouti et al., 2001; Faragher et al., 2005).

Studies examining the relationship between burnout and job satisfaction generally use the means of the variables and examine their relationships through analyses such as correlation and regression, proceeding from the assumption that the relationship affects the entire sample in the same way (Meyer & Morin, 2016). However, when differences between subgroups of the sample are of interest, a single correlation coefficient ignores this heterogeneity. In this case, it becomes difficult to distinguish a group that loves its work but is exhausted from a group that is both dissatisfied and exhausted. Morin et al. (2018) state that ignoring the distinction between different subgroups, which is needed to develop different management strategies for them, reduces the impact of the theoretical and practical implications that can be drawn. For this reason, an individual-level approach focuses on how the variables are specifically configured rather than questioning the relationship as a general judgement (Spurk et al., 2020). One of the analyses used in research to reveal the relationship between the profiles of sample subgroups and the variables is Latent Profile Analysis (LPA). LPA is a person-centred statistical method that divides individuals in a population into heterogeneous subgroups or profiles on the basis of continuous observed variables.

In recent years, LPA has been used very frequently in research with healthcare workers. Levels of burnout and job satisfaction among healthcare workers show individual differences. In this study, LPA was preferred because it reveals different employee profiles by dividing employees into groups with similar characteristics. Thus, the aim was to identify the different employee profiles and risk groups that lie behind the mean values.

In this study examining the job satisfaction and burnout of healthcare workers, the reliability and validity properties of the measurement instruments used were first established; then, the latent profiles formed by healthcare workers in terms of job satisfaction and burnout were identified with LPA and the characteristics of the profiles were examined. Accordingly, the study seeks to answer the question: "How many latent profiles do healthcare workers form in terms of their levels of job satisfaction and burnout, and what are the characteristics of these profiles?"

2. Method

2.1. Population and Sample

A quantitative research method was used in the study. The study was planned with a cross-sectional survey design. The study was conducted at a private hospital in Istanbul. Data were collected online using the

questionnaire method. Without selecting a sample, the aim was to reach all employees. Using convenience sampling, 268 questionnaire forms were collected. After excluding 4 incomplete questionnaires, the study was conducted with 264 healthcare workers (n = 264).

2.2. Data Collection Instruments

Personal Information Form. This form, prepared by the researcher, includes participants' gender, educational status and occupation.

Job-Related Emotional Exhaustion Scale: The Job-Related Emotional Exhaustion Scale was used to determine the level of job-related emotional exhaustion. The original scale, adapted into Turkish by Günay (2021), was developed by Wharton (1993), drawing on Maslach's approach to burnout. The internal consistency coefficient of the unidimensional 6-item scale obtained in this study is $\alpha = .886$. The scale is rated on a 5-point Likert-type scale; responses range from 1 = "I never feel this way at work" to 5 = "I feel this way every day". The scale contains 6 statements.

Job Satisfaction Scale (JSS): The short form of the Job Satisfaction Scale was used; the scale was developed by Brayfield and Rothe (1951), its 5-item short form was created by Judge et al. (1998), and its adaptation into Turkish was carried out by Keser and Öngen Bilir (2019). The scale consists of 5 statements rated on a 5-point Likert-type scale ranging from Strongly disagree to Strongly agree. Two items of the scale (JS3 and JS5) were reverse-coded prior to analysis. In this study, the Cronbach's alpha coefficient is $\alpha = 0.865$.

2.3. Data Analysis

Data analysis was carried out in two stages. First, the validity of the measurement model was tested; then, profile analysis was performed on the scale scores whose validity had been confirmed. IBM SPSS 31 software package and Lisrel 8.8 were used in the scale validity analysis stage. Based on the statistical results of the scales, mean, percentage and frequency values, and Cronbach's alpha coefficient for reliability, are presented. The normal distribution of the scales was evaluated with skewness and kurtosis values (±1). $p < 0.05$ was used as the level of statistical significance (95% confidence interval). Confirmatory factor analysis (CFA) was applied to each scale for construct validity. Model fit was evaluated with CFI, TLI, RMSEA and SRMR (Hu & Bentler, 1999).

Latent Profile Analysis (LPA) was performed using the Mplus 9.1 demo software. In determining the number of profiles, no single fit criterion was taken as the basis; model fit indices, profile sizes, classification quality and the theoretical interpretability of the profiles were evaluated together. In addition, it was taken into account that the smallest profile should not be less than 5% of the total sample. The number of profiles is decided on the basis of information criteria (AIC, BIC, sample-size adjusted BIC), classification precision (entropy and average posterior assignment probabilities), the relative size of the smallest profile (5% criterion), the bootstrap likelihood ratio test (BLRT; 100 replications) and theoretical interpretability (Nylund, Asparouhov & Muthén, 2007; Spurk et al., 2020). Lower AIC, BIC and aBIC values indicate better model fit. An entropy value approaching 1 indicates that individuals are more accurately classified into the profiles to which they belong. LMR-LRT and BLRT evaluate the difference in fit between the k-profile model and the k−1-profile model; a significant p value ($p < 0.05$) indicates that the k-profile model fits better than the k−1-profile model. In the latent profile analysis, the indicators are the job satisfaction and burnout scale means.

3. Results

The demographic characteristics of the healthcare workers are presented in Table 1.

Table 1. *Demographic Characteristics of the Participants*

Variable	Category	n	%
Gender	Female	180	68.2
	Male	84	31.8
Educational status	Bachelor's degree	164	62.1
	High school or equivalent	57	21.6
	Postgraduate	43	16.3
Occupation	Midwife/nurse	68	25.8
	Physician	16	6.1
	Administrative staff	67	25.4
	Health technician/technologist	79	29.9
	Manager	34	12.9

N = 264.

3.1. Psychometric Properties of the Scales

The internal consistency coefficients of both scales are presented in the table (Table 2). The CFA of the job satisfaction scale yielded good fit values (CFI = .991, TLI = .982, RMSEA = .066, SRMR = .025). The burnout scale also has acceptable fit values (CFI = .976, TLI = .961, RMSEA = .094, SRMR = .031). Convergent validity criteria (AVE > .50; CR > .70) and the CFA results are presented in Table 2.

Table 2. *Descriptive Statistics, Reliability and Confirmatory Factor Analysis Results of the Scales*

Indicator	Number of items	Mean (SD)	Skewness / Kurtosis	Cronbach's α	Mean inter-item r	χ^2 (df)	CFI / TLI	RMSEA / SRMR	AVE / CR
Job satisfaction	5	3.43 ±0.87	-0.44 - 0.25	0.865	0.561	10.69 (5)	.991 / .982	.066 / .025	.583 / .871
Job-Related Emotional Exhaustion	6	3.17± 0.97	-0.12 - 0.64	0.886	0.558	29.80 (9)	.976 / .961	.094 / .031	.579 / .889

N = 264. AVE = average variance extracted; CR = composite reliability.

Table 3. *Item Analysis Results*

Item	M	SD	Corrected item-total r	Standardised factor loading
Job satisfaction scale				
JS1	3.47	1.06	.772	.859
JS2	3.52	1.09	.755	.814
JS3	3.34	1.07	.462	.487
JS4	3.33	1.12	.715	.801
JS5	3.51	1.06	.742	.796
Burnout scale				
EE1	2.95	1.24	.795	.865
EE2	3.55	1.19	.632	.666
EE3	2.74	1.27	.746	.791
EE4	3.11	1.30	.832	.903
EE5	2.77	1.23	.718	.774
EE6	3.93	1.09	.476	.490

The factor loading of JS3 is .487 and that of EE6 is .490. Since the values of both items are > 0.30, the items were not removed from the scales (Büyüköztürk, 2017).

3.2. Relationship Between the Scales

Correlation analysis was performed to determine the relationship between the job satisfaction and job-related emotional exhaustion scales. The correlation analysis revealed a strong negative relationship between job satisfaction and job-related emotional exhaustion ($r = -.640$, $p < .001$). Although this finding reveals the general relationship between job-related emotional exhaustion and job satisfaction, it does not answer the question of whether this relationship holds in the same way for all employees. The LPA used to determine this aims to reveal these differences among employees and the different employee profiles.

3.3. Latent Profile Analysis (LPA): Model Selection

LPA is a person-centred analytical method that divides individuals into unobserved subgroups, i.e. profiles, according to their similar responses. Unlike approaches that examine general relationships among variables, LPA aims to reveal employee profiles with different combinations of characteristics among individuals (Weller et al., 2020).

Information criteria and likelihood ratio tests are used to decide on the number of profiles (Ferguson et al., 2020; Weller et al., 2020). Information criteria such as AIC, BIC and SABIC, likelihood ratio tests such as LMR-LRT and BLRT, entropy, profile sizes and the theoretical interpretability of the profiles are evaluated together (Nylund et al., 2007; Weller et al., 2020).

Entropy is a diagnostic measure that evaluates classification quality rather than a fit criterion that determines the number of profiles. Entropy approaching 1 indicates that individuals are classified into profiles more accurately and distinctly. Entropy should not be used on its own to determine the number of profiles; it should be evaluated together with other statistical and theoretical criteria (Weller et al., 2020).

In addition, the size of each profile within the sample and, in particular, the theoretical meaningfulness of small profiles should be taken into account. Rather than eliminating a small profile solely on the basis of its percentage within the sample, model fit, classification quality, sample size and the conceptual meaningfulness of the profile should be evaluated together (Weller et al., 2020).

In conclusion, AIC, BIC, SABIC, entropy, profile size and theoretical interpretability should be evaluated together when deciding on the optimal number of profiles. A model that appears statistically better should not be preferred on that basis alone if the profiles are not theoretically meaningful and interpretable (Nylund et al., 2007; Weller et al., 2020).

In the process of determining the number of profiles at the data analysis stage of the study, the data prepared in SPSS were first loaded into the Mplus program, and 2-3-4-5 profile assignments were made in turn by entering code into the syntax file created in Mplus. The results obtained were compared and evaluated. The fit indicators of the 5 profile solutions formed as a result of interpreting the outputs obtained from Mplus are presented in Table 4.

Table 4. Fit Indicators of the One- to Five-Profile Solutions

k	LL	AIC	BIC	a-BIC	Entropy	Smallest %	Class sizes
1	-705.263	1418.53	1432.83	1420.15	–	100.0	264
2	-648.599	1311.20	1336.23	1314.04	.687	41.3	109 / 155
3	**-629.625**	**1279.25**	**1315.01**	**1283.30**	**.712**	**24.6**	**65 / 134 / 65**
4	-620.245	1266.49	1312.98	1271.76	.795	1.5	4 / 65 / 130 / 65
5	-611.741	1255.48	1312.70	1261.97	.765	1.9	21 / 5 / 71 / 103 / 64

LL = log-likelihood; a-BIC = sample-size adjusted BIC. L-L: *LMR-LRT*

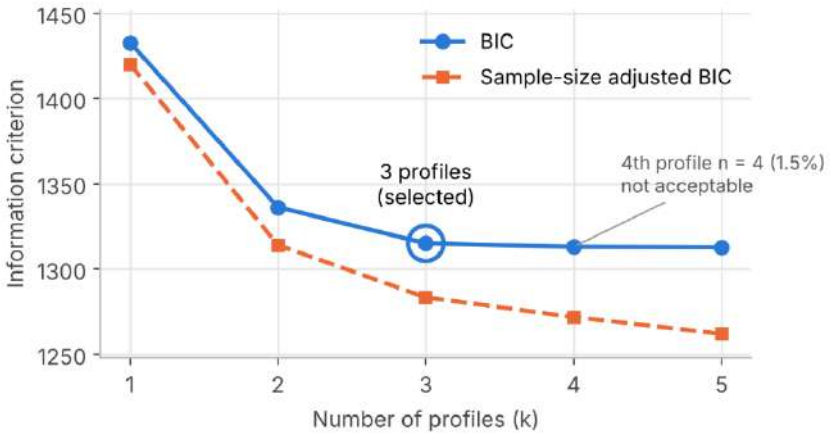


Figure 1. Information criteria by number of profiles.

The information criteria alone do not show a clear break point. The BIC value levels off after three profiles: 1315.01 for 3 profiles, 1312.98 for 4 profiles and 1312.70 for 5 profiles. This was evaluated according to whether the resulting difference was substantial. In the transition from two to three profiles, BIC decreased by 21.2 points. Profile sizes are the decisive criterion here. When the four-profile solution is examined, the smallest class consists of 4 individuals (1.5%) and is regarded as an outlier. Likewise, in the five-profile solution it consists of 5 individuals (1.9%). In mixture models, classes below 5% of the sample are regarded as outlying observations (Spurk et al., 2020; Weller et al., 2020). Classification precision clarifies the decision. Entropy is .712 at k = 3, rises to .795 at k = 4 and falls to .765 at k = 5. Although the four-profile solution has a higher entropy value, the higher entropy value alone was not considered sufficient for model selection, because the smallest profile consists of only four participants and the generalisability of the profile is therefore limited. The study results and fit values support the 3-profile solution. The graph of the proposed 3-profile solution is presented in the figure.

3.4. Preference for the Three-Profile Solution

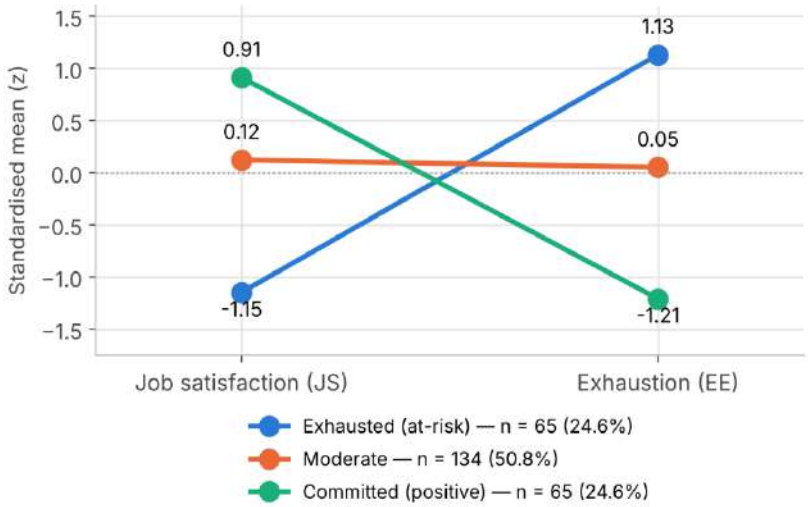


Figure 2. Levels of job satisfaction and burnout in the three-profile solution

Table 5. Profile Characteristics in the Three-Profile Solution

Profile	n	%	Job satisfaction M	Job-Related Emotional Exhaustion M
3-profile solution (entropy = .712)				
Exhausted (at-risk)	65	24.6	2.43	4.28
Moderate	134	50.8	3.54	3.22
Positive	65	24.6	4.23	2.00

Note. Means are model-estimated class means.

When the distributions formed by the 3-profile solution are examined, 3 profiles were defined: Profile 1: Exhausted (at-risk) workers, Profile 2: Moderate workers and Profile 3: Positive workers.

1. Profile: Exhausted (at-risk) workers: High burnout–low job satisfaction. n = 65, 24.6%. The job satisfaction mean of this profile is below average at 2.43, and its burnout mean is quite high at 4.28. Relative to the sample, this group constitutes the at-risk group and is the priority group requiring steps to be taken towards it.
2. Profile: Moderate workers: Moderate burnout–moderate job satisfaction. n = 134, 50.8%. Approximately half of the sample belongs to this group. With a job satisfaction mean of 3.54 and a job-related emotional exhaustion mean of 3.22, lying between both groups, it constitutes the group that requires monitoring and will require early intervention.
3. Profile: Positive workers: High job satisfaction–low burnout. n = 65, 24.6%. It constitutes the group with the highest job satisfaction mean (4.23) and the lowest job-related emotional exhaustion mean (2.00).

No group with both high job satisfaction and high burnout was identified.

4. Discussion

In this study, conducted with 264 healthcare workers at a private hospital in Istanbul, the profiles of healthcare workers were identified according to their levels of job satisfaction and burnout. Accordingly, 3 profiles emerged. By determining the relationship between the existing variables in all its aspects at the individual level, the profiles comprise, according to job satisfaction and burnout levels located at both extremes: an at-risk group with low satisfaction and high burnout, a positive group with low burnout and high satisfaction, and a moderate group close to the mean on both dimensions. The moderate group constitutes the largest group. Apart from these, the anticipated group in which high satisfaction and high burnout co-occur was not identified. In profile studies, it is expected that a group that disrupts the relationships between variables will be revealed (Meyer & Morin, 2016). In recent years, latent profile analysis has become increasingly common in burnout research. Hao and Zhang (2024) used the three dimensions of burnout with 602 healthcare workers in China and identified two profiles: low burnout (82.47%) and high burnout (17.53%). Employees in the high-burnout profile were found to have higher anxiety levels and lower self-esteem. In their study with 1,540 emergency nurses in China, Lan et al. (2025) identified three profiles: low burnout–low professional efficacy (41.0%), low burnout–high professional efficacy (32.3%) and high burnout–low professional efficacy (26.7%). Li et al. (2026), on the other hand, identified four profiles among 809 nurses in China: low burnout–high efficacy (11.5%), mild burnout–dissatisfied (33.9%), moderate burnout–fatigued (44.6%) and severe burnout–dysfunctional (10.0%).

In the study by Chang et al. (2026), using 16,730 data points from a medical centre in Taiwan, LPA was conducted with indicators of teamwork climate, job satisfaction and emotional exhaustion, and three profiles were identified: Balanced and Resilient (52.6%), Dedicated but Exhausted (24.2%) and Disengaged "quiet quitters" (23.1%).

Examining healthcare workers on a profile basis in this study is important for identifying at-risk groups and making the necessary interventions in this direction. At the same time, identifying the moderate group is also

important for keeping under control situations that may shift in either direction and for taking the necessary measures accordingly. In specialised sectors such as healthcare institutions, employee profiles need to be identified according to the characteristics of the variables, and activities need to be planned accordingly, with respect to both the management process and the quality of patient care. This is also important for developing management strategy. Regular monitoring should be used as an appropriate means of identifying at-risk employees. In research, in addition to comparing the mean levels of variables and making relational descriptions accordingly, it is necessary to examine the variables on the basis of employee profiles and to take steps accordingly. It should not be forgotten that examining demographic findings in future research will also guide interventions. Since this profile exhibits a more unfavourable pattern in terms of job satisfaction and burnout, it may be regarded as a group that should be further examined in future research in terms of institutional support, working conditions and psychosocial risk indicators.

In this study, the fact that the 4th profile consisted of only 4 individuals created a spurious profile; this also constitutes an example of the need to examine statistical methods with class size and interpretability criteria and to examine misleading results in detail. The fact that the smallest profile consisted of only four participants, that the profile size was low and that this profile did not offer a theoretically distinctive structure created considerable uncertainty regarding the generalisability and interpretability of the solution. It is also necessary to emphasise the importance of the moderate group constituting approximately half of the sample. This is an important result from an institutional perspective. The moderate profile is of particular importance; this group constitutes half of the sample and lies in a transitional zone between the two extremes. Directing preventive interventions towards this group may be effective in preventing transition to the at-risk group.

4.1. Limitations and Recommendations

The study has some limitations. First, owing to the cross-sectional design, the direction of the relationship between the variables cannot be determined. Longitudinal studies are recommended. Second, the limitation of the number of variables to 2 is a constraint. All data were collected from the same source and with the same method. Supporting them with supervisor evaluations or objective indicators will increase the strength of the findings. The analyses were conducted on a single sample. Replicating the profile structure in an independent sample is important for the generalisability of the findings.

5. Conclusion

In this study, the 264 healthcare workers examined were found to be best represented by three distinct profiles on the basis of their levels of job satisfaction and job-related emotional exhaustion. One quarter of the sample falls into the at-risk profile, defined by both low satisfaction and high burnout. Half of the sample falls into the moderate profile and lies in a transitional zone between the two extremes. This group constitutes the priority target population for preventive interventions. The findings show that, in combating burnout in healthcare institutions, an approach based on regular monitoring using scale scores and on profile-based intervention planning would be more appropriate.

References

Brayfield, A. H., & Rothe, H. F. (1951). An index of job satisfaction. Journal of Applied Psychology, 35(5), 307–311.

Büyüköztürk, Ş. (2017). Sosyal bilimler için veri analizi el kitabı [Data analysis handbook for social sciences]. Ankara: Pegem Akademi.

Chang, Y.-C., Lin, G.-M., Wu, C.-H., & Wang, Y.-C. (2026). A 6-year latent profile analysis of teamwork climate, job satisfaction, and emotional exhaustion among healthcare workers at a Taiwanese medical center. Nursing Outlook, 74, 102839.

Demerouti, E., Bakker, A. B., Nachreiner, F., & Schaufeli, W. B. (2001). The job demands-resources model of burnout. *The Journal of applied psychology*, *86*(3), 499–512.

Faragher, E. B., Cass, M., & Cooper, C. L. (2005). The relationship between job satisfaction and health: A meta-analysis. Occupational and Environmental Medicine, 62(2), 105–112.

Ferguson, S. L., Moore, E. W. G., & Hull, D. M. (2020). Finding latent groups in observed data: A primer on latent profile analysis in Mplus for applied researchers. International Journal of Behavioral Development, 44(5), 458–468.

Freudenberger, H. J. (1974). Staff burn-out. Journal of Social Issues, 30(1), 159–165.

Günay, A. (2021). İşe bağlı duygusal tükenmişlik: Bir ölçek uyarlama çalışması [Job-related emotional exhaustion: A scale adaptation study]. Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 30(1), 142–149. https://doi.org/10.35379/cusosbil.828921

Hao, S., & Zhang, X. (2024). Job burnout and anxiety among medical staff: A latent profile and moderated mediation analysis. Social Science & Medicine, 356, 117141.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal, 6(1), 1–55.

Judge, T. A., Locke, E. A., Durham, C. C., & Kluger, A. N. (1998). Dispositional effects on job and life satisfaction: The role of core evaluations. Journal of Applied Psychology, 83(1), 17–34.

Keser, A., & Bilir, B. Ö. (2019). İş Tatmini Ölçeğinin Türkçe güvenilirlik ve geçerlilik çalışması [Turkish reliability and validity study of the Job Satisfaction Scale]. *Kırklareli Üniversitesi Sosyal Bilimler Dergisi*, *3*(3), 229-239.

Lan, L., Chen, X., Zhang, H., Zhong, L., & Ye, L. (2025). Characterizing potential subtypes and influencing factors of burnout in emergency department nurses by latent profile analysis. Frontiers in Public Health, 13, 1654398.

Li, X., Yang, F., Chen, X., Zhao, H., & Yu, R. (2026). Latent profile analysis of nurse burnout categories and influencing factor differences among nurses in Southwest China. Frontiers in Public Health, 14, 1764970.

Locke, E. A. (1976). The nature and causes of job satisfaction. In M. D. Dunnette (Ed.), Handbook of industrial and organizational psychology (pp. 1297–1349). Rand McNally.

Maslach, C., & Jackson, S. E. (1981). The measurement of experienced burnout. Journal of Occupational Behaviour, 2(2), 99–113.

Maslach, C., Schaufeli, W. B., & Leiter, M. P. (2001). Job burnout. Annual Review of Psychology, 52, 397–422.

Meyer, J. P., & Morin, A. J. S. (2016). A person-centered approach to commitment research: Theory, research, and methodology. Journal of Organizational Behavior, 37(4), 584–612.

Morin, A. J. S., Bujacz, A., & Gagné, M. (2018). Person-centered methodologies in the organizational sciences: Introduction to the feature topic. Organizational Research Methods, 21(4), 803–813.

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. Structural Equation Modeling: A Multidisciplinary Journal, 14(4), 535–569. https://doi.org/10.1080/10705510701575396

Schaufeli, W. B., & Taris, T. W. (2014). A critical review of the Job Demands-Resources Model: Implications for improving work and health. In G. F. Bauer & O. Hämmig (Eds.), Bridging occupational, organizational and public health (pp. 43–68). Springer.

Spurk, D., Hirschi, A., Wang, M., Valero, D., & Kauffeld, S. (2020). Latent profile analysis: A review and "how to" guide of its application within vocational behavior research. Journal of Vocational Behavior, 120, 103445.

Weller, B. E., Bowen, N. K., & Faubert, S. J. (2020). Latent class analysis: A guide to best practice. Journal of Black Psychology, 46(4), 287–311. https://doi.org/10.1177/0095798420930932

West, C. P., Dyrbye, L. N., & Shanafelt, T. D. (2018). Physician burnout: Contributors, consequences and solutions. Journal of Internal Medicine, 283(6), 516–529.

Wharton, A. S. (1993). The affective consequences of service work: Managing emotions on the job. Work and Occupations, 20(2), 205–232.

IN VITRO ANTICANCER POTENTIAL OF FERMENTATION SUPERNATANT FROM *STREPTOMYCES GOBITRICINI*-LIKE ISOLATE BH026 AGAINST SH-SY5Y NEUROBLASTOMA CELLS

Berna OZDEM
Dilara Hande BARLIK
Gulsah EVYAPAN
ORCID: 0000-0002-4481-2866, Department of Medical Biology and Genetics, Medical Faculty, Inonu University, Malatya, Turkiye
ORCID: 0000- 0003-1668-1413, Department of Molecular Biology and Genetics, Science Faculty, Van Yuzuncu Yil University, Van, Turkiye
ORCID: 0000-0001-9870-4783, Department of Medical Biology, Medical Faculty, Van Yuzuncu Yil University, Van, Turkiye

Abstract

Neuroblastoma is one of the most common solid tumors of childhood, originating from the embryonic neural crest cells of the sympathetic nervous system. *Streptomyces* species play a critical role in novel drug discovery as rich sources of secondary metabolites. This study aims to investigate the secondary metabolite production potential of the *Streptomyces gobitricini*-like isolate BH026, which has been previously isolated and demonstrated to possess antibacterial potential, and to evaluate the in vitro anticancer effect of its fermentation broth on SH-SY5Y human neuroblastoma cells. Spores obtained from the isolate, which was activated by incubation on ISP2 agar at 30 °C for 5–7 days, were transferred to Tryptone-Yeast Extract-Glucose Broth (TYGB) to prepare the inoculum and cultured at 30 °C with 200 rpm agitation for 3 days. The prepared inoculum was inoculated at 5% (v/v) into a sterile Glucose-Yeast Extract-Malt Extract (GYM) Broth fermentation medium and incubated at 30 °C and 200 rpm for 10 days. At the end of the fermentation, the culture broth was centrifuged at 8000 rpm for 20 minutes and subsequently filtered through Whatman No. 1 filter paper to obtain a cell-free fermentation supernatant. The in vitro anticancer potential of this supernatant was evaluated on SH-SY5Y human neuroblastoma cells, proliferated under appropriate culture conditions, using the MTT assay, with uninoculated sterile GYM Broth serving as the negative control. The findings demonstrated that the metabolites produced by the BH026 isolate significantly reduced cell viability in SH-SY5Y neuroblastoma cells in a concentration-dependent manner compared to the control group. In conclusion, secondary metabolites derived from the BH026 isolate exhibited promising anticancer activity against SH-SY5Y neuroblastoma cells. These findings indicate that these metabolites possess the potential to be evaluated as lead compounds in studies aimed at developing novel anticancer agents.

Keywords: *Streptomyces*; BH026, Neuroblastoma; SH-SY5Y; Cytotoxicity.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE ROLE OF EPIGENETICS AND GENETIC MEMORY IN SEXUALITY AND SEXUAL BEHAVIORS, AND THE NURSING APPROACH

Rüveyda Suluhan
Halime Esra Meram
ORCID: 0009-0006-0887-6543, Selçuk University, Institute of Health Sciences, Master's Program in Obstetrics and Gynecology Nursing, Konya, Turkey.
ORCID: 0000-0002-9439-1369, Selçuk University, Faculty of Nursing, Department of Obstetrics and Gynecology Nursing, Konya, Turkey.

Abstract

Sexuality, a multidimensional concept that plays a role in an individual's emotional, cognitive, and behavioral processes, can be influenced by numerous factors, including genetic and epigenetic elements. The sexual differentiation of the brain plays a significant role in shaping the biological dimension of sexuality. Beginning in the womb, this process of sexual differentiation—along with ongoing brain development—can be influenced by a variety of environmental and biological factors. This process also influences epigenetic mechanisms, contributing to the shaping of sex-related traits and behaviors. Epigenetic mechanisms play a role in the regulation of gene expression without altering the DNA sequence. Epigenetics serves as a significant factor influencing reproductive processes and behaviors. It has been noted, in particular, that childhood trauma—such as abuse—can exert negative effects on sexuality through epigenetic mechanisms. Furthermore, research indicates that certain genes may undergo modifications related to sexuality. Beyond genetic and epigenetic influences, sexuality is shaped by a wide array of psychosocial factors. Consequently, sexuality and sexual behaviors should be addressed through a holistic approach that takes these diverse factors into account. In this context, professionals play a crucial role in providing the necessary psychosocial support.. Furthermore, the fact that epigenetic mechanisms can be influenced by factors such as nutrition, stress levels, and lifestyle underscores the importance of protective and preventive nursing care. This review has been prepared to evaluate the role of epigenetics and genetic memory in sexuality and sexual behaviors, as well as the corresponding nursing approach, in light of the existing current literature.

Keywords: Epigenesis, Genetic, Nursing, Sexuality.

Introduction

Sexuality, which plays a role in shaping various behaviors, emotions, and thoughts, is a multidimensional concept encompassing an individual's gender, cognitive and emotional processes, and their behavioral manifestations (Rao et al., 2024). At the same time, sexuality reflects the way an individual experiences and lives out their sexuality from social and psychological perspectives (Henkelman et al., 2023). Physiological, biological, and anatomical factors, as well as sociocultural elements and genetics, are among the determinants of sexuality (Rao et al. 2024). Sexual differentiation of the brain—a biological basis of sexuality—begins during the prenatal period and continues throughout life through the interaction of gonadal hormones, environmental factors, and sex chromosomes (Kundakovic and Tickerhoof 2024; McCarthy and Arnold 2011). The interaction of these factors can influence epigenetic mechanisms in the brain, thereby contributing to the emergence of sex-specific behaviors (Kundakovic and Tickerhoof 2024).

The concept of epigenetics, first employed by Conrad Waddington, was defined as the causal relationship between the genes that shape the phenotype and their gene products (Waddington 2012, Rivera-Bautista 2025). Today, however, it primarily describes meiotic and mitotic heritable changes in gene expression that occur without any alteration to the DNA sequence (Rivera-Bautista 2025, Wei et al. 2017). It is acknowledged that these epigenetic mechanisms play a significant role in the control of reproductive and socio-sexual behaviors (Rivera-Bautista 2025). Epigenetic modifications occurring during early life stages can prime genes to respond

to stimuli encountered later on. In this way, the functions of tissues and organs can be determined prior to exposure to these stimuli (Vaiserman 2015). Recent studies focus on understanding how adverse experiences occurring at early stages shape the negative effects on long-term health through epigenetic mechanisms (Chen et al. 2021). It has been shown that individuals who experienced sexual abuse, particularly during childhood, exhibit a tendency toward sexual behaviors such as sexual dysfunction and unprotected, multiple-partner sexual activity later in life, due to epigenetic memory (Selic and Jug 2025, Maniglio 2009).

It is thought that genetics, alongside epigenetic factors, may influence sexual behaviors. Twin and genome-based studies on the heritability of sexual behaviors indicate that genetic factors may play a role in same-sex behaviors (Felesina and Zietsch 2025, Ganna et al. 2019). A genome-wide association study conducted by Ganna et al. (2019) demonstrates that a polygenic architecture plays a role in same-sex behavior. Another study indicates that same-sex behavior involves a complex polygenic architecture and is shaped by distinct genetic influences in men and women (Felesina & Zietsch, 2025).It is thought that genetics may also influence sexual orientation. Research into the relationship between sexual orientation and genetics indicates that there may be a link between the two (Hu et al., 2021). Sexual orientation, which differs from sexual behavior, refers to heterosexuality (attraction to the opposite sex), homosexuality (attraction to the same sex), bisexuality (attraction to both sexes), and asexuality (the absence of sexual interest in either sex) (Wang et al. 2019).

The fact that factors such as nutrition, stress levels, and lifestyle can influence epigenetic regulation highlights the importance of protective and preventive approaches in nursing care. Therefore, it is crucial for nurses to provide individuals with counseling on healthy lifestyle behaviors, starting from the prenatal period (Collins et al., 2020).

However, studies regarding the role of genetic and epigenetic mechanisms in the development of sexuality and sexual behaviors remain limited. In particular, there is a lack of research examining the long-term effects of early-life experiences on sexual behaviors and sexual orientation through epigenetic regulation. Furthermore, a significant portion of existing studies relies on animal models, and it appears that the underlying mechanisms have not been fully elucidated in human studies (Wang et al. 2019, Balthazart 2020). The aim of this review is to examine the roles of epigenetic mechanisms and genetic memory in the development of sexuality and sexual behaviors, and to evaluate the current literature on this subject.

Concepts Of Genetıcs and Epıgenetıcs

Genes form the basis of heredity, and DNA constitutes genes (Cheng et al. 2022, Hall and Sankaran 2021). The field of genetics is utilized in the diagnosis and treatment of diseases such as cancer and sickle cell anemia, the development of personalized drugs and treatment methods, and gene therapy (Aiyegbusi et al. 2020, Rubio and Simon 2021, Cheng et al. 2022).

The concept of epigenetics was first proposed by Conrad Waddington and was initially used to describe undefined regulatory principles governing genetic processes. Today, however, epigenetics primarily encompasses the biological mechanisms that regulate gene expression without altering the DNA sequence (Halabian et al., 2021).These mechanisms play a role in controlling many vital processes, such as cellular differentiation, phenotypic plasticity, and adaptation to environmental stimuli (Berdasco and Esteller 2019, Halabian et al. 2021).

Epigenetic mechanisms primarily consist of a few key components. Foremost among these are DNA methylation and histone modifications. These two fundamental mechanisms work in concert to regulate gene expression, thereby shaping cellular responses (Halabian et al., 2021).In addition, “printer”, “eraser” and “reader” protein groups are involved in these processes, controlling the processing and transfer of epigenetic information (Zare et al 2017, Halabian et al 2021). Aberrations in DNA methylation can arise from functional errors in writer, eraser, and reader proteins (Halabian et al. 2021; Zare et al. 2017). Notably, abnormal methylation patterns are known to occur in complex diseases such as cancer and neurodegenerative disorders (Halabian et al. 2021).

Epıgenetıc Regulatıon Of Sexualıty and Sexual Behavıors

Hormonal factors play a role in the sex-specific development of the brain (Kundakovic and Tickerhoof 2024). However, the sex-specific development of the brain is shaped not only by hormones but also by epigenetic mechanisms.DNA methylation, in particular, can play a role in the male- or female-typical development of the brain (Forger, 2016). A study conducted on mice by Nugent et al. (2015) reports that hormonal influences affect behavioral characteristics and that male-typical sexual behaviors can be observed in female mice exposed to testosterone.In particular, the suppressive effect of DNA methylation on gene expression indicates that epigenetic mechanisms may play a significant role in the sex-specific differentiation of the brain (Forger 2016).

In humans, however, these epigenetic mechanisms are not fully understood. Nevertheless, prenatal and lifelong environmental factors—along with stress exposure—can play a role in shaping sex-specific neurobiological characteristics by influencing brain development through hormone levels and epigenetic regulations.It is noted that, in some cases, these effects may reduce or increase sex differences in the brain (Kundakovic and Tickerhoof 2024).

One of the most notable examples of these environmental and epigenetic effects is traumatic experiences during childhood. Traumatic events occurring in childhood can be biologically recorded through DNA methylation.Therefore, it can lead to problems with sexual behaviors and orientations—such as sexual dysfunctions (Gewirtz-Meydan & Opuda, 2022), hypersexuality, or sexual avoidance (Slavin et al., 2020)—in the long term (Cecil et al., 2020).A meta-analysis by Abajobir et al. (2017) indicates that risky sexual behaviors in adulthood (such as unprotected and casual sexual intercourse and early onset of sexual activity) are 1.59 times more prevalent among individuals who experienced childhood sexual abuse compared to those who did not, and that this phenomenon is observed more frequently in women (Abajobir et al., 2017).Another study reports that hypersexual men were exposed to higher levels of violence during childhood (Chatzittofis et al., 2017). Meanwhile, a study by Davis and Knight (2019) concludes that experiencing childhood abuse—particularly psychological abuse—can lead to hypersexual behaviors in adulthood and that such traumas can significantly influence patterns of sexual thought and behavior in individuals with a history of sexual offenses (Davis and Knight, 2019).In conclusion, this demonstrates that human sexuality has a structure too complex to be explained by a single biological or environmental factor (Georgousopoulou et al. 2026; Sakata and Balthazart 2026).Hormone exposure and brain organization, particularly during the prenatal period, play a critical role in sexual differentiation and the formation of subsequent sexual behavior patterns (VanRyzin et al. 2020). In addition to epigenetic mechanisms, genetic factors also play a significant role in the biological underpinnings of sexual orientation (Bragazzi et al. 2026).

The Influence Of Genetıc Factors On Sexual Orıentatıon and Sexual Behavıor

Scientific research into the genetic foundations of sexual orientation has undergone an extensive evolution, spanning from early sexology studies in the early 20th century to modern genomic approaches (Bragazzi et al., 2026).

The influence of genetics on homosexuality—the most common sexual orientation—has been studied from 1886 to the present day (Bragazzi et al. 2026; Bauer 2004). Initially, homosexuality was regarded as a natural variation of sexuality, and it was posited that if homosexuality existed within a family, this orientation would manifest in one of the family members.Subsequently, studies on twins began to touch upon epigenetics by considering environmental factors alongside genetics (Bragazzi et al. 2026, Kallman 1952). Although Hamer et al. (1993) proposed—based on their research on the X chromosome—that the Xq28 region was linked to male sexual orientation, this finding has not been substantiated.The large-scale GWAS (Genome-Wide Association Study) conducted by Ganna et al. (2019) demonstrated that sexual behavior is associated with the influence of numerous genes rather than a single gene (polygenic) and indicated that processes such as olfaction, neuronal excitability, and brain development play a role in sexual development.In conclusion, sexual orientation is considered a multidimensional phenomenon shaped by a complex interaction of genetic, epigenetic, and environmental factors, rather than by a single gene (Bragazzi et al., 2026).

The Role Of The Nurse Regardıng Epıgenetıc Factors In Sexualıty and Sexual Behavıors

Epigenetic mechanisms can be influenced by environmental factors throughout life, starting from the prenatal period. Prenatal stress and hormone exposure can affect fetal brain development differently in males and females (Georgousopoulou et al., 2026).It is stated that factors such as maternal nutrition, folic acid intake, stress levels, physical activity, and lifestyle influence DNA methylation and gene expression, and that this can shape an individual's health outcomes in later life (Irwin et al. 2019, Collins et al. 2020).In this regard, nurses should provide counseling to individuals on healthy nutrition, stress management, and healthy lifestyle behaviors, starting from the pre-pregnancy period and continuing through pregnancy, childbirth, and the postpartum period (Collins et al. 2020).

Nutrition holds a significant place among the environmental factors influencing epigenetic processes, with folate intake, in particular, playing a critical role. It is reported that adequate maternal folate intake is important for epigenetic and cognitive development and plays a role in the regulation of genes associated with certain diseases (Irwin et al. 2019, Collins et al. 2020).Therefore, it is of great importance for nurses to provide nutritional education—particularly to pregnant women—explain the importance of folic acid intake, and identify high-risk groups at an early stage (Collins et al. 2020). Furthermore, given the association between childhood sexual abuse and risky sexual behaviors later in life, nurses should provide psychosocial support, identify at-risk individuals, and offer sexual health counseling during the care processes involving children, adolescents, and families (Abajobir et al. 2017, Collins et al. 2020).

Conclusıon and Recommendatıons

In conclusion, biological (genetic and hormonal), epigenetic, and environmental factors—and their mutual interactions—influence sexuality.It is recommended that future research increase multidisciplinary studies analyzing genetic and epigenetic data in tandem; incorporate environmental and psychosocial variables—in addition to biological ones—into models studying sexual behavior and orientation; expand longitudinal studies to better elucidate epigenetic mechanisms in human subjects; and broaden research examining the biological effects of childhood trauma, particularly by focusing on the relationship between DNA methylation and the stress axis.Efforts should be made to integrate preventive mental health and prenatal care practices by specifically enhancing nurses' awareness of epigenetics. In sexuality research, ethical sensitivities must be observed, and care taken to ensure that biological findings do not lead to stigmatizing interpretations.

References

Abajobir AA, Kisely S, Maravilla JC, Williams G, Najman JM, 2017. Gender differences in the association between childhood sexual abuse and risky sexual behaviours: a systematic review and meta-analysis. Child Abuse Negl, 63, 249–261. https://doi.org/10.1016/j.chiabu.2016.11.023

Aiyegbusi OL, Macpherson K, Elston L, Myles S, Washington J, Sungum N, Briggs M, Newsome PN, Calvert MJ, 2020. Patient and public perspectives on cell and gene therapies: a systematic review. Nat Commun, 11, 6265.

Balthazart J, 2020. Sexual partner preference in animals and humans. Neurosci Biobehav Rev, 115, 34–47. https://doi.org/10.1016/j.neubiorev.2020.03.024

Bauer JE, 2004. Magnus Hirschfeld's doctrine of sexual intermediaries and the transgender politics of (no-) identity. Master's Thesis, University of Amsterdam, Amsterdam.

Berdasco M, Esteller M, 2019. Clinical epigenetics: seizing opportunities for translation. Nat Rev Genet, 20(2), 109–127. https://doi.org/10.1038/s41576-018-0074-2

Bragazzi N, Farah R, Khamisy-Farah R, 2026. Unraveling the genetics of sexual orientation: a historical and contemporary perspective. Isr Med Assoc J, 28, 126–132.

Cecil CAM, Zhang Y, Nolte T, 2020. Childhood maltreatment and DNA methylation: a systematic review. Neurosci Biobehav Rev, 112, 392–409. https://doi.org/10.1016/j.neubiorev.2020.02.019

Chatzittofis A, Savard J, Arver S, Öberg KG, Hallberg J, Nordström P, Jokinen J, 2017. Interpersonal violence, early life adversity, and suicidal behavior in hypersexual men. J Behav Addict, 6(3). https://doi.org/10.1556/2006.6.2017.027

Chen MA, LeRoy AS, Majd M, Chen JY, Brown RL, Christian LM, Fagundes CP, 2021. Immune and epigenetic pathways linking childhood adversity and health across the lifespan. Front Psychol, 12, 788351. https://doi.org/10.3389/fpsyg.2021.788351

Cheng A, Harikrishna JA, Redwood CS, Lit LC, Nath SK, Chua KH, 2022. Genetics matters: voyaging from the past into the future of humanity and sustainability. Int J Mol Sci, 23, 3976. https://doi.org/10.3390/ijms23073976

Collins N, Phillips NLH, Reich L, et al., 2020. Epigenetic consequences of adversity and intervention throughout the lifespan: implications for public policy and healthcare. Adv Res Sci, 1, 205–216. https://doi.org/10.1007/s42844-020-00015-5

Davis KA, Knight RA, 2019. The relation of childhood abuse experiences to problematic sexual behaviors in male youths who have sexually offended. Arch Sex Behav, 48, 2143–2155. https://doi.org/10.1007/s10508-018-1279-3

Felesina T, Zietsch B, 2025. Emerging insights into the genetics and evolution of human same-sex sexual behavior. Trends Genet, 41, 402–411.

Forger NG, 2016. Epigenetic mechanisms in sexual differentiation of the brain and behaviour. Philos Trans R Soc Lond B Biol Sci, 371, 20150114. https://doi.org/10.1098/rstb.2015.0114

Ganna A, Verweij KJH, Nivard MG, 23andMe Research Team, Lichtenstein P, Lundström S, Långström N, Auton A, Harris KM, Beecham GW, Martin ER, Sanders AR, Perry JRB, Neale BM, Zietsch BP, 2019. Large-scale GWAS reveals insights into the genetic architecture of same-sex sexual behavior. Science, 365(6456), eaat7693. https://doi.org/10.1126/science.aat7693

Georgousopoulou V, Serdari A, Manomenidis G, et al., 2026. Prenatal stress, hormones, and fetal brain development: gender differences. Hormones, 25, 5–10. https://doi.org/10.1007/s42000-025-00696-6

Gewirtz-Meydan A, Opuda E, 2022. The impact of child sexual abuse on men's sexual function: a systematic review. Trauma Violence Abuse, 23(1), 265–277.

Halabian R, Valizadeh Arshad M, Ahmadi A, et al., 2021. Laboratory methods for resolving epigenetic signatures: a comparative review. Cell Mol Biol Lett, 26(1), 46. https://doi.org/10.1186/s11658-021-00290-9

Hall K, Sankaran N, 2021. DNA translated: Friedrich Miescher's discovery of nuclein in its original context. Br J Hist Sci, 54(1), 99–107. https://doi.org/10.1017/S000708742000062X

Hamer DH, Hu S, Magnuson VL, Hu N, Pattatucci AM, 1993. A linkage between DNA markers on the X chromosome and male sexual orientation. Science, 261(5119), 321–327. https://doi.org/10.1126/science.8332896

Henkelman M, Friedman J, McInnis M, Pukall C, 2023. What is sexuality?: moving toward inclusive and comprehensive measurement. J Sex Med, 20, S92.

Hu SH, Li HM, Yu H, Liu Y, Liu CX, Zuo XB, Lu J, Jiang JJ, Xi CX, Huang BC, Xu HJ, Hu JB, Lai JB, Huang ML, Liu JN, Xu DG, Guo XC, Wu W, Wu X, Jiang L, et al., 2021. Discovery of new genetic loci for male sexual orientation in Han population. Cell Discov, 7(1), 103. https://doi.org/10.1038/s41421-021-00341-7

Irwin RE, Thursby SJ, Ondičová M, Pentieva K, McNulty H, Richmond RC, et al., 2019. A randomized controlled trial of folic acid intervention in pregnancy highlights a putative methylation-regulated control element at ZFP57. Clin Epigenetics, 11(1), 31.

Kallmann FJ, 1952. Comparative twin study on the genetic aspects of male homosexuality. J Nerv Ment Dis, 115(4), 283–298. https://doi.org/10.1097/00005053-195210000-00001

Kundakovic M, Tickerhoof M, 2024. Epigenetic mechanisms underlying sex differences in the brain and behavior. Trends Neurosci, 47(1), 18–35. https://doi.org/10.1016/j.tins.2023.09.007

Maniglio R, 2009. The impact of child sexual abuse on health: A systematic review of reviews. Clin Psychol Rev, 29(7), 647–657. https://doi.org/10.1016/j.cpr.2009.08.003

McCarthy MM, Arnold AP, 2011. Reframing sexual differentiation of the brain. Nat Neurosci, 14(6), 677–683. https://doi.org/10.1038/nn.2834

Nugent BM, Wright CL, Shetty AC, Hodes GE, Lenz KM, Mahurkar A, Russo SJ, Devine SE, McCarthy MM, 2015. Brain feminization requires active repression of masculinization via DNA methylation. Nat Neurosci, 18(5), 690–697. https://doi.org/10.1038/nn.3988

Rao TSS, Tripathi A, Manohar S, Tandon A, 2024. Promoting sexual well-being. Indian J Psychiatry, 66(Suppl 2), S262–S271. https://doi.org/10.4103/indianjpsychiatry.indianjpsychiatry_612_23

Rivera-Bautista GD, Arzate DM, Ávila-González D, Castro AE, Vázquez-Martínez ER, Díaz NF, Portillo W, 2025. Epigenetic changes and neurogenesis associated with socio-sexual behaviors. Neurosci Biobehav Rev, 178, 106359. https://doi.org/10.1016/j.neubiorev.2025.106359

Rubio C, Simón C, 2021. Embryo genetics. Genes, 12(1), 118. https://doi.org/10.3390/genes12010118

Sakata JT, Balthazart J, 2026. Cellular mechanisms regulating the timing of organizational effects of sex steroid hormones. Horm Behav, 181, 105923. https://doi.org/10.1016/j.yhbeh.2026.105923

Selič M, Jug V, 2025. Childhood sexual abuse, adult attachment styles, and involvement in BDSM practices in adult intimate relationships. Behav Sci (Basel), 15(6), 813. https://doi.org/10.3390/bs15060813

Slavin MN, Scoglio AAJ, Blycker GR, Potenza MN, Kraus SW, 2020. Child sexual abuse and compulsive sexual behavior: a systematic literature review. Curr Addict Rep, 7(1), 76–88. https://doi.org/10.1007/s40429-020-00298-9

Vaiserman AM, 2015. Epigenetic programming by early-life stress: evidence from human populations. Dev Dyn, 244(3), 254–265. https://doi.org/10.1002/dvdy.24211

VanRyzin JW, Marquardt AE, Pickett LA, McCarthy MM, 2020. Microglia and sexual differentiation of the developing brain: a focus on extrinsic factors. Glia, 68(6), 1100–1113. https://doi.org/10.1002/glia.23740

Waddington CH, 2012. The epigenotype. 1942. Int J Epidemiol, 41(1), 10–13.

Wang Y, Wu H, Sun ZS, 2019. The biological basis of sexual orientation: how hormonal, genetic, and environmental factors influence to whom we are sexually attracted. Front Neuroendocrinol, 55, 100798. https://doi.org/10.1016/j.yfrne.2019.100798

Wei J, Huang K, Yang C, Kang C, 2017. Non-coding RNAs as regulators in epigenetics (review). Oncol Rep, 37, 3–9. https://doi.org/10.3892/or.2016.5236

Zare M, Bastami M, Solali S, Alivand M, 2017. miRNAs involving abnormal miRNA promoter methylation and EMT in breast cancer metastasis: diagnostic and therapeutic effects. J Cell Physiol

DETERMINANTS OF CERVICAL CANCER MORTALITY AND DISEASE BURDEN IN OECD COUNTRIES: A PANEL DATA ANALYSIS FOR THE 2010–2023 PERIOD

Şerife Çalışkan Söylemez
Eda Yetimoğlu
0000-0002-6228-2432, Üsküdar University, Vocational School of Health Services, Medical Documentation and Secretarial Program, İstanbul, Türkiye
0000-0002-8078-7469, Üsküdar University, Vocational School of Health Services, Health Institutions Management. İstanbul, Türkiye

Abstract

The aim of this study is to examine the determinants of cervical cancer mortality and disease burden in OECD countries within the framework of health system and sociodemographic indicators. The study will use the cervical cancer mortality rate and Disability-Adjusted Life Years (DALY) values as dependent variables. The independent variables have been identified as per capita health expenditure, HPV vaccination rate (percentage of final doses administered), number of physicians per capita, and the Socio-Demographic Index (SDI).
The research will be conducted using a panel dataset for OECD countries covering the period 2010–2023. Cervical cancer data were obtained from the Global Burden of Disease (GBD) database; data on health expenditures and the number of physicians were obtained from the World Bank, OECD, and World Health Organization databases; and data on HPV vaccination rates were obtained from the World Bank's Human Capital Data Portal. The SDI variable was obtained from the Institute for Health Metrics and Evaluation (IHME) database.
The study will first present descriptive statistics and correlation analyses for the variables. Subsequently, the data will be analyzed using panel data analysis methods. During the model estimation process, fixed-effects and random-effects models will be evaluated; the appropriate model will be determined using the Hausman test. Furthermore, estimators robust to econometric issues such as heteroskedasticity, autocorrelation, and cross-sectional dependence are planned to be used.
The study aims to reveal the effects of health expenditures, HPV vaccination rates, physician density, and the level of sociodemographic development on cervical cancer mortality and the DALY burden. In particular, it is anticipated that an increase in HPV vaccination rates and a strengthening of health system capacity could reduce the burden of cervical cancer. The study is expected to provide significant contributions to policymakers in terms of women's health policies, cancer control programs, and preventive health services.

Keywords: Cervical Cancer, Disease Burden, DALY, Health Expenditure, Panel Data Analysis.

BRIDGING ELECTRICAL VOCATIONAL EDUCATION AND INTERDISCIPLINARY INNOVATION: ENHANCING WORKFORCE COMPETENCE THROUGH PRACTICE-BASED TECHNICAL TRAINING IN LIBERIA

Gibson W. Weh
ORCID: 0009-0009-0533-576X
Potential Scholar Vocational Training Institute, Duport Road, Paynesville, Liberia

Abstract

The increasing demand for competent technical professionals in developing economies highlights the need for interdisciplinary approaches to vocational education that integrate technical expertise, problem-solving, safety practices, entrepreneurship, and digital competencies. This study investigates how interdisciplinary teaching and practice-based electrical vocational training influence workforce competence and employability among trainees at Potential Scholar Vocational Training Institute in Liberia.

The research employed a qualitative case study approach involving vocational trainees, instructors, and selected industry stakeholders. Data were collected through semi-structured interviews, classroom and workshop observations, and document analysis of training curricula and institutional records. The data were analyzed using thematic analysis to identify patterns related to technical skill development, interdisciplinary learning, and workplace readiness.

The findings indicate that integrating electrical engineering principles with communication skills, occupational health and safety, teamwork, entrepreneurship, and practical problem-solving significantly enhance students' technical competence and confidence. Participants demonstrated improved troubleshooting abilities, stronger adherence to electrical safety standards, and greater readiness to meet labor market expectations. The study further revealed that hands-on learning, instructor mentorship, and collaboration with industry partners strengthened knowledge transfer and promoted innovation in vocational education. However, limited access to modern training equipment and insufficient industry partnerships remain significant barriers to achieving optimal training outcomes.

The study concludes that interdisciplinary vocational education provides an effective framework for developing a skilled, adaptable, and innovative technical workforce capable of supporting sustainable infrastructure development and economic growth in Liberia. Strengthening institutional capacity through updated curricula, investment in modern electrical training facilities, and expanded partnerships with industry can further improve graduate employability and national workforce development.

Keywords: Interdisciplinary Education; Electrical Vocational Training; Workforce Development; Technical Skills; Employability; Liberia.

DEVELOPMENT AND CHARACTERISATION OF A NANOCOMPOSITE PROTON EXCHANGE MEMBRANE BASED ON POLY (VINYL ALCOHOL) WITH LAYERED DOUBLE HYDROXIDES FOR PROTON EXCHANGE MEMBRANE FUEL CELLS (PEMFC).

Ichrak FETTAH
Doha BELFADIL
Asiya Rezzouq
Abderrahim Bouftou
Sanaa MAJID
Laboratory of Materials, Process, and Environmental Engineering, Faculty of Sciences Aïn Chock, Hassan II University of Casablanca, Casablanca, Morocco

Abstract

Polymer electrolyte membranes (PEM) are key components of proton exchange membrane fuel cells (PEMFC), particularly under high-temperature operating conditions. In this study, nanocomposite membranes based on poly(vinyl alcohol) (PVOH) incorporating nickel–aluminum layered double hydroxide (Ni–Al LDH) nanoplatelets were fabricated via solution casting. The Ni–Al LDH, synthesized by co-precipitation, was effectively dispersed within the polymer matrix, as confirmed by XRD, FTIR, TGA, and SEM-EDX analyses. The optimized membrane containing 5 wt% Ni–Al LDH exhibited superior performance, with high proton conductivity of 40 $mS \cdot cm^{-1}$ at 75 °C, reduced water uptake (8,16%), low methanol permeability ($2,7 \times 10^{-7}$ $cm^2 \cdot s^{-1}$), and enhanced mechanical properties compared to pristine PVOH. Moreover, oxidative stability, assessed via the Fenton test, was significantly improved. These results highlight the synergistic effect of Ni–Al LDH on proton transport, mechanical robustness, and fuel crossover resistance, positioning Ni–Al LDH/PVOH membranes as promising and cost-effective alternatives to commercial PEM for next-generation high-temperature PEMFC applications.

Keywords: PVOH, LDH, proton exchange membranes, proton conductivity.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE ROLE OF BUSINESS PROGRAMMING IN MODERN MANAGEMENT: ALGORITHMIC THINKING, DIGITAL INFRASTRUCTURE, AND HUMAN RESOURCE MANAGEMENT

Elza Bitsadze
Lia janadze
Nana oniani-saghinadze
Asst. Prof., Akaki Tsereteli State University, Georgia, Department of Computer Technologies, Faculty of Exact and Natural Sciences, Kutaisi, 4600, Georgia,
https://orcid.org/0009-0005-9256-8166
Invited specialist, Akaki Tsereteli State University, Georgia, Department of Computer Technologies, Faculty of Exact and Natural Sciences, Kutaisi, 4600, Georgia,
https://orcid.org/0009-0001-3596-6775
Associate Professor, Akaki Tsereteli State University, Georgia, Department of Computer Technologies, Faculty of Exact and Natural Sciences, Kutaisi, 4600, Georgia,
Email: nana.oniani-saghinadze@atsu.edu.ge

Abstract

The development of digital technologies in the modern business environment has significantly changed organizational management approaches. For the success of companies, financial resources and traditional management methods alone are no longer sufficient. Effective data management, programming knowledge, and algorithmic thinking have become important factors that provide organizations with competitive advantages. The application of business programming is particularly significant in areas such as accounting, financial services, human resource management, and business analytics.

Business programming involves the creation of software solutions that help companies automate daily processes and improve managerial decision-making. Through programming, it is possible to process large volumes of data, optimize business processes, and develop systems that can quickly respond to changing business requirements. Modern data management approaches allow organizations to obtain accurate information and use it effectively in strategic planning processes.

One of the important directions is the development of Human Resource Management (HRM) systems. Managing employee data, workflows, skills, and performance evaluation represents a complex challenge. To address these challenges, algorithms and data structures can be applied. In particular, graph theory represents an effective tool for modeling relationships, dependencies, and connections. For example, communication between employees, participation in projects, and organizational structure analysis can be performed using graph-based models.

Algorithmic analysis enables the creation of optimization solutions that reduce time and resource consumption. Efficient algorithms contribute to faster data processing and improve business operations. In addition, programming languages such as C++ are used to solve complex computational problems and develop high-performance business applications.

Modern digital infrastructure also includes object-oriented programming, graphical user interface design, and event-driven programming. These technologies allow companies to create convenient and efficient software systems that adapt to user needs and business requirements.

In conclusion, business programming represents an important component of modern management. The application of algorithms, data structures, and digital technologies helps companies manage resources effectively, automate processes, and make better decisions. The integration of business and computer science creates new opportunities for organizational development and ensures long-term competitiveness.

Keywords: Management; Business Programming; Algorithms; Graph Theory; Human Resource Management.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE CUMULATIVE KINETIC ENERGY LOSS OF A VERTICALLY BOUNCING BALL: AN ANALYTICAL APPROACH TOWARDS THE DEVELOPMENT OF AN OPTIMIZATION ALGORITHM

Johnson A. Obari
Eustace M. Dogo
Ibrahim M. Abdullahi
Danlami Maliki
https://orcid.org/0009-0002-1688-8000, Department of Computer Engineering, Federal University of Technology, Minna, Nigeria & Department of Computer Engineering, Federal University Lokoja, Nigeria.
https://orcid.org/0000-0002-6125-0180, Department of Computer Engineering, Federal University of Technology, Minna, Nigeria
https://orcid.org/0000-0003-2870-7959, Department of Computer Engineering, Federal University of Technology, Minna, Nigeria
https://orcid.org/0000-0003-2870-7959, Department of Computer Engineering, Federal University of Technology, Minna, Nigeria

Abstract

The dynamics of a bouncing ball have attracted significant exploits. Several mathematical models have been developed based on kinematics, while others are premised on kinetics. This paper presents an analytic expression for the cumulative kinetic energy loss of a vertically rebounding ball over a specified number of bounces in a vacuum with aim of laying the foundation to develop an innovative optimization algorithm. By dwelling on the kinematics of bouncing balls and deducing the kinetic energy loss from one rebound to the other, the cumulative kinetic energy loss was obtained from an exponential sequence. The result illustrates the convergence of the sum of a bouncing ball's kinetic energy losses and the lack of perpetuity in its rebounds, even in the absence of aerodynamic drag. This approach establishes a unique method for obtaining the most suitable ball in a population of identical rebounding balls whose coefficients of restitution have been dispersed by certain factors like differences in air pressure, frequency of use, and partial structural deformity, among others. In reality, the rebounding ball with the least cumulative kinetic energy over several rebounds, which is the best, is similar to a candidate solution to an optimization problem with the least cost or best fitness. An emphasis is placed on the potential development of an optimization algorithm based on the theoretical approach and results of this research.

Keywords: Bouncing ball, kinetic energy loss, sport physics, restitution coefficient, optimization algorithm.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

CAN AI DETECT INCONSISTENT DATA? STATISTICAL, RULE-BASED, AND LLM APPROACHES

Etibar Vazirov
Farid Tahirov
Amin Ismayilov
ADA University, School of IT and Engineering, Baku, Azerbaijan
Undergraduate Student, School of IT and Engineering, ADA University, Baku, Azerbaijan
High School Student, Baku Modern School, Baku, Azerbaijan

Abstract

Anomaly detection in tabular data is commonly approached as a statistical problem in which unusual observations are identified based on their deviation from learned data distributions. However, many data-quality problems are not statistically extreme; instead, they arise from logical inconsistencies, contradictions between related attributes, or contextually implausible combinations. This study investigates whether different artificial intelligence approaches can detect such anomalies and, importantly, whether a large language model (LLM) can correctly explain why a record is anomalous. Using the UCI Adult Census Income dataset, we construct a controlled benchmark containing four anomaly categories: range violations, deterministic education-mapping inconsistencies, marital–relationship contradictions, and contextual age–education anomalies. Three complementary approaches are evaluated: Isolation Forest as an unsupervised statistical detector, explicit constraint-based rules, and Qwen3-4B-Instruct as a general-purpose LLM operating without task-specific fine-tuning. The results reveal substantial differences across anomaly types. Under a fixed detection budget, Isolation Forest achieves an overall anomaly recall of 13.6%, demonstrating limited sensitivity to logical and semantic inconsistencies. Explicit rules identify all injected anomalies when the corresponding constraints are known, providing a deterministic reference for constraint-aware validation. The LLM achieves 61.5% overall anomaly recall, with 100% recall for range violations and marital–relationship contradictions, but only 36% for education-mapping inconsistencies and 10% for contextual anomalies. Evaluation of LLM explanations against predefined inconsistency-specific criteria further shows that correct anomaly classification does not necessarily imply an accurate explanation: the proportion of anomalies both correctly detected and explained reaches 100%, 22%, 62%, and 2% across the four anomaly categories, respectively. These findings demonstrate that anomaly detectability depends strongly on the type of knowledge required and highlight the complementary roles of statistical detection, explicit constraints, and language-model reasoning in explainable tabular data validation.

Keywords: anomaly detection; tabular data; data quality; large language models; explainable artificial intelligence; Isolation Forest; rule-based validation; semantic consistency.

I. INTRODUCTION

Data quality plays a fundamental role in the reliability of machine learning systems. Real-world tabular datasets frequently contain incorrect values, incompatible attributes, and logically inconsistent records that may affect subsequent analysis. While conventional data-cleaning techniques can identify numerical outliers, detecting inconsistencies involving relationships between multiple features remains challenging. Recent research has demonstrated that automated data cleaning can improve downstream predictive performance, highlighting the importance of reliable error detection [1]. Anomaly detection methods typically identify observations that deviate from learned data distributions. Although effective for unusual numerical patterns, statistical approaches may overlook records whose individual attributes appear normal, but whose combinations violate logical or contextual expectations. Recent work on tabular anomaly detection has emphasized the importance of modelling dependencies between features and observations [2]. Consequently,

statistical unusualness alone may not adequately represent all forms of data inconsistency. Large language models (LLMs) offer an alternative by interpreting structured records through natural-language reasoning. Li et al. [3] investigated the ability of LLMs to detect anomalies in tabular datasets, while Tsai et al. [4] demonstrated their potential for unsupervised anomaly detection. However, identifying an anomalous record and explaining its underlying inconsistency are distinct tasks. Recent studies have reported that LLM performance varies across different types of tabular reasoning and logical errors [5], [6]. This study investigates whether statistical, rule-based, and LLM approaches can identify different categories of inconsistent records and whether an LLM can accurately explain its predictions. Using the UCI Adult Census Income dataset, we construct a controlled benchmark containing four anomaly categories: numerical range violations, education-mapping inconsistencies, marital–relationship contradictions, and contextual age–education anomalies. Three approaches are evaluated: Isolation Forest, explicit constraint-based rules, and Qwen3-4B-Instruct without task-specific fine-tuning. The main contribution of this work is a controlled comparison of anomaly detection paradigms combined with an evaluation of explanation fidelity. Rather than introducing a new detection algorithm, the study examines how performance changes across different inconsistency categories and whether correct LLM predictions are supported by faithful explanations. The findings provide insights into the complementary capabilities and limitations of statistical detection, deterministic validation, and language-based reasoning for tabular data quality assessment.

II. RELATED WORK

Recent research on data quality and anomaly detection has increasingly emphasized the importance of relationships between attributes rather than treating unusual values in isolation. Li et al. [7] surveyed active learning approaches for data quality control, highlighting the challenges of identifying errors when labeled examples are limited. Zhao et al. [8] investigated the use of large language models for anomaly detection in tabular cybersecurity data, demonstrating the growing interest in language-based approaches to structured-data analysis. Together, these studies reflect different strategies for improving data-quality assessment, although neither directly addresses the distinction between detecting logical inconsistencies and explaining their underlying causes.

Rule-based validation remains an important component of data cleaning because it can represent relationships that statistical models may not learn reliably. Mecca et al. [9] investigated rule-driven data repair, while Akella et al. [10] explored the use of LLMs and code generation to assess tabular data quality. These approaches illustrate how explicit constraints and automated reasoning can support the identification of erroneous records. In contrast, the present study uses predefined constraints as a reference for comparing statistical and language-model detection rather than proposing a new data-repair framework. The application of LLMs to structured data has also received considerable attention. Lu et al. [11] reviewed recent developments in LLM-based table processing and discussed the challenges of representing structured information in language-oriented models. Beyond detection performance, the reliability of generated explanations has emerged as an important concern. Madsen et al. [12] examined whether LLM-generated self-explanations faithfully reflect model behavior, while Parcalabescu and Frank [13] investigated the distinction between explanation faithfulness and self-consistency. Similarly, Yang et al. [14] studied data-referencing errors in LLM-based table processing, highlighting the possibility of unreliable explanations even when a model produces plausible outputs. Building on these findings, the present research examines how statistical anomaly detection, explicit validation rules, and direct LLM judgments respond to four controlled categories of tabular inconsistency. Its contribution is not a new detection algorithm, but a comparative evaluation that distinguishes successful anomaly classification from explanations that correctly identify the source of an inconsistency. This approach provides a practical basis for understanding both the capabilities and limitations of different methods in explainable tabular data validation.

III. METHODOLOGY

A. Dataset Preparation and Controlled Anomaly Generation. The experiments were conducted using the Adult Census Income dataset from the UCI Machine Learning Repository [19]. The original dataset contains 48,842 observations describing demographic, educational, and employment-related characteristics. After

removing records with missing values, 45,222 observations remained available for analysis. A reproducible experimental benchmark was constructed using a fixed random seed of 42. From the cleaned dataset, 5,500 records were selected, including 5,000 normal reference observations and 500 records assigned to four controlled anomaly categories. Each category contained 125 anomalous observations. This design enabled the evaluation of different inconsistency types under known ground-truth conditions, following the broader motivation of controlled anomaly benchmarking [13], [15]. The anomaly categories were defined as follows. Level 1 introduced numerical range violations by modifying age or weekly working hours to unusually high values. Level 2 created deterministic inconsistencies between the education and education-num attributes. Level 3 introduced semantic contradictions between marital status and relationship, specifically combining Never-married with Husband or Wife. Level 4 represented contextual implausibility by assigning a Doctorate qualification to individuals aged 18–21. Unlike deterministic violations, Level 4 was defined relative to the observed dataset distribution and was not considered universally impossible. The anomaly-generation process preserved the remaining attributes of each record, allowing the experiments to focus on the effects of specific inconsistencies. Ground-truth anomaly labels were retained for evaluation and excluded from detector inputs.

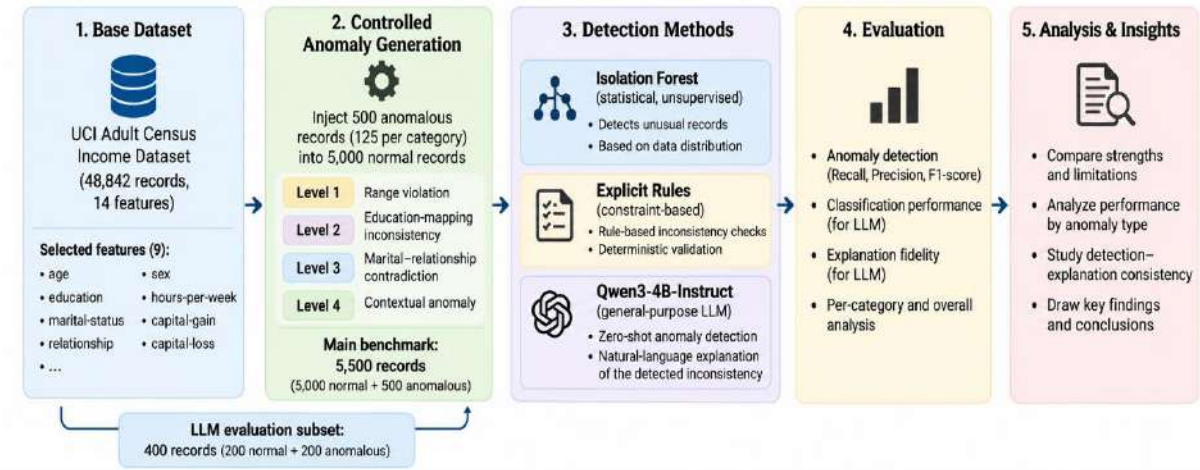


Fig. 1. Experimental workflow showing controlled anomaly generation, evaluation of statistical and rule-based methods on the 5,500-record benchmark, and LLM assessment on a 400-record subset.

Figure 1 illustrates the complete experimental framework. Isolation Forest and rule-based validation were evaluated on the 5,500-record benchmark, whereas the LLM was tested on a balanced subset of 400 observations. This separation enabled detailed language-model evaluation while keeping the larger benchmark available for the other approaches.

B. Isolation Forest-Based Detection. Isolation Forest was employed as the unsupervised statistical baseline. The method identifies unusual observations through recursive random partitioning, where anomalous records are generally isolated with shorter path lengths [16]. Its use provides a conventional statistical comparison for recent approaches addressing anomaly detection in tabular data [8], [15]. Numerical attributes were standardized, while categorical attributes were converted using one-hot encoding. The preprocessing transformations were fitted using the 5,000 normal reference observations. An Isolation Forest model with 300 estimators and a fixed random seed was subsequently trained on these records.

The anomaly score was defined as follows:

$$s(x,n) = 2^{-\frac{E[h(x)]}{c(n)}} \quad (1)$$

where E[h(x)] denotes the expected isolation path length of observation x, and c(n) is the normalization factor determined by the sample size. Higher anomaly scores indicate observations that are more easily isolated and therefore potentially anomalous [16].

The model was evaluated using its default decision threshold and a fixed-budget ranking procedure. In the latter, the 500 observations receiving the highest anomaly scores were selected, matching the total number of injected anomalies. This ranking-based evaluation permitted a direct comparison of detection sensitivity across the four anomaly categories.

C. Rule-Based Inconsistency Detection. A deterministic validation approach was implemented to assess whether known relationships between attributes could identify the injected inconsistencies. Constraint-based validation is widely used in data cleaning, particularly when errors involve explicit relationships between features [9], [10]. Four validation rules were constructed to correspond to the anomaly categories. These rules checked numerical limits, education-to-education-number mappings, marital–relationship compatibility, and the dataset-specific contextual condition involving age and Doctorate qualifications. For each record, the overall rule-based prediction was obtained by combining individual constraint violations:

$$\hat{y}_{rule}(x) = \mathbb{1}\left(\sum_{j=1}^{4} r_j\,(x) > 0\right) \tag{2}$$

Here, $r_j(x)$ represents the binary outcome of the j-th validation rule, and the indicator function returns 1 when at least one constraint is violated. Because these rules were defined using the same conditions employed during anomaly generation, the approach represents a constraint-aware reference rather than a general-purpose detector. Its purpose was to establish the performance achievable when the relevant inconsistency definitions are already available.

D. LLM-Based Anomaly Detection. The language-model approach employed Qwen3-4B-Instruct-2507 without task-specific fine-tuning [17]. Recent research has demonstrated the potential of LLMs for tabular anomaly detection and structured-data interpretation, while also identifying limitations in their reasoning capabilities [12], [13]. A balanced evaluation subset containing 400 observations was prepared, consisting of 200 normal records and 50 anomalous records from each category. Each observation was converted into a structured feature–value description and processed independently by the LLM. The prompt requested a binary classification, a confidence estimate, and a short explanation supporting the prediction. The final prompt was selected after preliminary testing and applied consistently during the main evaluation. Ground-truth labels and anomaly-generation metadata were excluded from the model input. This procedure enabled the evaluation of whether the model could recognize inconsistencies from the observed attributes and explain its decisions without access to the predefined anomaly rules.

E. Performance Evaluation and Explanation Fidelity. Detection performance was evaluated using accuracy, precision, recall, F1-score, and category-specific recall. For Isolation Forest, ROC-AUC was also examined to assess its ability to rank anomalous observations above normal records. In addition to classification performance, the LLM was evaluated according to the correctness of its explanations. An explanation was considered faithful only when the model correctly identified a record as anomalous and its justification referred to the actual source of the injected inconsistency. In this study, explanation fidelity refers to agreement between the generated explanation and the known source of the injected inconsistency, rather than direct verification of the model's internal reasoning process. This distinction is important because an accurate classification may be accompanied by an unrelated or unsupported explanation [13], [18]. To quantify this relationship, the joint detection-and-explanation fidelity rate was defined as:

$$F_k = \frac{1}{N_k}\sum_{i=1}^{N_k} d_i\ e_i \tag{3}$$

where N_k is the number of anomalous records belonging to category k, d_i indicates whether the anomaly was correctly detected, and e_i indicates whether the explanation correctly identified the injected inconsistency. The

resulting measure represents the proportion of records for which both detection and explanation were successful. Explanation assessment used category-specific criteria reflecting the known anomaly-generation mechanisms. Automated keyword-based checks were used for preliminary assessment, and records were exported for manual examination of explanation correctness. This procedure was intended to distinguish meaningful identification of an inconsistency from generic statements about unusual records.

IV. EXPERIMENTAL RESULTS

A. Comparative Detection Performance. The experimental evaluation revealed considerable differences in the ability of the three approaches to identify inconsistent records. Figure 2 presents the anomaly recall achieved by Isolation Forest, explicit rules, and Qwen3-4B-Instruct across the four anomaly categories.

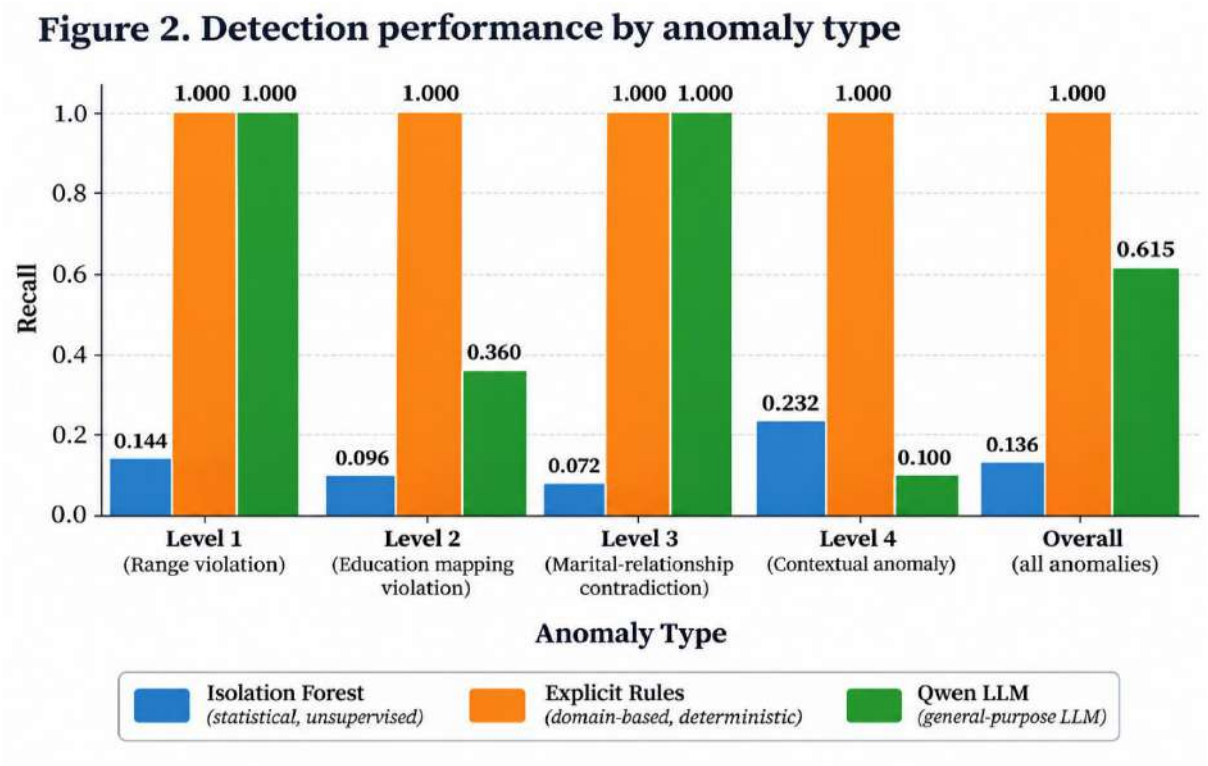


Fig. 2. Per-category and overall anomaly recall for Isolation Forest, explicit rules, and Qwen LLM.

Isolation Forest achieved an overall anomaly recall of 13.6% under the fixed top-500 detection budget. Its recall values were 14.4%, 9.6%, 7.2%, and 23.2% for Levels 1–4, respectively. The model also obtained a ROC-AUC of 0.5995, indicating limited discrimination between normal and anomalous observations. Among the four categories, contextual anomalies produced the highest recall, whereas marital–relationship contradictions were detected least frequently. Explicit rule-based validation achieved 100% recall across all anomaly categories. Since the rules were constructed to match the injected inconsistencies, all 500 anomalous observations were identified. This result represents performance under known validation constraints rather than detection of previously unspecified anomalies. Qwen achieved an overall anomaly recall of 61.5%. The model correctly identified all 50 anomalous records in both Level 1 and Level 3, corresponding to 100% recall in these categories. However, its performance decreased to 36% for education-mapping inconsistencies and 10% for contextual anomalies. These results correspond to 18 and 5 correctly detected anomalies out of 50, respectively. The Isolation Forest and rule-based results were obtained using the 5,500-record benchmark, whereas Qwen was evaluated on a balanced 400-record subset. Consequently, Figure 2 provides a descriptive comparison across the respective evaluation settings rather than a strictly matched comparison on identical test observations.

B. LLM Classification Performance. The classification performance of Qwen was further examined using the confusion matrix presented in Figure 3. The evaluation subset contained 200 normal records and 200 anomalous records, with the latter distributed equally across the four anomaly categories.

Figure 3. Confusion matrix for Qwen LLM (400 records)

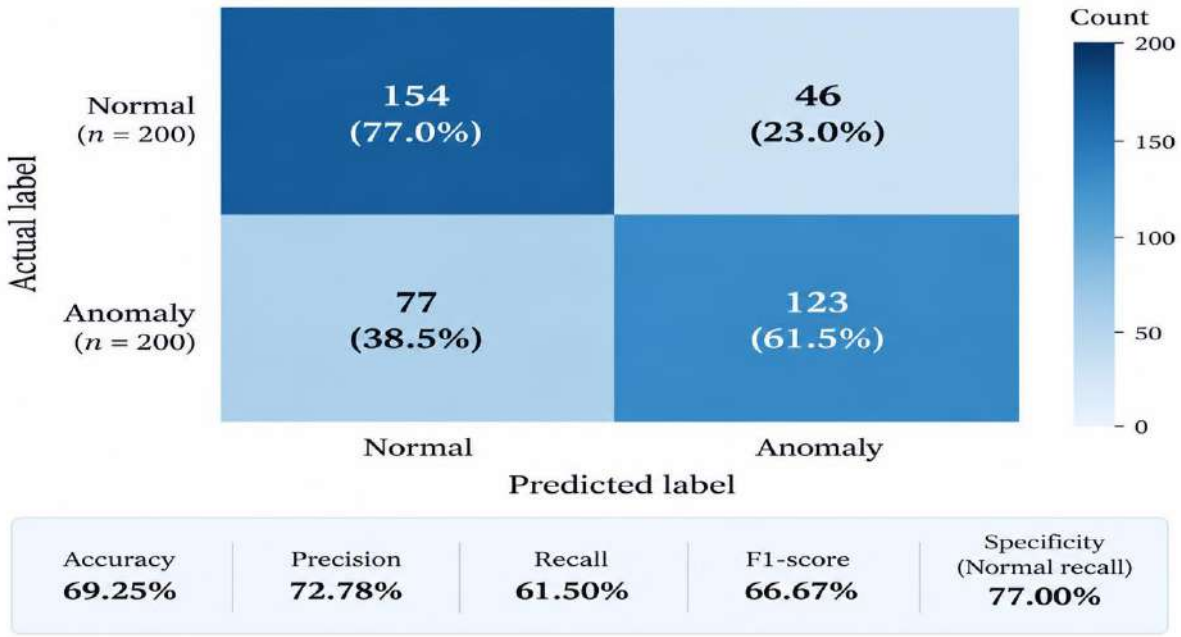


Fig. 3. Confusion matrix and overall classification metrics for Qwen3-4B-Instruct on the 400-record evaluation subset.

The model correctly classified 154 normal observations and 123 anomalous observations. The remaining predictions consisted of 46 false positives and 77 false negatives. These results produced an overall accuracy of 69.25%, precision of 72.78%, recall of 61.50%, and F1-score of 66.67%. Specificity reached 77.00%, indicating that the model correctly recognized 154 of the 200 normal observations. The confusion matrix also shows that false negatives occurred more frequently than false positives. Of the 200 anomalous records, 38.5% were classified as normal. This result is consistent with the low detection recall observed for education-mapping and contextual anomalies in Figure 2.

C. Explanation Fidelity Analysis. In addition to anomaly classification, the evaluation examined whether Qwen correctly identified the underlying inconsistency in its generated explanations. Figure 4 compares detection recall with joint detection-and-explanation fidelity for each anomaly category. The latter measures the proportion of anomalous records for which both the classification and the explanation were correct.

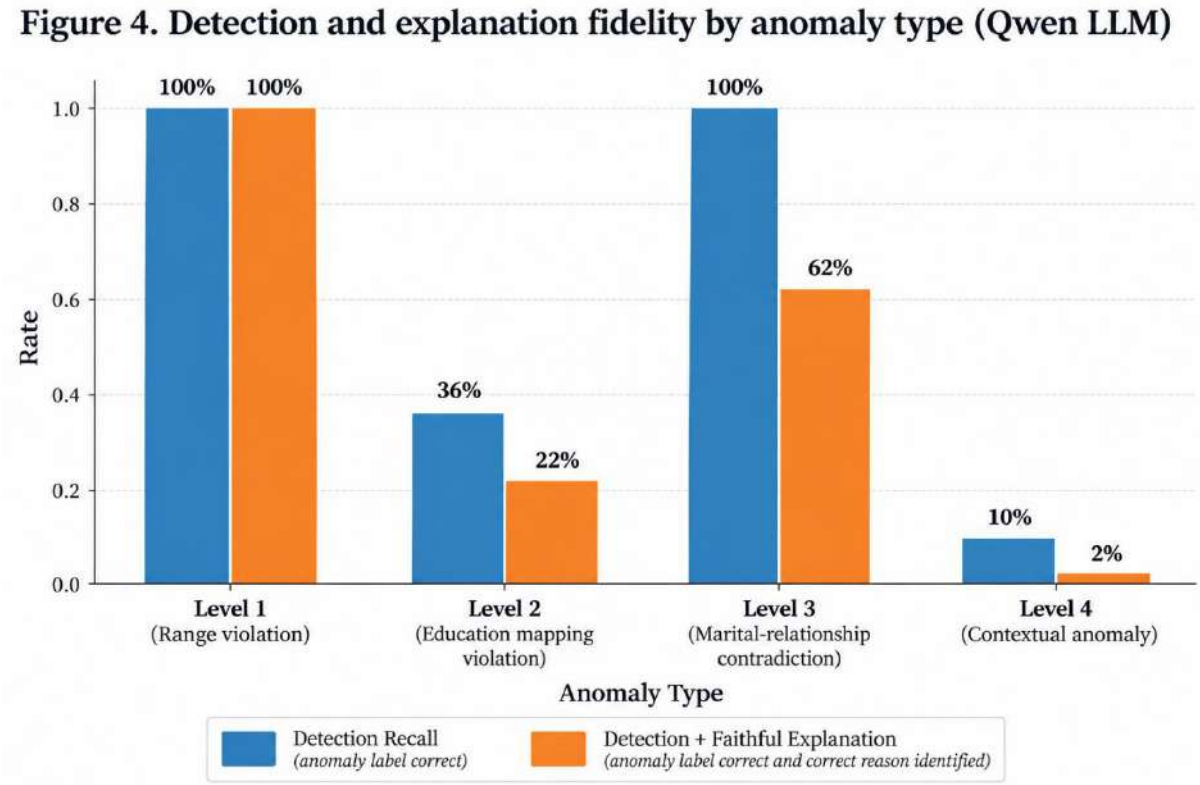


Fig. 4. Detection recall and joint detection–explanation fidelity of Qwen across four anomaly categories.

For Level 1, both detection recall and joint explanation fidelity reached 100%, corresponding to 50 correctly detected and explained anomalies. In Level 2, detection recall was 36%, while joint fidelity decreased to 22%, representing 18 correctly detected anomalies and 11 records with both correct detection and explanation. Level 3 exhibited the largest absolute difference between the two measures. Although all 50 marital–relationship contradictions were detected, only 31 received explanations satisfying the predefined fidelity criteria, resulting in joint fidelity of 62%. For Level 4, the model detected 5 of the 50 contextual anomalies, but only one record was both correctly classified and explained, corresponding to 2% joint fidelity.

Across the 200 anomalous observations, 123 were correctly identified, while 93 satisfied both the detection and explanation criteria. Thus, overall joint fidelity was 46.5%, compared with 61.5% detection recall. The largest reduction occurred for marital–relationship contradictions, where 19 correctly detected records did not receive explanations meeting the fidelity criteria. These findings establish a measurable difference between anomaly identification and explanation correctness. The broader implications of this difference, together with the limitations of the experimental design, are discussed in Section V.

V. DISCUSSION AND CONCLUSION

This study examined how statistical, rule-based, and language-model approaches identify inconsistencies in tabular data. The results show that anomaly detection depends not only on how unusual a record appears, but also on the relationships between its attributes. Isolation Forest showed limited sensitivity to the injected inconsistencies, while explicit rules detected all violations when the corresponding constraints were known. Qwen demonstrated stronger performance on certain numerical and semantic contradictions but struggled with deterministic education mappings and contextual anomalies. A particularly important finding concerns the gap between detection accuracy and explanation reliability. Although Qwen correctly identified all marital–relationship contradictions, only 62% were accompanied by faithful explanations. This suggests that recognizing an inconsistent record does not necessarily mean understanding the specific reason behind it. The main contribution of this research lies in its controlled comparison of three complementary detection

paradigms and the separate evaluation of explanation fidelity. Rather than proposing another anomaly detection algorithm, the study provides a structured way to examine which types of inconsistencies different approaches can recognize and whether their decisions are supported by appropriate explanations. This distinction is especially relevant for applications where data-quality decisions must be understandable and verifiable. Several limitations should be acknowledged. The experiments relied on synthetically introduced anomalies within a single dataset, and the rule-based approach benefited from prior knowledge of the injected constraints. Additionally, the LLM was evaluated on a smaller subset, limiting direct comparability between methods. Explanation fidelity was assessed against predefined criteria, which may not capture every valid interpretation. Future research will focus on extending the benchmark to additional real-world datasets and naturally occurring inconsistencies, evaluating larger and more diverse language models, and strengthening explanation assessment through independent human evaluation. A promising direction is the development of a hybrid validation framework that combines statistical anomaly scores, explicit constraints, and LLM-generated explanations. Such a system could use deterministic checks for known violations while supporting the investigation of less clearly defined inconsistencies. Overall, the findings suggest that no single approach adequately addresses every form of tabular inconsistency. Reliable data validation requires not only detecting suspicious records but also establishing whether the reasons provided for those decisions are correct. This study offers an experimental foundation for developing data-quality systems that are both more effective and more interpretable.

References

[1] S. Jäger and F. Biessmann, “From Data Imputation to Data Cleaning—Automated Cleaning of Tabular Data Improves Downstream Predictive Performance,” in Proc. 27th Int. Conf. Artificial Intelligence and Statistics (AISTATS), PMLR, vol. 238, pp. 3394–3402, 2024.

[2] H. Thimonier, F. Popineau, A. Rimmel, and B.-L. Doan, “Beyond Individual Input for Deep Anomaly Detection on Tabular Data,” in Proc. 41st Int. Conf. Machine Learning (ICML), PMLR, vol. 235, pp. 48097–48123, 2024.

[3] A. Li, Y. Zhao, C. Qiu, M. Kloft, P. Smyth, M. Rudolph, and S. Mandt, “Anomaly Detection of Tabular Data Using LLMs,” arXiv:2406.16308, 2024.

[4] C.-P. Tsai, G. Teng, P. Wallis, and W. Ding, “AnoLLM: Large Language Models for Tabular Anomaly Detection,” in Proc. International Conference on Learning Representations (ICLR), 2025.

[5] T. Liu, F. Wang, and M. Chen, “Rethinking Tabular Data Understanding with Large Language Models,” in Proc. NAACL-HLT, pp. 450–482, 2024. DOI: 10.18653/v1/2024.naacl-long.26.

[6] M. R. Choudhury, A. I. K. N. Iyengar, S. Siingh, S. Puranam, and V. Gupta, “TABARD: A Novel Benchmark for Tabular Anomaly Analysis, Reasoning and Detection,” in Findings of EMNLP, pp. 21783–21817, 2025. DOI: 10.18653/v1/2025.findings-emnlp.1189.

[7] N. Li, Y. Qi, C. Li, and Z. Zhao, “Active Learning for Data Quality Control: A Survey,” *ACM Journal of Data and Information Quality*, vol. 16, no. 2, Art. no. 11, pp. 1–45, 2024, doi: 10.1145/3663369.

[8] X. Zhao, X. Leng, L. Wang, N. Wang, and Y. Liu, “Efficient anomaly detection in tabular cybersecurity data using large language models,” *Scientific Reports*, vol. 15, Art. no. 3344, 2025, doi: 10.1038/s41598-025-88050-z.

[9] G. Mecca, P. Papotti, D. Santoro, and E. Veltri, “BUNNI: Learning Repair Actions in Rule-driven Data Cleaning,” *ACM Journal of Data and Information Quality*, vol. 16, no. 2, Art. no. 12, pp. 1–31, 2024, doi: 10.1145/3665930.

[10] A. Akella, A. Kaul, K. Narayanam, and S. Mehta, "Quality Assessment of Tabular Data using Large Language Models and Code Generation," in *Proc. EMNLP 2025: Industry Track*, pp. 2713–2748, 2025, doi: 10.18653/v1/2025.emnlp-industry.183.

[11] W. Lu, J. Zhang, J. Fan, Z. Fu, Y. Chen, and X. Du, "Large Language Model for Table Processing: A Survey," *Frontiers of Computer Science*, vol. 19, Art. no. 192350, 2025, doi: 10.1007/s11704-024-40763-6.

[12] A. Madsen, S. Chandar, and S. Reddy, "Are self-explanations from Large Language Models faithful?" in *Findings of the Association for Computational Linguistics: ACL 2024*, pp. 295–337, 2024, doi: 10.18653/v1/2024.findings-acl.19.

[13] L. Parcalabescu and A. Frank, "On Measuring Faithfulness or Self-consistency of Natural Language Explanations," in *Proc. 62nd Annual Meeting of the Association for Computational Linguistics (ACL)*, pp. 6048–6089, 2024, doi: 10.18653/v1/2024.acl-long.329.

[14] Y. Yang *et al.*, "When LLMs Read Tables Carelessly: Measuring and Reducing Data Referencing Errors," in *Proc. 64th Annual Meeting of the Association for Computational Linguistics (ACL)*, pp. 16734–16752, 2026, doi: 10.18653/v1/2026.acl-long.762.

[15] C. Mok and S. B. Kim, "Corruption-based anomaly detection and interpretation in tabular data," *Pattern Recognition*, vol. 159, Art. no. 111149, 2025, doi: 10.1016/j.patcog.2024.111149.

[16] F. T. Liu, K. M. Ting, and Z.-H. Zhou, "Isolation Forest," in *Proc. 8th IEEE Int. Conf. Data Mining (ICDM)*, pp. 413–422, 2008, doi: 10.1109/ICDM.2008.17.

[17] A. Yang *et al.*, "Qwen3 Technical Report," arXiv:2505.09388, 2025.

[18] Z. Ji *et al.*, "Survey of Hallucination in Natural Language Generation," *ACM Computing Surveys*, vol. 55, no. 12, Art. no. 248, 2023, doi: 10.1145/3571730.

[19] B. Becker and R. Kohavi, "Adult," UCI Machine Learning Repository, 1996, doi: 10.24432/C5XW20.

SYNTHESIS, CRYSTAL STRUCTURE AND OPTICAL PROPERTIES OF A NON-CENTROSYMMETRIC ORGANIC-INORGANIC HEXACHLOROBISMUTHATE(III) HYBRID MATERIAL

Manel Essid
Zouhaier Aloui
University of Carthage, Faculty of Sciences of Bizerte, LR13ES08, Laboratory of Materials Chemistry, 7021, Zarzouna Bizerte, Tunisia.
King Khalid University, College of Science, Chemistry Department, Abha, Saudi Arabia.

Abstract

A new organic-inorganic hybrid compound, **$(C_8H_{12}N)_3BiCl_6$**, was successfully synthesized by solution growth and characterized using single-crystal X-ray diffraction, FTIR, Raman spectroscopy, solid-state CP-MAS NMR, UV-Vis spectroscopy, luminescence measurements, differential scanning calorimetry (DSC), and Hirshfeld surface analysis. The compound crystallizes in the non-centrosymmetric orthorhombic space group **$Pna2_1$**, featuring isolated distorted **$[BiCl_6]^{3-}$** octahedra surrounded by three crystallographically independent 2-phenylethylammonium cations. The crystal packing is stabilized by a three-dimensional network of N-H···Cl hydrogen bonds and electrostatic interactions. Hirshfeld surface and fingerprint plot analyses reveal that H···Cl and H···H contacts dominate the intermolecular interactions, contributing 42.5% and 38.6% of the total surface, respectively. Optical investigations show absorption bands at 281, 320, and 364 nm, with an optical band gap of 4.42 eV. The material exhibits yellow-green luminescence under UV excitation, with emission bands centered at 545 and 584 nm, attributed to electronic transitions within the chlorobismuthate inorganic framework. Thermal analysis confirms structural stability up to approximately 210 °C. The combination of a non-centrosymmetric crystal structure, wide band gap, and luminescent behavior makes this hybrid bismuth halide a promising candidate for optical and photonic applications.

Keywords: Organic-inorganic hybrid materials; Bismuth halides; Crystal structure; Hirshfeld surface analysis; Luminescence; Optical properties.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

WIND-INDUCED KELVIN–HELMHOLTZ INSTABILITY AT THE AIR–SEA INTERFACE: IMPLICATIONS FOR MARINE HYDRODYNAMICS

Jamila BOUCHGL
Hamid OUAISSA
Mustapha LAMINE
Khadija OUAISSA
Higher Institute of Marine Fisheries-Agadir
Laboratory of Energy Engineering, Materials and Systems, ENSA, Agadir Morocco
Laboratory of Mechanics and High Energy Physics, Faculty of Sciences Aïn-Chock, Hassan II University of Casablanca, P.O. Box 5366 Maarif Casablanca 20100, Morocco.
Environmental, Ecological and Agro-Industrial Engineering Laboratory. Department of Biology, Faculty of Sciences and Techniques. University Sultan Moulay Slimane. Beni-Mellal, Morocco.

Abstract
Wind-wave initiation involves the interaction of atmospheric shear with a deformable air–sea interface. Here, a hierarchical linear-stability framework is developed to examine capillary–gravity disturbances under idealized velocity discontinuities, viscous two-layer shear and prescribed non-uniform wind profiles. First, an inviscid Kelvin-Helmholtz dispersion relation is used to identify unstable wavenumber intervals and a reference minimum velocity difference. For air and seawater densities of 1.225 and 1025 kg m^{-3} and surface tension of 0.072 N m^{-1}, the idealized minimum shear threshold is 6.63 m s^{-1} at a wavelength of approximately 1.68 cm. A two-domain Chebyshev collocation solver is then verified against finite-depth analytical dispersion roots. Next, the coupled viscous Orr–Sommerfeld problem is formulated with interfacial kinematic and stress conditions. The selected capillary–gravity branch is damped over the investigated wavenumbers. Finally, prescribed logarithmic-like air and exponential water profiles are considered to explore the influence of wind forcing. For the reference profile parameter U_{10} = 8 m s^{-1}, the tracked interfacial branch exhibits growth rates of 0.04399 and 0.02540 s^{-1} at wavenumbers 100 and 150 m^{-1}, while at 200 m^{-1} it is damped at −0.00786 s^{-1}. Convergence and parameter-sensitivity analyses demonstrate reproducibility of the selected eigenbranch but also substantial dependence on the near-interface wind-profile regularization. This study provides a transparent numerical foundation for investigating air–sea instability and clarifies why ideal Kelvin–Helmholtz thresholds cannot be equated with observed wind-wave onset. The calculations are linear-stability predictions-not direct numerical simulations, experiments, or a calibrated Miles-Phillips model

Keywords: Kelvin–Helmholtz instability; air–sea interface; Orr–Sommerfeld equation; Chebyshev spectral collocation; capillary–gravity waves; wind shear; marine hydrodynamics.

INTRODUCTION

The air–sea interface is a dynamically active boundary through which momentum and energy are exchanged between atmosphere and ocean. Wind stress, fluctuations of turbulent pressure and the response of gravity–capillary surface waves jointly control the earliest stages of surface-wave formation. Characterizing the stability of this interface matters for wave forecasting, near-surface transport and the environmental forcing experienced by vessels and offshore facilities. Nevertheless, different physical mechanisms are often grouped under the generic label “Kelvin–Helmholtz instability,” which can obscure the actual onset physics.
For two inviscid fluids moving with different uniform velocities, the classical Kelvin–Helmholtz formulation provides an explicit relation between shear, gravity, surface tension and disturbance growth. Its idealized interface permits a discontinuity of tangential velocity. iles [1] identified a shear-flow mechanism associated with such critical layers, whereas Phillips [2] described initial excitation by turbulent pressure fluctuations. Neither mechanism is identical to a simple vortex-sheet instability. The distinction is essential when numerical thresholds are translated into wind speeds measured at height.

The numerical treatment of two-fluid stability problems has benefited from spectral discretizations of the Rayleigh and Orr–Sommerfeld equations. Chebyshev methods can resolve smooth eigenfunctions efficiently [3,4], and the inclusion of interfacial conditions permits systematic examination of viscosity, stratification and capillarity [5–7]. Viscous wave damping and additional decaying eigenmodes must also be considered [8]. The present work combines these elements in one reproducible hierarchy of models, connecting analytical limits with spectral eigenvalue calculations.

Our objectives are to (i) quantify the classical inviscid Kelvin–Helmholtz instability domain; (ii) verify a two-layer Chebyshev solver against the exact finite-depth vortex-sheet relation; (iii) study a viscous case using coupled Orr–Sommerfeld equations; and (iv) characterize the sensitivity of an interfacial eigenbranch to a prescribed non-uniform wind profile. The aim is methodological and mechanistic. No claim is made here to a measured oceanic onset speed, a fully resolved turbulent atmosphere, or a computed nonlinear wave field.

PHYSICAL MODEL AND MATHEMATICAL FORMULATION

a) Configuration and fluid properties

Let x be the horizontal coordinate and z the vertical coordinate, with the undisturbed interface at z = 0. The air layer occupies z > 0 and the seawater layer z < 0. Both fluids are treated as incompressible and Newtonian. Perturbations are two-dimensional, infinitesimal and normal-mode periodic in x.

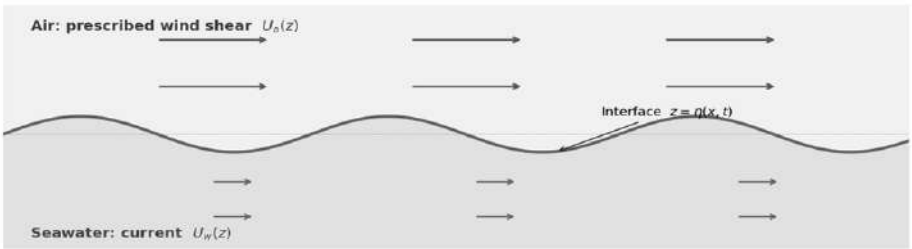


Figure 1: Sheared flow on both sides of a deformable interface

Table 1: Fluid properties and physical constants used in the air–sea interface model

Property	Air	Seawater
Density, ρ (kg m^{-3})	1.225	1025
Dynamic viscosity, μ (Pa s)	1.81×10^{-5}	1.08×10^{-3}
Kinematic viscosity, ν = μ/ρ (m^2 s^{-1})	1.48×10^{-5}	1.05×10^{-6}
Surface tension, σ (N m^{-1})	-	0.072
Gravity, g (m s^{-2})	-	9.81

Each stage employs its own computational truncation, as specified below. Gravity acts in the negative z direction and the surface tension coefficient is taken constant.

These properties are representative reference values for exploratory calculations, not measurements from a specific field campaign. Salinity, temperature and surfactant concentrations may change density, viscosity and surface tension.

b) Perturbation representation and governing equations

The incompressible continuity and momentum equations apply separately in each layer, with base velocity $U_j(z)$ aligned with x. A disturbance of the interface takes the form:

$$\eta(x,t) = \hat{\eta} e^{ik(x-ct)},\ c = c_r + ic_i \qquad (1)$$

The vertical velocity perturbation is represented by a stream function amplitude $\varphi_j(z)$. The temporal amplitude varies as $\exp(\gamma t)$, with $\gamma = k\,\mathrm{Im}(c)$. Positive γ denotes exponential growth and negative γ denotes damping. A positive imaginary phase speed is therefore an unstable temporal eigenvalue.

$$y(k) = kln(c) \tag{2}$$

c) Inviscid Kelvin–Helmholtz model

For uniform velocities U_a and U_w in inviscid layers of infinite depth, linearized kinematic and dynamic conditions yield:

$$\rho_a(\omega - kU_a)^2 + \rho_w(\omega - kU_w)^2 = (\rho_w - \rho_a)gk + \sigma k^3 \tag{3}$$

Writing $\Delta U = |U_a - U_w|$ and using $\omega = kc$, the temporal growth rate is:

$$\gamma = \left[\frac{\rho_a\rho_w}{(\rho_a+\rho_w)^2}(\Delta U)^2k^2 - \frac{(\rho_w-\rho_a)gk+\sigma k^3}{\rho_a+\rho_w}\right]_+^{1/2} \tag{4}$$

The notation $[\cdot]_+$ indicates that the growth rate is set to zero outside the unstable band. The threshold at each wavenumber is obtained from vanishing discriminant:

$$\Delta U^2_{\mathrm{crit}}(k) = \frac{\rho_a+\rho_w}{\rho_a\rho_w}\left[\frac{(\rho_w-\rho_a)g}{k} + \sigma k\right] \tag{5}$$

For finite layer depths H_a and H_w with impermeable distant boundaries, the corresponding exact inviscid phase-speed roots are expressed using weights $W_j = \rho_j \coth(kH_j)$. These finite-depth roots are the appropriate analytical reference for the finite-domain Rayleigh solver; the infinite-depth threshold is reported separately.

$$c_\pm = \frac{W_aU_a + W_wU_w}{W_a+W_w} \pm \sqrt{\frac{(\rho_w-\rho_a)g+\sigma k^2}{k(W_a+W_w)} - \frac{W_aW_w(\Delta U)^2}{(W_a+W_w)^2}} \tag{6}$$

d) Inviscid shear flow and viscous Orr–Sommerfeld equations

For a non-uniform inviscid basic flow, the streamfunction satisfies the Rayleigh eigenvalue equation (with $D \equiv d/dz$). For viscous two-layer motion it is replaced by the fourth-order Orr–Sommerfeld equation in each phase:

$$(U_j - c)(D^2 - k^2)\phi_j - U_j''\phi_j = 0 \tag{7}$$

$$\mu_j(D^2-k^2)^2\phi_j - ik\rho_j\left[U_j(D^2-k^2)\phi_j - U_j''\phi_j\right] = -ik\rho_j c(D^2-k^2)\phi_j \tag{8}$$

At $z = 0$, both fluids share the same infinitesimal interfacial displacement. The linearized kinematic relations ensure that the normal fluid velocity follows the interface. In the viscous formulation, tangential velocity and tangential stress are continuous, while the jump of normal stress balances gravity and surface tension. The displaced-interface corrections associated with jumps in base-flow derivatives are retained. At the artificially truncated remote boundaries, perturbation no-slip and no-penetration conditions are imposed; these are computational boundary conditions, not physical ocean-floor or atmospheric conditions.

NUMERICAL METHODOLOGY

The air and water domains are mapped independently to the standard interval $\xi \in [-1,1]$ of Chebyshev. We employ Chebyshev–Gauss–Lobatto nodes $\xi_m = \cos(m\pi/N)$, $m = 0,\ldots,N$. Spectral differentiation matrices

approximate D, D^2 and D^4 with metric factors that account for each physical layer thickness. The discrete interior operators and interfacial boundary rows are assembled into the generalized eigenvalue problem:

$$\mathbf{A}\mathbf{q} = c\,\mathbf{B}\mathbf{q}, \qquad \mathbf{q} = (\phi_a, \phi_w, \eta)^T \tag{9}$$

The matrices are solved with a generalized eigensolver (QZ/eig). Eigenvectors are normalized for visualization and selected branches are followed by proximity to an inviscid capillary–gravity reference and interfacial participation criteria. A small algebraic eigenpair residual establishes that the assembled matrix equation is solved, but does not by itself demonstrate physical convergence. Spectral refinement and branch identification are therefore carried out separately [3–7].

Four checks are applied: (i) comparison of inviscid eigenvalues with the finite-depth dispersion relation; (ii) Chebyshev-order refinement of individual branches; (iii) comparison of zero-shear viscous dispersion and damping with the expected capillary–gravity scale; and (iv) residual monitoring and parametric sensitivity. Mode tracking is restricted to a selected right-going interfacial branch, not a global search of every eigenvalue. The difference is important because more unstable shear modes may exist outside the tracked family.

RESULTS AND DISCUSSION

a) Ideal Kelvin–Helmholtz threshold and unstable wavelengths

Minimizing Eq. (5) with respect to k gives $k^c = [(\rho_w - \rho_a)g/\sigma]^{1/2}$. At the reference properties, the minimum threshold is $\Delta U^c = 6.6299$ m s^{-1}, attained at $k^c = 373.48$ m^{-1} and $\lambda^c = 2\pi/k^c = 1.682$ cm.

Table 2: Unstable wavelength intervals and peak growth rates of Kelvin–Helmholtz instability at the air–sea interface for different velocity differences.

Velocity difference ΔU	Unstable wavelength interval	Peak growth rate, γmax
6 m s^{-1}	None	0 s^{-1}
7 m s^{-1}	about 1.05–2.70 cm	about 32.1 s^{-1}
8 m s^{-1}	about 0.67–4.23 cm	about 81.3 s^{-1}
10 m s^{-1}	about 0.39–7.27 cm	about 200.3 s^{-1}

These are exact algebraic consequences of the ideal infinite-depth discontinuous-velocity model. The neutral value is not a wind-onset speed at meteorological observation height.

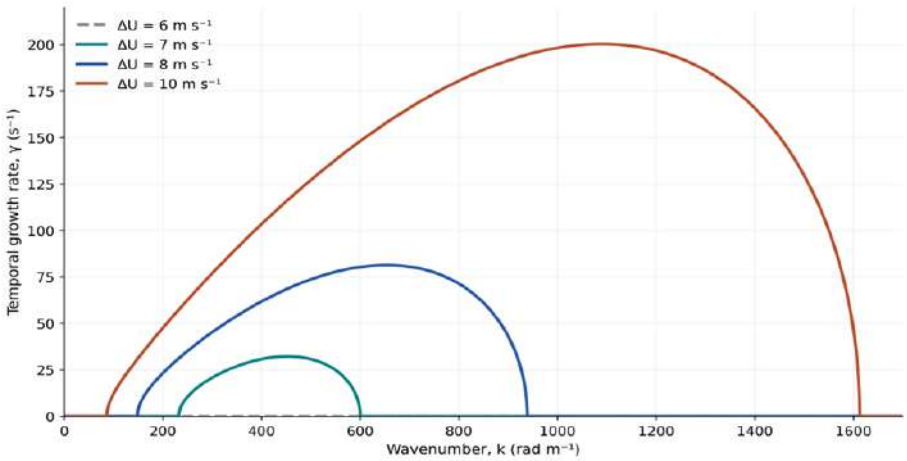


Figure 2: Linear Kelvin–Helmholtz growth rate at the air–sea interface

The unstable intervals widen rapidly with increasing velocity difference, and maximum growth increases sharply. Such values are large because viscosity, turbulence and finite interface-thickness effects are absent. They serve as an instructive analytical limit, not as forecasts of actual ocean-wave exponential growth.

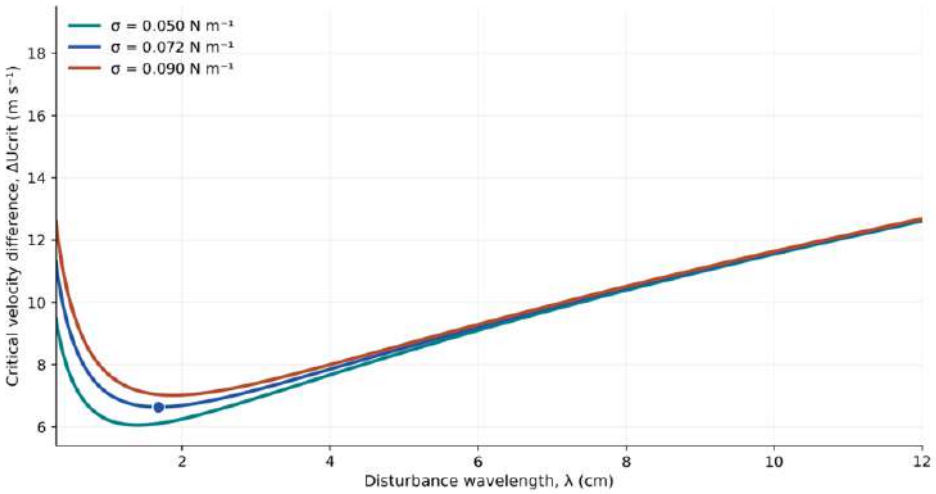


Figure 3: Effect of surface tension on neutral stability

b) Verification of the inviscid Chebyshev solver

With finite-depth impermeable boundaries, the spectral solver reproduces the associated analytical roots for the uniform-velocity problem. For the $\Delta U = 8$ m s^{-1} benchmark, the computed discrete growth points overlay the finite-depth analytical curve. The relative error for growing modes is on the order of 10^{-9} in the reported sample at N = 80 per layer. This is a strong discretization check for the simple vortex-sheet limit, but does not establish the accuracy of sheared or viscous flows.

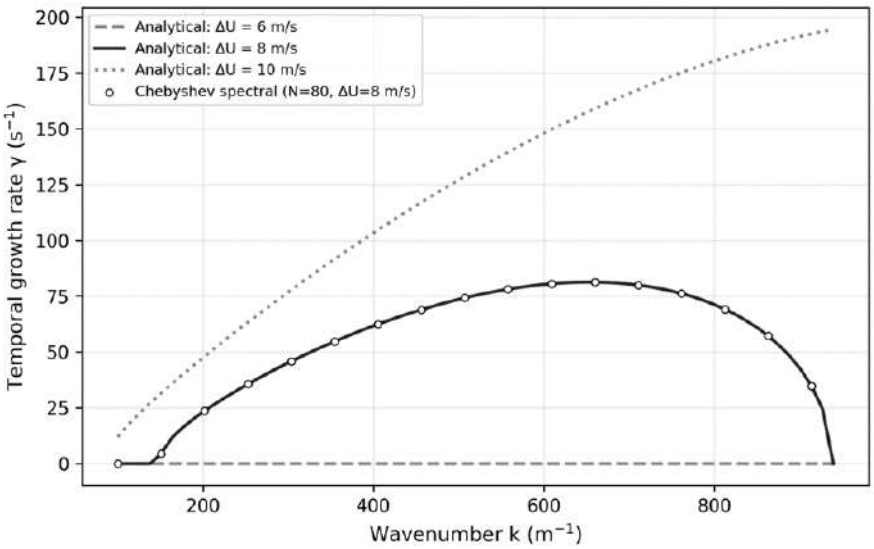


Figure 4: Air–Sea Kelvin–Helmholtz instability: validation

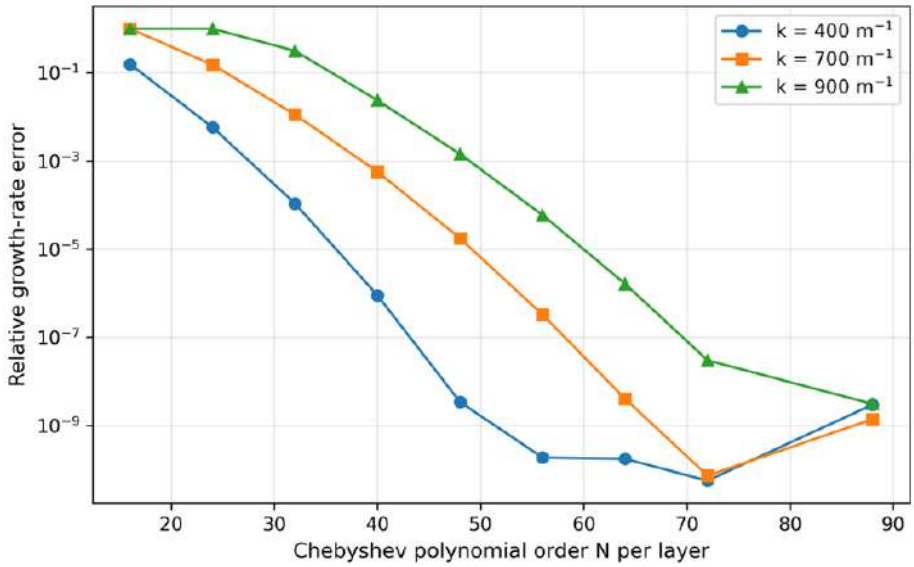


Figure 5: Spectral convergence against exact finite-depth dispersion

c) Prescribed logarithmic wind: growth and damping of the tracked branch

The prescribed air profile is strongly curved near the interface, while the water current varies over a short exponential scale. For U_{10} = 8 m s^{-1} and U_i = 0.10 m s^{-1}, the selected interfacial eigenbranch has positive growth at k = 100 and 150 m^{-1}, changing to damping by k = 200 m^{-1}. When U_{10} increases to 12 m s^{-1}, the tracked branch also grows at k = 200 m^{-1}.

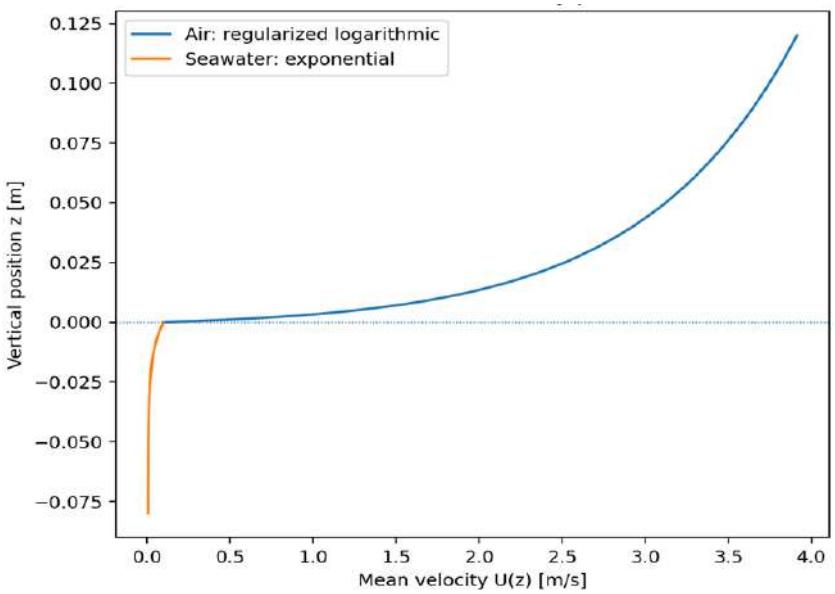


Figure 6: Prescribed mean-flow profiles in the air and water domains. The air curve is the part of the logarithmic-like profile lying within the 0.12 m computational domain.

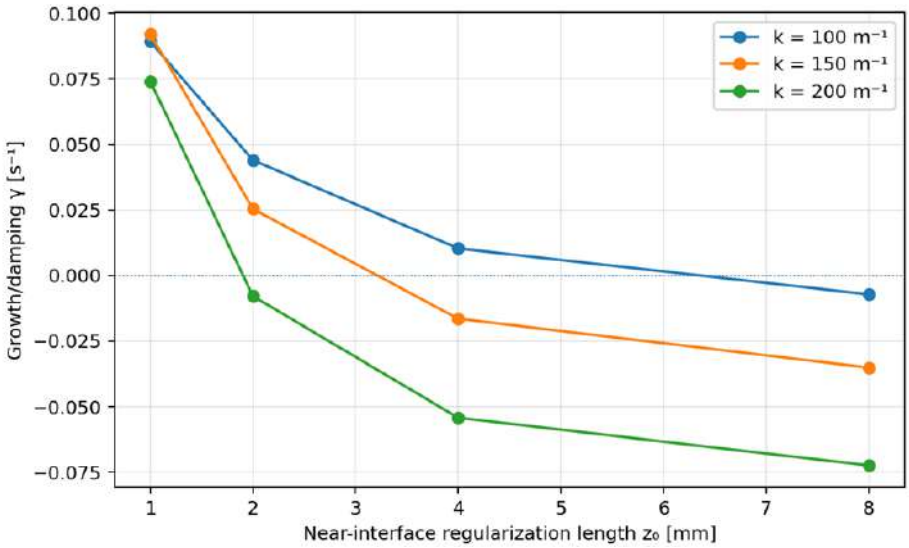


Figure 7: Sensitivity of the selected growth rate to the prescribed near-interface regularization length z_0 at $U_{10} = 8$ m s^{-1}. This is a numerical model-sensitivity test.

The ideal-model results illustrate the competition between destabilizing velocity shear and the restoring effects of gravity and surface tension. Increasing the velocity difference broadens the unstable wavelength interval and increases the maximum growth rate. For example, increasing ΔU from 7 to 10 m s^{-1} expands the unstable interval from approximately 1.05–2.70 cm to 0.39–7.27 cm, while the peak growth rate increases from approximately 32.1 to 200.3 s^{-1}. These predictions describe the initial amplification of infinitesimal disturbances within the assumptions of the ideal formulation.

The minimum velocity-difference threshold of approximately 6.63 m s^{-1}, associated with a wavelength near 1.68 cm, provides a reference for the ideal air–seawater configuration. However, this threshold cannot be interpreted directly as a critical wind speed at 10 m above the sea surface. The ideal velocity discontinuity and the reference speed U_{10} of a vertically varying wind profile represent different base-flow descriptions.

Agreement between Chebyshev collocation and the exact finite-depth dispersion relation supports the numerical accuracy of the ideal formulation. This verification must be distinguished from validation of the viscous calculations and their physical applicability. The latter require independent checks of spatial resolution, domain extent, eigenvalue residuals, and interfacial boundary conditions.

The viscous calculations highlight the importance of the prescribed base flow. Whereas the selected capillary–gravity mode is damped, the tracked branch exhibits growth at $k = 100$ and 150 m^{-1} for $U_{10} = 8$ m s^{-1} with the logarithmic-like wind profile, and damping at $k = 200$ m^{-1}. These observations concern the selected branch and do not establish the stability of the complete eigenvalue spectrum.

The strong sensitivity to near-interface regularization is a central limitation of the present predictions. Changing the regularization modifies the local velocity gradients and therefore the coefficients governing the stability problem. A systematic sensitivity analysis is needed to identify which growth-rate trends remain robust across plausible profile choices. Furthermore, the present linear analysis does not resolve finite-amplitude saturation, wave breaking, or turbulent mixing. Its relevance to marine hydrodynamics therefore lies in identifying conditions for initial disturbance growth and providing a basis for subsequent experimental and nonlinear investigations.

CONCLUSION

A progressive spectral framework was developed to investigate air–sea interfacial stability, extending from the ideal Kelvin–Helmholtz model to viscous formulations incorporating uniform shear and a prescribed non-uniform wind profile. Chebyshev collocation accurately reproduces the finite-depth analytical dispersion relation for the ideal configuration. For the reference air–seawater properties, the ideal model predicts a minimum velocity-difference threshold of approximately 6.63 m s^{-1} at a wavelength near 1.68 cm. Increasing the velocity difference broadens the unstable wavelength interval and enhances the maximum growth rate.

The viscous results show damping of the selected mode in the viscous configuration and growth of the tracked branch at selected wavenumbers under the prescribed logarithmic-like wind profile. However, the strong dependence on near-interface regularization limits the generality of these predictions and emphasizes the importance of precise base-flow specification. The ideal threshold should therefore be regarded as a theoretical reference rather than a direct predictor of ocean-wave onset. Future work should establish convergence of the viscous modes, assess the full spectrum, compare predictions with independent benchmarks and measurements, and investigate nonlinear disturbance evolution.

REFERENCES

[1] Miles, J. W. (1957). On the generation of surface waves by shear flows. Journal of Fluid Mechanics, 3(2), 185–204. https://doi.org/10.1017/S0022112057000567

[2] Phillips, O. M. (1957). On the generation of waves by turbulent wind. Journal of Fluid Mechanics, 2(5), 417–445. https://doi.org/10.1017/S0022112057000233

[3] Orszag, S. A. (1971). Accurate solution of the Orr–Sommerfeld stability equation. Journal of Fluid Mechanics, 50(4), 689–703. https://doi.org/10.1017/S0022112071002842

[4] Trefethen, L. N. (2000). Spectral Methods in MATLAB. SIAM. https://doi.org/10.1137/1.9780898719598

[5] Boomkamp, P. A. M., & Miesen, R. H. M. (1997). Classification of instabilities in parallel two-phase flow. International Journal of Multiphase Flow, 22(Suppl.), 67–88. https://doi.org/10.1016/S0301-9322(96)90005-1

[6] Boomkamp, P. A. M., Boersma, B. J., Miesen, R. H. M., & Beijnon, G. V. (1997). A Chebyshev collocation method for solving two-phase flow stability problems. Journal of Computational Physics, 132(2), 191–200. https://doi.org/10.1006/jcph.1996.5571

[7] Barmak, I., Gelfgat, A., Vitoshkin, H., Ullmann, A., & Brauner, N. (2016). Stability of stratified two-phase flows in horizontal channels. Physics of Fluids, 28, 044101. https://doi.org/10.1063/1.4944588

[8] Martel, C., & Knobloch, E. (1997). Damping of nearly inviscid water waves. Physical Review E, 56, 5544. https://doi.org/10.1103/PhysRevE.56.5544

[9] Benjamin, T. B. (1959). Shearing flow over a wavy boundary. Journal of Fluid Mechanics, 6(2), 161–205. https://doi.org/10.1017/S0022112059000568

[10] Miles, J. W. (1960). On the generation of surface waves by turbulent shear flows. Journal of Fluid Mechanics, 7(3), 469–478. https://doi.org/10.1017/S0022112060000220

[11] Drazin, P. G., & Reid, W. H. (2004). Hydrodynamic Stability (2nd ed.). Cambridge University Press.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

CONNECTIVITY, AUTOMATION AND ROBOTIC SYSTEMS IN SMART FACTORIES

Emine Kambur
0000-0003-4946-6867, Mudanya University, Faculty of Arts and Social Sciences, Business Administration, Bursa, Turkey.

Abstract

The Industrial Revolution has typically had an impact on factories, and with the advent of Industry 5.0, they can create and enhance smart industrial output. Automation, robotics, and artificial intelligence are examples of new technologies that can greatly increase operational efficiency and support output in smart factories. The purpose of this study is to investigate how production processes are affected by the interconnected machines, systems, and gadgets utilized in smart factories.

To build intelligent and networked systems, these factories employ a variety of cutting-edge technology, including robotics and cloud computing. Real-time data collection and analysis are made possible by Industry 4.0 factories' sensor-equipped machines that are linked to a network. The decision-making process is then enhanced and optimized using the data. The brain and neurons are where this process starts. Additionally, robots and intelligent systems are frequently used in smart industries to carry out occupations and duties that have historically been performed by people.

Production lines and intelligent systems can be improved by new technologies. Practically speaking, certain smart sensors have the ability to change the current paradigm on various factories' production lines. A range of items are used by smart factories to automate and optimize manufacturing. Additionally, smart factories use cutting-edge technologies to deliver better results than ever before. A people-centered industrial revolution, Industry 5.0 unites human skills. In order to improve the efficiency of production operations and processes, smart factories integrate automation and state-of-the-art technologies. In contemporary factories, smart factories significantly rely on networked machinery, systems, and gadgets that interact with one another and have a centralized control system. Real-time monitoring, analysis, and decision-making are made possible by this kind of link. It enables smooth data transfer between components, allowing for real-time control and monitoring. Automation and robotics are used by certain smart factories to streamline manufacturing procedures. In conclusion, because of linked systems, automation, and robotic technologies, smart factories improve production process efficiency, facilitate quicker decision-making, and enable more effective process management.

Keywords: Smart factories, Robot, Automation.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

DEVELOPMENT OF AN ARTIFICIAL INTELLIGENCE-BASED DECISION SUPPORT SYSTEM FOR DATA RECOVERY FROM HARD DISK DRIVES

Gökhan Erdi DAĞI
Çelebi ULUYOL
0009-0001-4807-4960], Gazi University, Institute of Informatics, Department of Digital Forensics, Ankara, Türkiye.
Prof. Dr., 0000-0001-9774-0547, Gazi University, Gazi Faculty of Education, Department of Computer Education and Instructional Technologies, Ankara, Türkiye.

Abstract

Data recovery from hard disk drives (HDDs) is known to be affected by the selection of an inappropriate method, which can decrease the probability of successful recovery and lead to permanent data loss. Data recovery practices rely on expert experience, manual diagnosis, and case-specific trial-and-error methods. This study aims to develop an artificial intelligence-based decision support system that can classify hard disk errors and recommend appropriate data recovery methods based on technical symptoms and diagnostic data. The aim of approach combines data analytics, machine learning, and knowledge-based decision support methods.In the case, data will be gathered from real error cases and laboratory-generated simulations representing software, mechanical, and electronic HDD errors. Following data preprocessing steps such as handling missing values, detecting outliers, normalising, and encoding categorical variables, a machine learning model will be developed to classify errors types based on symptoms, error logs, hardware characteristics, and performance indicators. The resulting classification outputs will then be integrated into a decision-support module that provides data-recovery recommendations, including whether disk imaging is appropriate and which intervention path to give primacy. The system will be developed using Python, evaluated through statistical performance metrics and operational criteria, and compared with conventional manual decision-making practices. So the aim is to standardise the decision-making process for different failure types and reduce dependence on experts. The study will base the data recovery process on a systematic structure rather than primarily on experience. In another saying that, by transforming it into a data-driven and repeatable decision-making structure, it is expected to reduce human error, improve decision consistency, and support more efficient use of time and resources. The proposed structure is expected to provide a practical approach in environments where data continuity is critical, such as public institutions, data centres, telecommunications operators, and cybersecurity units.

Keywords: data recovery, decision support systems, digital forensics, hard disk drives, machine learning.

SABİT DİSK SÜRÜCÜLERİNDEN VERİ KURTARMA İÇİN YAPAY ZEKÂ TABANLI BİR KARAR DESTEK SİSTEMİNİN GELİŞTİRİLMESİ

Özet

Sabit disk sürücülerinden (HDD) veri kurtarmada, yanlış yöntem seçiminin başarılı kurtarma olasılığını azaltığı ve kalıcı veri kaybına yol açtığı bilinmektedir. Veri kurtarma uygulamaları uzman deneyimine, manuel teşhise ve vakaya özgü deneme-yanılma yöntemlerine dayanmaktadır. Bu çalışma, sabit disk arızalarını sınıflandırabilen ve teknik belirtiler ile tanısal verilere dayanarak uygun veri kurtarma yöntemleri önerebilen yapay zekâ tabanlı bir karar destek sistemi geliştirmeyi hedeflemektedir. Önerilen yaklaşım; veri analitiği, makine öğrenmesi ve bilgi tabanlı karar destek yöntemlerini bir araya getirmektedir. Çalışmada, HDD'lerin mekanik, elektronik ve yazılımsal arızalarını temsil eden gerçek arıza vakalarından ve laboratuvar ortamında oluşturulan simülasyonlardan veri toplanacaktır. Eksik değerlerin giderilmesi, aykırı değerlerin belirlenmesi,

normalizasyon ve kategorik değişkenlerin encode(kodlanması) edilmesi gibi veri ön işleme adımlarının ardından; belirtiler, hata kayıtları, donanım özellikleri ve performans göstergeleri kullanılarak arıza türlerini sınıflandıran makine öğrenmesi modeli geliştirilecektir. Elde edilen sınıflandırma çıktıları daha sonra, disk imajı alınmasının uygun olup olmadığı ve hangi müdahale yolunun önceliklendirilmesi gerektiği gibi veri kurtarma önerileri sunan bir karar destek modülüne entegre edilecektir. Sistem Python yazılım dili kullanılarak geliştirilecek; istatistiksel performans ölçütleri ve operasyonel kriterler aracılığıyla değerlendirilecek ve geleneksel manuel karar verme uygulamalarıyla karşılaştırılacaktır. Böylece farklı arıza türleri için karar sürecinin standart hale getirilmesi ve eğitimli uzmanlara olan bağımlılığın düşürülmesi amaçlanmaktadır. Çalışmanın, veri kurtarma süreci deneyimden daha çok sistematik bir yapıya dayanacaktır. Yani veriye dayalı ve yeniden üretilebilir bir karar verme yapısına dönüştürerek uzman hatasının azaltılması, karar tutarlılığının artırılması ve zaman ile kaynakların daha verimli kullanılmasının desteklemesi hedeflenmektedir. Geliştirilecek yapının kamu kurumları, veri merkezleri, telekom operatörleri ve siber güvenlik birimleri gibi veri sürekliliğinin önemli olduğu ortamlarda uygulanabilir bir yaklaşım sunması hedeflenmektedir.

Anahtar Kelimeler: veri kurtarma, karar destek sistemleri, dijital adli bilişim, sabit disk sürücüleri, makine öğrenmesi.

Giriş

Sabit disk sürücüleri (hard disk drive, HDD), bilgi kaydeden ve okuma/yazma kafalarının konumlandırılmasıyla veriyle iletişim sağlayan depolama olarak tanımlanmaktadır. (SWGDE, 2025b). Bir sabit disk sürücü arızası, sadece aygıtın işletim sistemi tarafından fark edilmemesi şeklinde ortaya çıkmayabilir. Okuma hataları, bölüm tablolarının bozulması, elektronik sorunlar ve fiziksel hasar gibi birbirinden farklı durumlarda görülebilir (Güllüce & Benzer, 2015). Bu kapsamda veri kurtarma, tek bir yazılım aracılığıyla yapılabilecek bir çalışma olmayıp, arızanın türü ve uygulanması planlanan müdahalenin veriye tesirinin birlikte değerlendirilmesi gereken teknik bir problemdir.

Veri kurtarmada önemli kısım, kurtarılması planlanan içeriğin erişebilirliğiyle birlikte orijinal verinin korunmasının da gerektirmesidir. ISO/IEC 27037:2012, bize tüm dijital delil ortamları için elde etme ve muhafaza eylemlerine ilişkin genel bir çerçeve sunmaktadır (ISO/IEC, 2012). Arızalı ya da sorunlu bir diskte geleneksel adli kopyalama işlemleri uygulanması her zaman güvenli değildir ve yeterli olmayabilir. Scientific Working Group on Digital Evidence (SWGDE), arızalanmış veya arızalanma sürecindeki disklerde geleneksel uygulama yaklaşımlarının delil niteliğindeki veriye zarar verebileceği belirtmektedir. Ayrıca özel müdahalelerin ise bu konuda gerekli yetkinliği erişmiş uzman personelce uygun koşullarda yapılması gerektiğini belirtmektedir (SWGDE, 2025b). Aynı zamanda National Institute of Standards and Technology (NIST) rehberi veri inceleme ve raporlamada kullanılan uygulamaların delilenebilir olması gerektiğini önemle vurgulamaktadır (Kent et al. 2006). The United Nations Office on Drugs and Crime (UNODC), dijital verinin elde edilmesi ve saklanması sürecinde bütünlüğün korunması aynı zamanda yapılan işlemlerin kaydı tutularak belgelendirilmesi temel ilkeler arasındadır (UNODC, t.y.).

Bir HDD bulunan hasar türlerini ayırt etmek önemlidir. Örnek verecek olursak; sehven silinmiş bir dosya, dosya sistemi üst verilerinin yanı sıra içerik tabanlı kurtarma teknikleriyle incelenebilir. Fakat anormal ses çıkaran bir sürücüde yinelenen çalıştırma denemeleri daha potansiyel yüksek risk taşıyabilir. Bu karışık ve ikircikli durumlarda veri kurtarma uzmanının görevi sadece bulguları yorumlamakla kalmamaktadır. Aynı zamanda disk imajına geçmenin uygunluğu, okuma işlemlerinin sınırlandırılması, hangi uzmanlık düzeyinin gerektiği ve ne zaman müdahalenin durdurulacağı gibi kararlar alınmalıdır. INTERPOL'ün ilk müdahale rehberi, veri ediniminde kullanılan yöntem, araç, hedef ortam, özet değer ve işlem sırasında meydana gelen olayların kayıt edilmesini önermektedir (INTERPOL, 2021).

Bu çalışmada amaç, HDD arızalarının yazılımsal, mekanik ve elektronik sınıflar bakımından değerlendirilmesini sağlayacak makine öğrenmesi bileşeni ile uzman bilgisine ihtiyaç duyulan güvenlik ve müdahale kurallarını bir araya getiren bir karar destek sistemi geliştirmektir. Sistem, teknik belirtiler, hata kayıtları, donanım bilgileri ve performans göstergelerinden faydalanarak arıza sınıfını tahmin edecek; bu

tahmini disk imajının uygunluğu, kurtarma yolunun önceliği ve uzman müdahalesi gereksinimi hakkında gerekçeli önerilere dönüştürecektir. Bu çalışmada diskin gelecekte ne zaman arızalanacağının tahmini değil, arızalanmış veya veri erişimi bozulmuş bir HDD için güvenli veri kurtarma yönteminin belirlenmesine yönelik kararın desteklenmesi hedeflenmektedir.

Araştırmanın faydası, literatürdeki veri kurtarma, arıza belirlenmesi ve adli karar verme çalışmalarını aynı işlem bağlamında birleştirmeyi amaçlamaktadır. Çalışma, henüz deneysel doğrulaması tamamlanma aşamasında olup bir sistem tasarımı olarak sunulmaktadır.

Materyal ve Method

Kullanılacak yöntem, gerçek HDD arıza vakalarıyla laboratuvar ortamında kontrollü biçimde oluşturulacak simülasyonları bir araya getiren uygulamalı araştırma tasarımı üzerine kurulmuştur. Temel araştırma, belirli bir diske ait tekil vaka kaydıdır. Her vakada gözlemlenen belirtiler, aygıt özellikleri, hataların gözlenme koşulları, uzman tarafından sonradan doğrulanan arıza sınıfı ve gerçekleştirilebilen güvenli müdahalenin sonucu ayrı alanlarda saklanacaktır. INTERPOL'ün laboratuvar rehberinde fiziksel delillerin türü, seri numarası, üreticisi ve gözlenen kusurları gibi tanımlayıcı bilgilerin belgelenmesi önerilmektedir (INTERPOL, 2019). Böylece model girdileri ile öğrenmede hedef olarak kullanılan etiketlerin birbirine karışması önlenmesi hedeflenmektedir. Hasarlı ortamlara yapılacak müdahalelerde yetkili personel ve delilin korunması gereklilikleri temel alınacaktır (SWGDE, 2025b). Adli veri ediniminin kayda alınmasında SWGDE'ye ait edinim rehberindeki ilkeler gözetilecektir (SWGDE, 2025a).

Toplanan veri seti;

(i) disk kimliği ve donanım özellikleri,

(ii) fiziksel/işitsel belirtiler,

(iii) erişim ve okuma davranışı,

(iv) sistem ve aygıt hata kayıtları,

(v) varsa performans ve tanısal göstergeler,

(vi) tanı doğrulama ve müdahale sonuçları başlıkları altında tasarlanmaktadır.

Marka, model, kapasite, bağlantı arabirimi, üretim ailesi ve arıza geçmişi gibi bilgiler vaka bağlamını belirlemek için kullanılabilir. INTERPOL'ün ilk müdahale rehberi, delil olarak ele alınan dijital aygıtın fiziksel özellikleri ve bağlantılarının kayıt edilmesi adli belgelemenin parçası olarak ele almaktadır (INTERPOL, 2021). Bununla birlikte bir belirti tek başına kesin arıza etiketine eşitlenmeyecektir. Örneğin aygıtın tanınmaması bağlantı, elektronik kart veya daha farklı sorunlardan meydana gelebilir. Doğrulama sırasında birden fazla uzmanın görüşü ve teknik inceleme kayıtları birlikte değerlendirilecektir.

Arıza etiketleri, yazılımsal, mekanik ve elektronik olmak üzere üç ana sınıfta başlayacaktır. Karışık yani çoklu arıza olasılığı ve yeterli kanıtın olmadığı durumlar da bu üç sınıfın dışında harici olarak kayıt edilecektir. Tasarım tercihi, eğitim için planlanan örneklerin ölçüt kriterlerinin önceden tanımlanmasını gerektirmektedir. Gerçek vaka kayıtlarından yola çıkılan vakalar ayrı kaynaklar olarak tutulmaktadır. Aynı diskin farklı, değişken zamanlarda kaydedilen gözlemler, test kümelerine dağıtılmayacaktır. Roberts ve arkadaşları, birbirleriyle ilişkili gözlemlere sahip verilerde çapraz doğrulama stratejisi kullanılarak değerlendirme sonuçlarını etkileyebileceğini değerlendirmişlerdir (Roberts et al. 2017). Kapoor ve Narayanan, makine öğrenmesi çalışmalarında veri sızıntısının önemine dikkat çekmişlerdir (Kapoor & Narayanan, 2023). Bu kaynaklar HDD verisi üzerinde deney yapmamış olup, grup düzeyinde ayrım burada önerilen araştırmanın yöntemsel önlemidir.

Tablo 1. Arıza değerlendirmesinde planlanan tanısal kanıtlar, özel durumlar ve güvenli karar ilkeleri.

Arıza	Örnek belirti / veri	Olası karıştırıcı açıklama	Karar desteğinin koruyucu sınırı
Yazılımsal / mantıksal	Dosya sistemi açılamıyor; bölüm kaydı tutarsız; silinmiş içerik	Alttaki fiziksel okuma hataları mantıksal bozulma gibi görülebilir.	Kaynak üzerinde yazma yok; uygun ise doğrulanmış kopyada analiz (Güllüce & Benzer, 2015).
Mekanik / fiziksel	Darbenin nasıl olduğu; olağan dışı ses; kararsız dönme/okuma	Ses veya erişim kesilmesi tek başına hasarlı parçayı teşhis etmez.	Yeniden çalıştırma yerine durdurma ve uzman laboratuvar (SWGDE, 2025b).
Elektronik	Güç almama; PCB üzerinde görünür hasar; aygıtın tanınmaması	Kablo, güç kaynağı ve denetleyici sorunları benzer belirti verir.	Yetkin teknik kontrol; rastgele kart değişimi önerilmez (Sobey et al., 2006).
Hatalı sektör / kısmi erişim	Tekrarlayan okuma hatası; bazı alanlara erişilememe	Aracın hata atlama davranışı ek kayıp üretebilir.	İmaj yöntemi ve atlanan alanlar belgelenir (Lyle & Wozar, 2007).
Belirsiz	Çelişkili bulgular veya eksik tanı verisi	Tek etiket gerçeği temsil etmeyebilir.	Model kararı askıya alınır, yeni doğrulama istenir (Horsman, 2019).

Tablo 1, bir tanı kılavuzu değil; veri setinin hangi tür bilgi ve belirsizlikleri temsil etmesi gerektiğini gösteren kavramsal bir yapıdır. SWGDE'nin hasarlı medya rehberi (SWGDE, 2025b), darbe, sıvı ve yüksek ısı hasarı veya beklenmedik ses gibi durumlarda sürücünün çalıştırılmasının önlenmesi ya da sonlandırılması yönünde somut sınırlamalara ihtiyaç duyar. Bundan dolayı sistemin yapay zeka çıktıları, daha yüksek güvenlik önceliğine sahip kuralları devre dışı bırakamayacaktır. ENFSI'nin uygulama kılavuzu, adli yöntemlerin doğrulanmasında risk analizi ve bilinen hata kaynaklarının belirlenmesini gerekli değerlendirme bileşenleri arasında göstermektedir (ENFSI, 2015). Örneğin model yüksek olasılıkla "yazılımsal/ mantıksal arıza" tahmin etse bile doğrulanmış fiziksel hasar göstergeleri varsa otomatik imaj önerisi üretilmemesi, araştırmada test edilecek önemli bir güvenlik ilkesidir.

Veri ön işleme aşamasında değişkenlerin dağılımları, eksiklik oranları, sınıf dengesizliği ve aykırı örnekler incelenmektedir. Dayanıklı atama yöntemleri ve kategorik alanlarda anlamlı kodlama, gerekirse ölçekleme uygulanmaktadır. Bir kısım aygıtlarda gözlenmeyen ölçümlere başka aygıtlardan gelen gerçek dışı değerlerin benzer olarak direkt taşınmaması temel alınır. Ön işleme yalnızca eğitim bölümünde öğrenilerek test bölümüne uygulanmaktadır. Harici olarak laboratuvar işlemleri, karar anında erişilemeyen bilgi ise model girdisine dahil edilmemektedir. Bu ayrım, modelin gerçekte kullanamayacağı bilgileri öğrenmesinden doğan veri sızıntısını azaltmayı hedeflemektedir (Kapoor & Narayanan, 2023).

Tablo 2. Planlanan veri sözlüğü ve etiket doğrulama

Veri grubu	Önerilen değişken örnekleri	Toplama / kalite notu	Modeldeki işlev
Vaka ve aygıt tanımı	Vaka kodu, disk kodu, marka/model, kapasite, arabirim.	Kimlikler ayrıştırılmalı; aynı disk birden çok örnek oluşturmamalı. Delil kimliği için kurumsal kayıt yaklaşımı (INTERPOL, 2019).	Gruplu veri ayrımı; cihaz bağlamı.
Gözlenebilir belirtiler	Dönme/ses durumu, darbe/ısı öyküsü, nasıl tanındığı.	Teşhis koymadan önceki gözlem; öznel değerlendirme kaydedilir.	Birincil özellik grubu.

Veri grubu	Önerilen değişken örnekleri	Toplama / kalite notu	Modeldeki işlev
Okuma ve hata davranışı	Okuma başarısızlığı, hata türü, hata tekrarı, erişilen bölüm.	Araç ve bağlantı türü ile birlikte kaydedilir.	Arıza sınıflandırması ve risk değerlendirmesi.
Donanım	Arayüz, aygıt ailesi, varsa tanısal ölçüm.	Her disk için bulunmayabilir; ölçüm yokluğu korunur.	Destekleyici özellik.
Uzman doğrulaması	Bağımsız tanı, belirsizlik, doğrulayan uzman, tarih.	Kör veya uzlaşıyla etiketleme; gerekçe raporlanır.	Hedef sınıfın oluşturulması.
Müdahale ve sonuç	İmaj kararı, yöntem, atlanan alan, zarar olayı, veri elde etme	Karar sonrasına ait veri giriş olarak kullanılmaz.	Operasyonel değerlendirme; çıktı etiketi

Sınıflandırma için Logistik Regresyon temel model olarak kullanılacaktır. Ardından Random Forest, LightGBM, KNN ve XGBoost modellerini kullanılarak eğitim yapılacak ve ardından birbirleriyle karşılaştırılıp en iyi sonuç veren model seçilecektir. Daha sonra ise eşik değeri belirlenecek ve bu eşik değere göre ayrı bir karar verilecektir. Belirlenen eşik değerinin altında ise karar verilemiyor/uzmana danışılması gerekiyor yönlendirmesinde bulunması planlanmaktadır.

Karar modülünün önerileri, üç olası müdahale düzeyinde değerlendirilecektir:

(a) uygun koşullarda yazma engellemeli ve kayıtlı adli görüntüleme,

(b) imajdan sonra veya yalnızca güvenli bir kopyada mantıksal kurtarma ve

(c) fiziksel/elektronik risk için deneyimli kurtarma laboratuvarına yönlendirme.

Öneri, zorlayıcı bir komut değil, kanıtlara dayalı tavsiye ve sınırlılık beyanı olarak tasarlanmaktadır. Bir vaka için nihai işlem seçimi, uzman tarafından onaylanmadan uygulanmış sayılmamaktadır. Sistemin her önerisi, kullanılan vaka özellikleri, model sürümü, tetiklenen güvenlik kuralı ve varsa çelişen bulgularla birlikte denetlenebilir olarak kaydedilmektedir (SWGDE, 2025a). INTERPOL, adli kopyalama sürecinde kullanılan araçların, özet değerlerin ve yapılan işlemlerin vaka notlarında belgelenmesini önermektedir (INTERPOL, 2019).

Tablo 3. Yapay zeka sınıflandırması ile bilgi tabanlı güvenlik kurallarını ayıran önerilen hibrit karar destek sisteminin katmanları

Aşama	Sistem katmanı	Planlanan içerik ve işlev
01	Vaka verisi	Teknik belirtiler; hata kayıtları; aygıt özellikleri; uzman notu; kaynak türü.
02	Veri kalitesi	Eksik değer analizi; aykırı değer; kodlama/ölçekleme; kaynak ve etiket denetimi.
03	Makine öğrenmesi	Yazılımsal, mekanik ve elektronik arıza olasılıkları; model güveni; açıklama.
04	Bilgi tabanlı kısıtlar	Delil bütünlüğü; zarar riski; güvenli durdurma; yetki ve müdahale koşulları.
05	Uzman kararı ve çıktı	Teknik müdahale kararı; öncelikli kurtarma yaklaşımı; alternatif; gerekçe; kayıt/raporlama.

Tablo 3'te gösterilen kavramsal katmanlar veri analitiği, makine öğrenmesi ve bilgi tabanlı karar desteği bileşenlerini göstermektedir. Model ile kuralların ayrıştırılması iki nedenle tercih edilmiştir. İlk olarak eğitim verisinden öğrenilen istatistiksel örüntüler, hasarlı HDD ile ilişkili güvenlik kısıtlarını her zaman yakalanmaya bilinmektedir. İkinci olarak, önerinin neden üretildiğinin açıklanması adli bağlamda uzmanın

değerlendirmesini kolaylaştırabilir. ENFSI, dijital adli süreçlerde araçlara ve insan değerlendirmesine bağlı sınırlılıkların anlaşılması ve raporlanması gereğini vurgulamıştır (ENFSI, 2015).

Sistemin yazılımı Python ortamında geliştirilecek; veri işleme, model eğitimi ve öneri oluşturma aşamalarının farklı sürümleri saklanmaktadır. Aynı HDD'ye ait ilişkili gözlemlerin eğitim ve test arasında dağılmaması için disk/vaka düzeyinde grup ayrımı yapılmaktadır; bu tercih yapılandırılmış gözlemler için önerilen bloklu doğrulama yaklaşımıyla uyumludur (Roberts et al., 2017). Model seçimi ve hiperparametre ayarı yalnızca eğitim verisine uygulanmakta; nihai performans, model seçiminde kullanılmamış bağımsız bir test kümesinde raporlanmaktadır. Birleşik Krallık Adli Bilimler Düzenleyicisi, yeni veya uyarlanmış adli yöntemlerin kullanım amacına uygunluğunun belgelenmiş kabul ölçütleri ve doğrulama testleriyle gösterilmesini önermektedir (Forensic Science Regulator, 2024). Varma ve Simon, parametre seçimi ve hata tahmininin aynı çapraz doğrulama sonucuna uygunsuz biçimde dayandırılmasının yanlı performans tahminleri yaratabileceğini göstermiştir (Varma & Simon, 2006). Bu nedenle bütün ön işleme ve model seçimi adımları değerlendirme protokolünde önceden belirlenmektedir. Veri işleme süreçlerinde bilgi sızıntısı riski ayrıca takip edilmektedir (Kapoor & Narayanan, 2023).

Bulgular ve Tartışma

Performans değerlendirmesi birbirini tamamlayan iki seviyede yapılmaktadır. İlk seviyede karışıklık matrisi, sınıf bazında kesinlik ve duyarlılık ile ROC eğrileri ve AUC değerlerine bakılacak bu ölçütlerle arıza sınıflandırma niteliği incelenmektedir. Sokolova ve Lapalme, sınıflandırma başarısının tek bir sayıyla ifade edilmesinin farklı sınıf dağılımları ve hata tipleri bakımından eksik kalabileceğini belirtmiştir (Sokolova & Lapalme, 2009). Bu nedenle az görülen mekanik veya elektronik arıza türlerinde sınıf bazlı hata oranları ayrı raporlanmaktadır. İkinci seviyede önerilen müdahalenin uzman kararıyla örtüşme oranı, tehlikeli öneri sıklığı, gereksiz çalıştırma girişimi, karar süresi, kullanılan kaynak ve kayıt bütünlüğü gibi operasyonel çıktılar incelenmektedir. ENFSI'nin doğrulama yaklaşımında ihtiyaçların belirlenmesi, risk değerlendirmesi, test veri kümeleri ve rutin doğrulama birbirini tamamlayan unsurlar olarak ele alınmaktadır (ENFSI, 2015). Kritik güvenlik ihlallerinin ayrıca raporlanması, hasarlı medya için tanımlanan sınırlamalarla uyumludur (SWGDE, 2025b).

Tablo 4. Araştırmada sınanacak karar destek çıktıları ve değerlendirme ölçütleri.

Ölçüm alanı	Gösterge	Referans veya karşılaştırma
Arıza sınıflandırması	Karışıklık matrisi; sınıf duyarlılığı; ROC eğrileri ve AUC değerleri.	Uzman doğrulamalı vaka etiketi (Sokolova & Lapalme, 2009)
Müdahale önerisi	Uzman onayıyla eşleşme; ilk önerinin uygunluğu.	Bağımsız uzman önerisi / mevcut manuel uygulama.
Güvenlik	Durdurma kuralını ihlal; zararlı işlem önerisi.	Önceden tanımlanan SWGDE tabanlı güvenlik kuralları (SWGDE, 2025b)
Veri kurtarma	Elde edilebilen byte/dosya kapsamı; hatalı sektör kaydı	Vaka hedefi ve doğrulanabilir çıktı (Lyle & Wozar, 2007)
Süre ve kaynak	Karar için süre; uzman müdahale düzeyi; yeniden inceleme	Aynı vaka türlerinde geleneksel(manuel) yöntemle kıyas.
Açıklanabilirlik	Öneri gerekçesi, tetiklenen kural, belirsizlik bildirimi.	Uzman değerlendirmesi (Horsman, 2019).
Genellenebilirlik	Yeni model, farklı disk ailesi, gerçek/simülasyon alt grubu.	Haricî veri bölümü; grup temelli duyarlılık analizi (Roberts et al., 2017)

Tablo 4, deney sonuçlarının yerini tutan bir başarı tablosu değildir. Değerlendirme tamamlandığında hangi göstergelerin raporlanacağını belirleyen ölçüm planıdır. Özellikle verimlilik ve kurtarılan veri miktarı ile güvenlik arasında gerilim yaşanabileceğinden, sistemin başarısı yalnızca kısa süre veya çok sayıda kurtarılan dosya üzerinden belirlenmeyecektir. Adli bağlamda kaynağın değiştirilmesi, atlanan alanların kayıtsız kalması veya riskli cihazın gereksiz yeniden çalıştırılması, teknik sınıflandırma doğru olsa bile kabul edilemez bir sonuç meydana getirebilir. UNODC, kullanılan araçların sınırlılıklarının edinimden önce değerlendirilmesi ve edinim işlemlerinin ayrıntılı biçimde belgelenmesi gerektiğini vurgulamaktadır (UNODC, t.y.). Hasarlı diskin yeniden çalıştırılmasına ilişkin riskler SWGDE rehberinde değinilmektedir (SWGDE, 2025b). Hatalı sektörlerin görüntülenmesi esnasında bazı alanların atlanması sorunu Lyle ve Wozar tarafından incelenmiştir (Lyle & Wozar, 2007).

Tablo 5. Planlanan model testleri ve uzman kararlarıyla karşılaştırmanın ölçüm çerçevesi.

Değerlendirme aşaması	Planlanan ölçüt veya karşılaştırma	Temel amaç / sınır
Vaka düzeyinde ayrım	Gerçek arızalar ve simülasyonlar; disk ve vaka kimliğine göre bağımsız test ayrımı.	Aynı vakadan gelen kayıtların farklı veri bölümlerine dağılmasını önlemek.
Tanı testleri	Karışıklık matrisi; sınıf bazında kesinlik ve duyarlılık; ROC eğrileri ve AUC değerleri; belirsizlik ve kalibrasyon.	Arıza sınıflandırmasını birden fazla ölçüt üzerinden değerlendirmek.
Güvenlik testleri	Yanlış müdahale önerisi; durdurma/yönlendirme kararı; veri bütünlüğü kayıtları.	Riskli önerileri ve koruyucu kararların uygunluğunu ölçmek.
Uzman kararıyla karşılaştırma	Aynı vakalarda kör değerlendirme; seçilen yöntem; karar süresi; uzmanlar arası tutarlılık.	Sistemin uzman kararına katkısını bağımsız karşılaştırmak.

Değerlendirme aşaması	Planlanan ölçüt veya karşılaştırma	Temel amaç / sınır
Başarı koşulu ve sınırlılıklar	Düşük riskli öneri; raporlanabilir gerekçe; gerçek vaka sonuçları.	Başarı sonuçları önceden varsayılmaz.

Deney tasarımında kritik karışıklık kaynaklarından biri, aynı arıza vakasına ilişkin farklı zamanlarda kayıt edilmesi bağımsız gözlemler olarak değerlendirilmesidir. Karar destek modülünün planlanan faydası, sınıflandıran kişiden bağımsız olarak da ölçülecek; sadece model, uzman kuralı ve hibrit sistem önerileri aynı vakada karşılaştırılmaktadır.

Araştırma, HDD veri kurtarmayı sadece teşhis, tanı sorunu değil, sınırlı müdahale ihtimallerinin bulunduğu bir karar verme problemi olarak ele almaktadır. Fiziksel arızaları olan HDD için veri kurtarma araştırmalarında HDD'nin bileşen özellikleri kullanılmıştır (Sobey et al., 2006). Hatalı sektörlerin veri eld etmeyi nasıl etkileyebileceği literatür araştırılmıştır (Lyle & Wozar, 2007). Dosya araştırmalarında, üst veriler bulunmadığında yeniden oluşturmanın sınırları değerlendirilmiştir (Garfinkel, 2007). Karar kuramı yaklaşımı ise veri kurtarma uygulamalarının değerlendirilmesine farklı bir bakış açısı eklemiştir (Gladyshev & James, 2017). Bu kanıtlar birleştirildiğinde, yalnızca arıza sebebi bilinen modellerin ihtiyacı karşılandığı anlaşılmıştır. Ancak asıl ihtiyaç zarar riski, veri bütünlüğü, metodun uygulanabilirliği ve uzman onayıyla birlikte değerlendiren öneri katmanıdır. ISO/IEC 27037:2012, dijital delilin elde edilmesinden önceki tanımlama ve veri elde etme aşamaları önemlidir (ISO/IEC, 2012).

Karar destek sistemlerinde istatistiksel tahmin ile güvenlik kuralını ayırmanın önemi açıktır. Goh ve Chan'ın sistemi, HDD alanında bilginin şekillendirilebileceği düşüncesini desteklemektedir (Goh & Chan, 1990). Horsman ve arkadaşlarının araştırması, önceki incelemelerden faydalanmaya açık bir örnektir (Horsman et al., 2014). Daha sonra Horsman adli kararların gerekçelendirilerek verilmesini ele almaktadır (Horsman, 2019). Bu çalışmanın özgün katkısı, direkt olarak verilerle ve denenecek testlerle bir bütünleşme önerisidir.

Sonuç ve Öneriler

Bahse konu yapılan çalışmanın sınırları açıktır. Arıza kayıtları etiketlenirken uzman görüşleri arasında farklılık olması doğaldır ve değişkenlikler olabilir; fiziksel müdahale gerektiren vakalar diğer vakalara oranla daha az sayıda bulunabilir; simülasyonlardan öğrenilenler tüm diğer aygıtlara tamamen genellenmeyebilir. Ayrıca farklı disk üreticilerinin hata göstergeleri her seferinde tam olarak karşılanabilir durumda olmayabilir. Belli başlı arızalarda kesin teşhis riskli müdahaleler gerektirebilir. Bu sebeple belirsiz yani birden çok olan nedenler ayrıca kaydedilecek, güven düzeyi düşük çıktılar direkt işlem önerisine dönüştürülmeyerek bağımsız ve objektif uzman görüşü olmadan kabul edilmeyecektir. Güvenlik ve riskler SWGDE rehberine dayandırılacaktır (SWGDE, 2025b). Veri sızıntısı riskleride ayrıca göz önünde bulundurulacaktır (Kapoor & Narayanan, 2023). Gözlemler arasındaki bağımlılık için harici değerlendirme ve gözden geçirme uygulanacaktır (Roberts et al., 2017). Birleşik Krallık Adli Bilimler Düzenleyicisi, yöntem doğrulamasının sadece araçların kullanılmasına dayanmaması ayrıca amaç, risk, kabul kriterlerinin ne olduğu ve sonuçlarının delillendirilmesine dayanması gerektiğini belirtmektedir (Forensic Science Regulator, 2024).

Sonuç olarak makale, gerçek arıza durumları ve varsayımsal olarak öğrenen, arızaları daha önce belirtildiği gibi 3 ayrı başlıkta sınıflandıran, en uygun verinin nasıl kurtarılacağını gerekçeli bir biçimde öneren karar destek sisteminin araştırma temelini ortaya koymaktadır. Geliştirilecek uygulamanın karar tutarlılığını artırıp artırmadığı, insan hatasını azaltıp azaltmadığı ve zaman-kaynak kullanımını iyileştirip iyileştirmediği ancak önceden tanımlanmış sınıflandırma, güvenlik ve uzman karşılaştırma testleri tamamlandıktan sonra değerlendirilebilecektir. Bu yaklaşım, sistematik, tekrarlanabilir ve adli bütünlüğü önceleyen veri kurtarma kararlarının geliştirilmesine dönük sınanabilir bir araştırma zemini sunmaktadır.

Kaynaklar

European Network of Forensic Science Institutes (ENFSI). (2015). Best practice manual for the forensic examination of digital technology (ENFSI-BPM-FIT-01, Version 01; Kasım 2015). https://enfsi.eu/wp-content/uploads/2016/09/1._forensic_examination_of_digital_technology_0.pdf

Forensic Science Regulator. (2024). Method validation in digital forensics (Issue 2; güncelleme 22 Temmuz 2024). UK Government. https://www.gov.uk/government/publications/method-validation-in-digital-forensics/method-validation-in-digital-forensics-accessible

Garfinkel, S. L. (2007). Carving contiguous and fragmented files with fast object validation. Digital Investigation, 4(Supplement), S2–S12. https://doi.org/10.1016/j.diin.2007.06.017

Gladyshev, P. ve James, J. I. (2017). Decision-theoretic file carving. Digital Investigation, 22, 46–61. https://doi.org/10.1016/j.diin.2017.08.001

Goh, W. L. ve Chan, C. K. (1990). ESHDD—An expert system for hard disk drives. Engineering Applications of Artificial Intelligence, 3(3), 186–197. https://doi.org/10.1016/0952-1976(90)90041-J

Güllüce, Y. Z. ve Benzer, R. (2015). Hard disk failure and data recovery methods in computer forensic / Adli bilişimde hard disk arızaları ve arızalı disklerden veri kurtarma yöntemleri. Journal of Human Sciences, 12(1), 206–225. https://doi.org/10.14687/ijhs.v12i1.3115

Horsman, G. (2019). Formalising investigative decision making in digital forensics: Proposing the Digital Evidence Reporting and Decision Support (DERDS) framework. Digital Investigation, 28, 146–151. https://doi.org/10.1016/j.diin.2019.01.007

Horsman, G., Laing, C. ve Vickers, P. (2014). A case-based reasoning method for locating evidence during digital forensic device triage. Decision Support Systems, 61, 69–78. https://doi.org/10.1016/j.dss.2014.01.007

International Organization for Standardization & International Electrotechnical Commission (ISO/IEC). (2012). ISO/IEC 27037:2012 — Information technology — Security techniques — Guidelines for identification, collection, acquisition and preservation of digital evidence. https://www.iso.org/standard/44381.html

INTERPOL. (2019). Global guidelines for digital forensics laboratories (13 Mayıs 2019). INTERPOL Global Complex for Innovation. https://www.interpol.int/content/download/13501/file/INTERPOL_DFL_GlobalGuidelinesDigitalForensicsLaboratory.pdf

INTERPOL. (2021). Guidelines for digital forensics first responders: Best practices for search and seizure of electronic and digital evidence (Mart 2021). https://www.interpol.int/content/download/16243/file/Guidelines_to_Digital_Forensics_First_Responders_V7.pdf

Kapoor, S. ve Narayanan, A. (2023). Leakage and the reproducibility crisis in machine-learning-based science. Patterns, 4(9), 100804. https://doi.org/10.1016/j.patter.2023.100804

Kent, K., Chevalier, S., Grance, T. ve Dang, H. (2006). Guide to Integrating Forensic Techniques into Incident Response (NIST SP 800-86). National Institute of Standards and Technology. https://doi.org/10.6028/NIST.SP.800-86

Lyle, J. R. ve Wozar, M. R. (2007). Issues with imaging drives containing faulty sectors. Digital Investigation, 4(Supplement), S13–S15. https://doi.org/10.1016/j.diin.2007.06.002

Roberts, D. R., Bahn, V., Ciuti, S., Boyce, M. S., Elith, J., Guillera-Arroita, G., Hauenstein, S., Lahoz-Monfort, J. J., Schröder, B., Thuiller, W., Warton, D. I., Wintle, B. A., Hartig, F. ve Dormann, C. F. (2017). Cross-validation strategies for data with temporal, spatial, hierarchical, or phylogenetic structure. Ecography, 40(8), 913–929. https://doi.org/10.1111/ecog.02881

Scientific Working Group on Digital Evidence (SWGDE). (2025a). Best Practices for Computer Forensic Acquisition (17-F-002-2.1; 5 Ağustos 2025). https://www.swgde.org/documents/published-complete-listing/17-f-002-2-1/

Scientific Working Group on Digital Evidence (SWGDE). (2025b). Best Practices for Handling Damaged Digital Storage Devices (14-F-002-2.0; 4 Mart 2025). https://www.swgde.org/documents/published-complete-listing/14-f-002-best-practices-for-handling-damaged-digital-storage-devices/

Sobey, C. H., Orto, L. ve Sakaguchi, G. (2006). Drive-independent data recovery: The current state-of-the-art. IEEE Transactions on Magnetics, 42(2), 188–193. https://doi.org/10.1109/TMAG.2005.861757

Sokolova, M. ve Lapalme, G. (2009). A systematic analysis of performance measures for classification tasks. Information Processing & Management, 45(4), 427–437. https://doi.org/10.1016/j.ipm.2009.03.002

United Nations Office on Drugs and Crime (UNODC). (t.y.). Cybercrime Module 6: Practical aspects of cybercrime investigations and digital forensics – Handling of digital evidence. Education for Justice (E4J). https://www.unodc.org/e4j/en/cybercrime/module-6/key-issues/handling-of-digital-evidence.html

Varma, S. ve Simon, R. (2006). Bias in error estimation when using cross-validation for model selection. BMC Bioinformatics, 7, 91. https://doi.org/10.1186/1471-2105-7-91

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FORMATIVE FEEDBACK STRATEGIES PROVIDED BY GENERATIVE ARTIFICIAL INTELLIGENCE IN EDUCATION AND THEIR EFFECTS ON STUDENT MOTIVATION AND ENGAGEMENT

Behiye Canbaz
Çelebi Uluyol
0000-0002-8195-8223, Department of Computer Programming, Cide Rıfat Ilgaz Vocational School, Kastamonu University, Kastamonu, Turkey.
0000-0001-9774-0547, Department of Computer Education and Instructional Technologies, Gazi Faculty of Education, Gazi University, Ankara, Turkey.

Abstract

This study aims to examine the various formative feedback strategies provided by generative artificial intelligence in educational settings and the effects of these strategies on student motivation and engagement. Accordingly, the conceptual foundations of the formative feedback literature, prominent feedback theories in the field, the content and timing dimensions of feedback strategies, and applications specific to computer science education were examined together, and existing research findings were evaluated within this framework. The theoretical background of the study is formed by approaches centered on self-regulated learning, the theory of feedback intervention, and models based on the distinction between feedback, retroactive feedback, and prospective feedback. These theories demonstrate that feedback is not merely an output indicating right or wrong, but rather a process that supports students in monitoring and directing their own learning process. In terms of strategies, it was observed that the distinction between verification and elaboration on the content dimension, and the balance between immediate and delayed feedback on the timing dimension, directly affect student engagement; in particular, hybrid feedback forms that combine clarity with reflection were found to strengthen revision behavior. The results of the evaluation show that feedback generated by generative AI is largely perceived by students as formative and has measurable effects on motivation, engagement, and positive emotions. However, the findings indicate that teacher feedback remains more effective in supporting performance improvements, particularly in complex tasks, while generative AI feedback tends to be more repetitive and less rich from a pedagogical perspective. Furthermore, it was determined that overreliance on AI carries cognitive and motivational risks regarding students' independent thinking skills and intrinsic motivation. This picture suggests that generative AI feedback should be positioned as a tool that complements-rather than replaces-human feedback. In light of these findings, the study concludes that generative AI feedback must be designed in a way that is theoretically grounded, supported by human judgment, and promotes students' self-regulation skills.

Keywords: formative feedback, generative artificial intelligence, self-regulated learning.

EĞİTİMDE ÜRETKEN YAPAY ZEKÂ TARAFINDAN SUNULAN BİÇİMLENDİRİCİ GERİBİLDİRİM STRATEJİLERİ VE BUNLARIN ÖĞRENCİ MOTİVASYONU İLE KATILIMINA ETKİLERİ

Özet

Bu çalışma, eğitim ortamlarında üretken yapay zekâ tarafından sunulan farklı biçimlendirici geribildirim stratejilerini ve bu stratejilerin öğrencilerin motivasyonu ile katılımı üzerindeki etkilerini incelemeyi amaçlamaktadır. Bu doğrultuda, biçimlendirici geribildirim literatürünün kavramsal temelleri, alanda öne

çıkan geribildirim kuramları, geribildirim stratejilerinin içerik ve zamanlama boyutları ile programlama eğitimine özgü uygulamalar birlikte ele alınmış ve mevcut araştırma bulguları bu çerçevede değerlendirilmiştir. Çalışmanın kuramsal arka planını, öz düzenlemeli öğrenmeyi merkeze alan yaklaşımlar, geribildirim müdahalesi kuramı ve geri bildirim-geri besleme-ileri besleme ayrımına dayanan modeller oluşturmaktadır. Bu kuramlar, geribildirimin yalnızca doğru-yanlış bildiren bir çıktı olmadığını, aksine öğrencinin kendi öğrenme sürecini izlemesini ve yönlendirmesini destekleyen bir süreç olduğunu ortaya koymaktadır. Stratejiler açısından, içerik boyutunda doğrulama ile ayrıntılandırma arasındaki ayrımın ve zamanlama boyutunda anlık ile gecikmeli geribildirim arasındaki dengelemenin öğrenci katılımını doğrudan etkilediği, özellikle netliği düşünümsellikle birleştiren karma geribildirim biçimlerinin revizyon davranışını güçlendirdiği görülmektedir. Değerlendirme sonucunda, üretken yapay zekâ tarafından üretilen geribildirimin öğrenciler tarafından büyük ölçüde biçimlendirici olarak algılandığı; motivasyon, katılım ve olumlu duygular üzerinde ölçülebilir etkiler yarattığı görülmektedir. Bununla birlikte bulgular, öğretmen geribildiriminin özellikle karmaşık görevlerde performans artışını destekleme bakımından hâlâ daha etkili olduğunu, üretken yapay zekâ geribildiriminin ise pedagojik açıdan daha tekrarlı ve daha az zengin kalabildiğini göstermektedir. Ayrıca yapay zekâya aşırı bağımlılığın, öğrencilerin bağımsız düşünme becerileri ve içsel motivasyonu açısından bilişsel ve motivasyonel riskler taşıdığı belirlenmiştir. Bu tablo, üretken yapay zekâ geribildiriminin insan geribildiriminin yerini alması yerine onu tamamlayan bir araç olarak konumlandırılması gerektiğine işaret etmektedir. Bu sonuçlar ışığında çalışma, üretken yapay zekâ geribildiriminin kuramsal olarak gerekçelendirilmiş, insan yargısıyla desteklenmiş ve öğrencinin öz düzenleme becerisini teşvik edecek biçimde tasarlanması gerektiği sonucuna ulaşmaktadır.

Anahtar Kelimeler: biçimlendirici geribildirim, üretken yapay zekâ, öz-düzenlemeli öğrenme.

1. Giriş

Biçimlendirici geribildirim, öğrencinin düşüncesini veya davranışını öğrenmeyi geliştirecek biçimde değiştirmeyi amaçlayan, öğrenciye iletilen bilgi olarak tanımlanır (Shute, 2008). Bu tanım, geribildirimin yalnızca doğru-yanlış bildirmediğini, öğrencinin mevcut durumu ile hedefi arasındaki boşluğu anlamlandırmasını gerektiren etkin bir süreç olduğunu vurgular. Alanyazın, nitelikli biçimlendirici geribildirimin değerlendirici olmayan, destekleyici, zamanında ve spesifik özellikler taşıması gerektiğini göstermektedir (Shute, 2008). Ancak geribildirim üretimi öğretim elemanları için zaman alıcı bir yüktür ve bu durum sıklıkla öğrencilerin geribildirimden yoksun kalmasına yol açar (Meyer et al., 2023). Üretken yapay zekâ, bu darboğazı ölçeklenebilir biçimde aşma potansiyeli taşımaktadır. 2022'den itibaren eğitim bağlamında hızla yaygınlaşan bu araçlar, öğrencilere anlık, kişiselleştirilmiş ve açıklayıcı biçimlendirici geribildirim sunabilmekte ve geribildirimi hata düzeltmenin ötesine taşıyarak düşünümselliğe yönlendirebilmektedir (Lourenço & Valente, 2026). Bu çalışma, ÜYZ geribildirim stratejilerini kuramlar temelinde değerlendirmeyi ve öğrenci motivasyonu ile katılımına etkilerini tartışmayı amaçlamaktadır.

2. Biçimlendirici Geribildirimin Kavramsal Temelleri

Bu bölümde biçimlendirici geribildirimin tanımı, ayırt edici özellikleri ve kuramsal dayanağını oluşturan öz düzenlemeli öğrenme ele alınmıştır.

2.1. Temel Kavramlar

Geribildirim türleri temelde doğrulama ve ayrıntılandırma olarak ayrılmaktadır. Doğrulama yanıtın doğruluğunu teyit ederken, ayrıntılandırma ipuçları ve açıklamalarla anlayışı güçlendirir (Shute, 2008; Knaut et al., 2022). Ayrıntılandırılmış geribildirim ipuçları, ek bilgiler, düşündürücü sorular, açıklamalar veya olası çözümleri kapsar (Weinhandl et al., 2025).

Ayrıntılandırılmış geribildirim, bilişsel yükü önlemek için küçük parçalara bölünerek ve her seferinde tek bir bilgi parçası sunularak verilmelidir (Knaut et al., 2022). Nitekim Narciss ve Huth'a (2004) göre, ayrıntılandırılmış geribildirim biçimindeki ince ipuçları, kapsamlı çözüm önerilerinden daha etkilidir (Weinhandl et al., 2025). Zamanlama boyutunda ise alanyazın net bir üstünlük ortaya koymamaktadır: anlık geribildirim prosedürel becerilerin öğretilmesinde hataların hızla düzeltilmesine yardımcı olurken, gecikmeli geribildirim kavram oluşumu bağlamında transfer öğrenmesini daha fazla desteklemekte ve öğrencide aktif bilişsel-üstbilişsel işlemleme yoluyla özerklik duygusu yaratabilmektedir (Knaut et al., 2022). Dijital ortamlarda yürütülen bir meta-analizde, 46 makaleden 116 müdahale üzerinden hesaplanan özet etki 0.41 olarak bulunmuş, hem anlık hem de gecikmeli geribildirim öğrenme performansını anlamlı biçimde iyileştirmiş, gecikmeli geribildirim hafifçe daha etkili olmuş, ancak zamanlama yaklaşımlarının birleştirilmesi etkisiz kalmıştır (Brummer et al., 2024). Öğrenen tercihleri ise farklı bir tablo çizmektedir. 599 katılımcıyla yürütülen bir çalışmada katılımcıların %95.33'ü yanıtlarının hemen ardından geribildirimi görüntülemeyi seçmiştir (Lefèvre & Cox, 2016). Bu bulgu, etkili olduğu gösterilen bir stratejinin öğrenci tercihiyle örtüşmediğinde motivasyon ve dolayısıyla katılım üzerinde olumsuz etki yaratabileceğini göstermesi bakımından önemlidir (Lefèvre & Cox, 2016).

2.2. Öz Düzenlemeli Öğrenme

Biçimlendirici geribildirimin kuramsal çekirdeği, öğrencinin kendi öğrenmesini izleme, değerlendirme ve yönlendirme kapasitesi olan öz düzenlemeli öğrenmedir. Nicol ve Macfarlane-Dick, biçimlendirici değerlendirme ve geribildirim araştırmasını SRL modeli içinde yeniden yorumlayarak öğrencilerin geribildirim üretme ve kullanma sürecinde tepkisel değil, proaktif bir role sahip olduğunu savunmaktadır (Nicol & Macfarlane-Dick, 2006). Bu yaklaşımda geribildirim, öğrenmeyi destekleyen etkin bir öğrenen yaratma aracı olarak görülür. Öğretmenlerin tüm çabasını uzman geribildirim sunmaya yöneltmek yerine, öğrencinin geribildirimi arama, yorumlama ve kullanma kapasitesini geliştirmesi beklenir (Boud & Molloy, 2012). ÜYZ, yapılandırılmış istemler ve öğretmen rehberliğiyle birleştirildiğinde öğrencinin üstbilişsel içgörüsünü ve öz düzenlemesini etkili biçimde destekleyerek özyinelemeli bir iskele işlevi görebilir (Le et al., 2026; Lourenço & Valente, 2026; Rodríguez et al., 2026).

3. Geribildirim Kuramları

Bu bölümde öz düzenlemeyi destekleyen yedi ilke, geribildirim müdahalesi kuramı ve geri bildirim-geri besleme-ileri besleme modeli sırasıyla ele alınmıştır.

3.1. Yedi İlke

Nicol ve Macfarlane-Dick'in (2006) öz düzenlemeyi destekleyen "yedi iyi geribildirim ilkesi", biçimlendirici geribildirimin tasarımına ilişkin en etkili çerçevelerden biri olarak kabul edilmektedir (Boud & Molloy, 2012). Bu ilkeler şunlardır: iyi performansın ne olduğunu netleştirmek, öğrenmede öz değerlendirmeyi geliştirmek, öğrencilere öğrenmeleri hakkında yüksek nitelikli bilgi sunmak, öğrenme etrafında öğretmen-öğrenci ve akran diyaloğunu teşvik etmek, olumlu motivasyonel inançları ve öz saygıyı desteklemek, mevcut performans ile arzulanan performans arasındaki boşluğu kapatma fırsatları sağlamak ve öğretimi şekillendirmek için kullanılabilecek bilgiyi öğretmenlere sunmak (Mulliner & Tucker, 2015). Bu ilkeler, geribildirimi öğrencinin geribildirimle etkin biçimde meşgul olmasını gerektiren sürdürülebilir bir uygulama olarak çerçeveler (Mulliner & Tucker, 2015). Yedi ilkelilik çerçeve, öğrencileri "doğru cevabın söylenmesini beklemek" eğiliminden uzaklaştırmayı ve kendi çalışmalarının niteliğine ilişkin yargı oluşturma kapasitesini geliştirmeyi hedefler (Yeatman & Hewitt, 2020). ÜYZ geribildirimi bu ilkeler açısından değerlendirildiğinde, özellikle "yüksek nitelikli bilgi sunma" ve "boşluğu kapatma fırsatı sağlama" işlevlerinde güçlü olduğu, ancak diyalog ve öz değerlendirme boyutlarında pedagojik tasarıma bağımlı kaldığı görülmektedir.

3.2. Geribildirim Müdahalesi

Kluger ve DeNisi'nin Geribildirim Müdahalesi Kuramına göre davranış, geribildirimin hiyerarşik olarak düzenlenmiş hedef veya standartlarla karşılaştırılmasıyla düzenlenir; dikkat sınırlıdır ve yalnızca dikkat alan geribildirim-hedef boşlukları davranış düzenlemesine katılır (Olencevičius, 2019). Kuramın beş temel varsayımı bulunmaktadır. Davranış, geribildirimin hedef veya standartlarla karşılaştırılmasıyla düzenlenir. Hedefler veya standartlar hiyerarşik olarak düzenlenmiştir. Dikkat sınırlıdır ve bu nedenle yalnızca dikkat alan geribildirim-standart boşlukları davranış düzenlemesinde etkin rol oynar. Dikkat normalde hiyerarşinin orta düzeyine yönelir. Geribildirim müdahaleleri dikkatin odağını değiştirerek davranışı etkiler (Larson et al., 2011).

Bu çerçevede geribildirim müdahaleleri dikkati görev öğrenmesi, görev motivasyonu ve üst-görev süreçleri olmak üzere üç hiyerarşik düzey arasında kaydırmaktadır. Etkinlik, dikkat bireye ve görevden uzağa kaydıkça azalır (Olencevičius, 2019). GMK'in en çarpıcı bulgusu, geribildirimin koşulsuz olarak yararlı olduğu varsayımını çürütmesidir. Yapılan bir meta-analizde, geribildirimin davranış üzerinde genel olarak olumlu etkisi olmakla birlikte, müdahalelerin üçte birinden fazlasının aslında daha kötü performansla ilişkili olduğu bulunmuştur (Larson et al., 2011). Örneğin övgü içeren geribildirim, bireyin dikkatini görev yerine üst düzey benlik hedeflerine yönelttiği için performansı bozabilmektedir (Parker et al., 2021). Bu bulgu, ÜYZ geribildiriminin tasarımı açısından kritik bir uyarı içerir: motivasyonel olarak iyi niyetli görünen övgü veya benlik odaklı ifadeler, görev odaklı ayrıntılandırmayı geri plana ittiğinde öğrenmeyi zayıflatabilir. Nitekim geribildirim etkililiğini belirleyen üç etken: geribildirimin kendi özellikleri, görevin niteliği ile durumsal ve kişilik değişkenleridir (Hysong, 2009).

3.3. Geri Bildirim, Geri Besleme ve İleri Besleme

Hattie ve Timperley'nin (2007) modeli, geribildirimi üç soruyla ilişkilendirir: nereye gidiyorum, nasıl gidiyorum ve bundan sonra nereye (Wisniewski et al., 2020). Model ayrıca geribildirimin bilişsel karmaşıklık düzeyine göre görev, süreç, öz düzenleme ve benlik düzeylerinde verilebileceğini öne sürmektedir. Görev düzeyi geribildirim içerik, olgu veya yüzeysel bilgilere, süreç düzeyi geribildirim ise performans stratejilerine ve görevi anlamak için gerekli bilgi işlemeye ilişkindir (Wisniewski et al., 2020). İleri besleme, öğrencinin gelecekte yapabileceklerine yöneldiği için öğrenciler açısından en çok istenilen geribildirim biçimi olarak tanımlanmaktadır (McPherson et al., 2022). Bu modelin eğitsel önemi, geribildirimin öğrenme süreci tamamlanmadan önce gerçekleşmesi gerektiğidir. Öğrenme bittikten sonra alınan geribildirim nadiren yeni öğrenme bağlamlarına aktarılır (Brooks et al., 2019). ÜYZ, ileri beslemeyi ölçeklenebilir kılma potansiyeline sahiptir ancak bunun için süreç odaklı tasarlanması gerekir (Winstone et al., 2026).

4. Geribildirim Stratejileri

Bu bölümde geribildirim stratejileri içerik, zamanlama, özerklik-kişiselleştirme ve biçim olmak üzere dört boyutta incelenmiştir.

4.1. İçerik ve Zamanlama

Geribildirim stratejilerinin etkililiği, içerik ve zamanlama boyutlarının birlikte ele alınmasını gerektirir. İçerik açısından, doğrulama geribildirimi öğrenciye yalnızca sonucun doğru olup olmadığını bildirirken, ayrıntılandırılmış geribildirim ipuçları ve açıklamalarla öğrencinin anlayışını derinleştirir (Knaut et al., 2022; Weinhandl et al., 2025). Deneysel kanıtlar, doğrulama ve ayrıntılandırma stratejilerinin, ancak öğrenci tarafından anlamlandırıldığında değer kazandığını göstermektedir (Jablonski, 2024). Kişiselleştirilmiş geribildirim öğrenme çıktılarını iyileştirse de genellikle sadece mevcut bilgi düzeyine odaklanmakta, duygusal durum gibi faktörleri göz ardı etmektedir (Maier & Klotz, 2022). Özerklik boyutu da strateji tasarımında belirleyicidir. Zamanlamayı öğrencinin kontrol ettiği kendi kendine denetimli düzenlemeler öğrenmeyi ve katılımı önemli ölçüde geliştirmektedir (Chiviacowsky & Wulf, 2002). Bu sonuç, öğrenciye geribildirim talebi

üzerinde denetim veren araç tasarımlarının motivasyon ve katılım açısından avantajlı olabileceğine işaret etmektedir.

4.2. Etkileşimli Görevler ve Geribildirim Türleri

ÜYZ bağlamında geribildirim türlerinin karşılaştırılması, tasarım tercihlerinin öğrenci davranışına nasıl yansıdığını göstermektedir. Giriş düzeyinde bir tasarım ve programlama dersinde 329 öğrenciyle yürütülen yarıyıl boyu randomize kontrollü bir çalışmada, öğrenciler yönlendirici, üstbilişsel veya her ikisini harmanlayan hibrit ÜYZ geribildirimi koşullarından birine atanmıştır. Bulgular, revizyon davranışının koşullara göre farklılaştığını, hibrit geribildirimin, yönlendirici ve üstbilişsel koşullara kıyasla en fazla revizyona yol açtığını göstermiştir. Güven düzeyleri tüm koşullarda yüksek bulunmuş ve kaynak kalitesi çıktıları koşullar arasında benzer çıkmıştır (Alsaiari et al., 2026). Bu bulgu, netliği ve düşünümselliği birleştiren hibrit tasarımların katılım davranışını artırma potansiyelini ortaya koymaktadır (Alsaiari et al., 2026).

5. Programlama Eğitiminde Geribildirim

Bu bölümde programlama eğitiminde yapay zekâ tabanlı otomatik geribildirim uygulamaları, çevrimiçi öğrenme süreçleri ve öğrencilerin davranışsal katılımları değerlendirilmektedir.

5.1. Otomatik Geribildirim

Programlama eğitimi, otomatik geribildirim araştırmalarının en yoğun yürütüldüğü alanlardan biridir. ChatGPT ile Java programlama ödevleri için üretilen otomatik geribildirimi inceleyen bir çalışmada, öğrencilerin geribildirimi Shute'un biçimlendirici geribildirim ilkeleriyle büyük ölçüde uyumlu algıladıkları; öğrencilerin kendi kodlarını isteme dâhil eden geribildirimi belirgin biçimde tercih ettikleri ve bu tercihin temel nedeninin geribildirimin spesifikliği, netliği ve düzeltici niteliği olduğu bulunmuştur (Zhang et al., 2024). Karşılaştırmalı çalışmalar, ÜYZ geribildiriminin insan geribildirimi karşısındaki konumuna ilişkin daha incelikli bir tablo sunar. Bir çalışmada uzmanlar programlama projelerini tutarlı biçimde ChatGPT'den daha yüksek puanlamış, ancak ChatGPT öğrencilerin çalışmalarına daha kapsamlı metinsel geribildirim sağlama konusunda güçlü yönler sergilemiştir. Öğrenciler ise ChatGPT geribildirimini alan uzmanlarının geribildiriminden daha olumlu değerlendirmiştir (Alshammari, 2025). Başka bir çalışmada ChatGPT'nin ürettiği geribildirim hızlı, doğru ve insan benzeri yanıtlar üretebilmiş ve araştırmaya katılan öğrencilerin %75'i geleneksel yöntemlere kıyasla ChatGPT tarafından üretilen geribildirimi tercih ettiğini belirtilmiştir. Fakat bazı öğrenciler kod parçacıkları gibi daha spesifik yönlendirme ihtiyacı dile getirmiştir. Öğretim elemanları ise yapay zekâ geribildiriminin bazen insan yorumlarındaki empatik tonlamadan yoksun olduğunu not etmişlerdir (McGowan et al., 2025).

Bununla birlikte, öğrenciler daha kapsamlı metinsel geribildirimi olumlu karşılarken, uzmanlar ChatGPT geribildiriminin öğretmen yorumlarındaki empatik tondan yoksun olabileceğini ve pedagojik açıdan daha tekrarlı kaldığını belirtmektedir. Ayrıca ÜYZ geribildiriminin insan geribildirimine kıyasla daha tekrarlı ve pedagojik açıdan daha az zengin olduğu ortaya koyulmuştur (Pecuchova et al., 2026).

5.2. Çevrimiçi Öğrenme ve Davranışsal Katılım

ÜYZ destekli programlama süreçlerinin öğrenci davranışlarına etkisi de incelenmiştir. 82 üniversite öğrencisinin rastgele iki sınıfa ayrıldığı yarı deneysel bir çalışmada, ChatGPT destekli programlama uygulaması yapan sınıf, kendi kendine yönlendirilen programlama yapan sınıfla karşılaştırılmıştır. CFP koşulundaki öğrenciler daha sık hata ayıklama ve hata mesajı alma davranışı sergilemiş, konsol mesajlarını siteye yapıştırmış ve geribildirim okumuştur; ayrıca ChatGPT'den kod kopyalama yapıştırma ve hata ayıklama davranışları da daha sık görülmüştür. CFP uygulaması öğrencilerin programlama performansını iyileştirmekle

birlikte, iki koşul arasında istatistiksel olarak anlamlı bir fark bulunmamıştır (Sun et al., 2024). Bu bulgu, davranışsal katılımın artmasının tek başına performans artışına dönüşmediğini, geribildirimin nasıl kullanıldığının belirleyici olduğunu göstermektedir.

Türkiye bağlamında yürütülen deneysel bir çalışmada ise farklı bir sonuç elde edilmiştir. Üniversite düzeyinde bir programlama dersini alan 45 lisans öğrencisi rastgele deney ve kontrol gruplarına ayrılmış. Deney grubu haftalık programlama uygulamalarında ChatGPT'den yararlanırken kontrol grubu bu aracı kullanmamıştır. Bulgular, deney grubu öğrencilerinin hesaplamalı düşünme becerilerinin, programlama öz yeterliklerinin ve derse yönelik motivasyonlarının kontrol grubundaki öğrencilerden anlamlı biçimde yüksek olduğunu ortaya koymuştur (Yılmaz & Yılmaz, 2023). Bu çalışma, yapay zekâ destekli geribildirimin motivasyonel çıktılarla doğrudan ilişkilendirilebileceğine dair programlama eğitimindeki güçlü kanıtlardan birini sunmaktadır.

6. Üretken Yapay Zekâ Geribildirimi

Bu bölümde ÜYZ geribildiriminin farklı biçimleri, öğrenci yazma becerileri ve duyuşsal çıktıları üzerindeki etkileri, ayrıca sistem güvenilirliği ve pedagojik kullanımı tartışılmaktadır.

6.1. Geribildirim Biçimleri ve Etkileri

ÜYZ geribildiriminin yazma ve içerik üretimi bağlamındaki etkileri, deneysel kanıtlarla desteklenen en olgun araştırma hattını oluşturmaktadır. Yabancı dil olarak İngilizce yazan 459 üst ortaöğretim öğrencisiyle yürütülen randomize kontrollü bir çalışmada, ÜYZ geribildiriminin revizyon performansını, görev motivasyonunu ve olumlu duyguları geribildirim almayan koşula kıyasla artırdığını göstermiştir (Meyer et al., 2023). Yükseköğretimde yazma becerisi bağlamında daha geniş örneklemli birçalışmada, geribildirim alan öğrencilerde katılım ve motivasyon artışının yanı sıra revizyon sürecinde karmaşık bir duygusal deneyime işaret edilmiştir (Chan et al., 2024). Benzer biçimde, yapay zekâ desteğinin yazma motivasyonu, öz yeterlik, katılım ve işbirlikli yazma eğilimi üzerinde anlamlı olumlu etkileri olduğu, bazı katılımcıların ise ChatGPT kullanımına ilişkin çekinceler dile getirdiği belirtilmiştir (Teng, 2024). Ancak bazı çalışmalarda ÜYZ ile insan geribildirimi arasında öğrenme çıktıları bakımından fark bulunmamış ve her iki yöntemin güçlü yönlerini harmanlayan karma yaklaşımlar önerildiğini belirtmektedir (Escalante et al., 2023).

Kişiselleştirme ve sahiplenme boyutunda ise ÜYZ geribildiriminin belirgin avantajları raporlanmaktadır. Çok disiplinli bir örneklemde 263 lisans öğrencisiyle yürütülen deney kontrol gruplu bir çalışmada, ÜYZ kullanan öğrenciler istatistiksel olarak anlamlı biçimde daha yüksek memnuniyet düzeyi ve geribildirim sürecinde daha güçlü bir sahiplenme duygusu bildirmiş. Geribildirim aracının yapılandırılmış ve erişilebilir bir ortam sunarak sürekli iyileştirmeyi ve etkin öğrenci katılımını desteklediği, öğrencilerin %97'sinin aracı yeniden kullanmaya istekli olduğu bulunmuştur (Huesca et al., 2025). Kanada ve Avrupa'da ortaöğretim ve yükseköğretim öğrencilerinden oluşan toplam 380 katılımcıyla yürütülen standart ölçek uygulamalarında süreç odaklı ÜYZ geribildiriminin üstbilişsel yansımayı %18–%22, öz yeterliği %12–%16 ve öğrenme transferini %15–%20 artırdığı bildirilmektedir (Lourenço & Valente, 2026).

6.2. Güvenilirlik, Güven ve Kullanım

ÜYZ geribildiriminin kabulü, yalnızca içeriğin niteliğine değil, öğrencilerin geribildirim kaynağına duyduğu güvene de bağlıdır. Deneysel bir çalışmada, geribildirim sağlayıcısı yapay zekâ, eğitimci veya akran olarak değişkenlendiğinde, katılımcılar yapay zekâya eğitimci ve akranlara kıyasla özellikle uzmanlık bakımından daha fazla güvenilirlik atfetmiş, ancak beklentilerin aksine başka anlamlı etkiler bulunmamıştır (Ruwe & Mayweg-Paus, 2023). Buna karşılık, öğrencilerin aynı geribildirim yorumlarını insan veya yapay zekâ kaynaklı olarak etiketlendiğinde değerlendirdiği bir başka çalışmada, yapay zekâ olarak sunulan yorumlar insan yorumlarından daha az güvenilir bulunmuştur. Ek olarak yüksek nitelikli geribildirim genel olarak daha güvenilir görülmüştür (Winstone et al., 2026). Avustralyalı öğrencilerle yapılan bir ankette ise katılımcıların

%90.5'i eğitimci geribildirim bilgisini biraz veya çok güvenilir bulduğunu bildirirken, bu oran yapay zekâ üretimi geribildirim için yalnızca %60.1 olmuştur. Temel kaygılar olarak güvenilirlik ve inandırıcılık öne çıkmıştır (Winstone et al., 2026). Bu bulgular güvenin statik olmadığını, yapay zekâ sistemleriyle tekrarlı etkileşimlerin öğrencilerin güvenini zamanla artırabileceğini göstermesi bakımından da önemlidir (Winstone et al., 2026).

Güvenilirlik ve pedagojik zenginlik sorunları, öğretmen denetiminin gerekliliğini desteklemektedir. Yükseköğretimde üretken yapay zekânın değerlendirmeyi nasıl dönüştürdüğüne ilişkin bir kapsam taraması, incelenen 31 makalenin %26'sının öğretmenleri değerlendirmelerinde ÜYZ kullanmaya teşvik ettiğini ama öğretmenlerin ChatGPT geribildiriminin sıklıkla uzun ve karmaşık olması, ilgisiz yorumlar içermesi ve düşük yetenekli öğrenciler için anlama güçlükleri yaratması gibi sınırlılıkları fark ettiğini ortaya koymaktadır. Bazı öğretmenler ChatGPT'nin kendilerininkinden farklı değerlendirme ölçütleri kullanabildiğini ve sınıf ile öğrenciler hakkında spesifik bilgi eksikliğinin uygun olmayan geribildirime yol açabildiğini belirtmiştir (Xia et al., 2024). Bu nedenle, makine geribildirimi güçlü olsa dahi öğretmenlerin makine geribildirimini değerlendirme rolü üstlenmesi gerektiği vurgulanmaktadır (Xia et al., 2024). Geribildirimin bilgi odaklı değil süreç odaklı bir anlayışla ele alınması gerektiği aksi hâlde ÜYZ araçlarının yalnızca otomatik yorum üreticileri olarak işlev gördüğünde, Sadler'in "sarkan veri" olarak eleştirdiği, öğrenciye iletilen ancak anlamlı biçimde kullanılmayan geribildirim pratiklerini tekrarlama riski taşıdığı belirtilmektedir (Winstone et al., 2026).

7. Motivasyon ve Katılım

Bu bölümde yapay zekâ geribildiriminin Öz Belirleme Kuramı çerçevesinde öğrenci motivasyonuna ve çok boyutlu katılıma etkileri ile aşırı bağımlılığın getirebileceği olası riskler ele alınmaktadır.

7.1. Öz Belirleme Kuramı Çerçevesinde ÜYZ Geribildirimi

ÜYZ geribildiriminin motivasyon üzerindeki etkilerini açıklamak için en yaygın kullanılan çerçeve Öz Belirleme Kuramı'dır. ÖBK, bireylerin özerklik, yetkinlik ve ilişkisellik temel psikolojik ihtiyaçlarının karşılanmasının bireysel ve sosyal işleyiş için yaşamsal olduğunu öne sürer (Chiu, 2024). Bu çerçevede ÜYZ geribildirimi, kişiselleştirilmiş öğrenme yolları ve etkinlik seçenekleri sunarak özerkliği, anlık ve kişiselleştirilmiş geribildirim ve iskele sağlayarak yetkinliği destekleyebilmektedir (Al-Smadi et al., 2025). Nitekim 20 makalenin PRISMA temelli sistematik taraması, yapay zekâ destekli geribildirimin zamanında ve spesifik yönlendirmeyle yetkinliği geliştirdiğini, uyarlanabilir kişiselleştirmeyle özerkliği teşvik ettiğini ve etkileşimli özellikler ile oyunlaştırmayla ilişkiselliği desteklediğini göstermiştir (Larasati et al., 2025). 324 yabancı dil öğrencisiyle yürütülen bir çalışmada, ChatGPT'nin sürekli kullanımına yönelik motivasyonun belirleyicileri özerklik ve ilişkisellik olarak bulunmuştur. Özerklik, önem ve performans bakımından en yüksek faktör olarak belirlenmiştir. Doğrulanan ÖBK modeli, öğrencilerin ChatGPT'yi sürekli kullanma motivasyonundaki toplam varyansın %70.8'ini açıklamıştır (Annamalai et al., 2024).

Ancak ÖBK çerçevesi aynı zamanda riskleri de görünür kılmaktadır. Yapay zekâya aşırı güven, öğrencilerin yapay zekâyı karar verici olarak algıladığında özerklik duygusunu zayıflatabilir ve aşırı geribildirim, problem çözme becerilerini baltalayan bir bağımlılık yaratabilir (Al-Smadi et al., 2025). Bu nedenle yapay zekâ desteğinin öğrencileri uygun düzeyde zorlaması gerektiği belirtilmektedir (Al-Smadi et al., 2025).

7.2. Katılımın Çok Boyutlu Yapısı

Öğrenci katılımı, bilişsel, davranışsal ve duygusal boyutları bir arada kapsayan çok boyutlu bir yapı olarak ele alınmaktadır (Vreede et al., 2021). ÜYZ geribildiriminin bu boyutlar üzerindeki etkilerine ilişkin sistematik kanıtlar umut vericidir. Deneysel çalışmaları sentezleyen ve ilişki kuralı madenciliği uygulayan bir sistematik derleme ve meta-analiz, ÜYZ'nin üniversite öğrencilerinin motivasyonu ve katılımı üzerinde çeşitli eğitim ortamlarında anlamlı olumlu etkileri olduğunu belirlemiştir. Konu kategorisi bilişsel ve duygusal katılımı

etkilerken, örneklem büyüklüğünün davranışsal katılımı düzenlediği, faillik katılımında ise anlamlı düzenleyici etki gözlenmemiştir. Bulgular ayrıca ChatGPT kullanılan bireysel ve küçük grup öğrenmesinin bilişsel ve duygusal katılımı anlamlı biçimde artırdığını göstermektedir (Xia et al., 2025). Öğrenci katılımının davranışsal göstergeleri ise çalışmalarda doğrudan gözlem ve kayıt yoluyla da ölçülmektedir (Nawahdah et al., 2026).

7.3. Riskler: Aşırı Bağımlılık, Üstbilişsel Tembellik ve Yüzeysel Öğrenme

Motivasyon ve katılım üzerindeki olumlu bulgular, ÜYZ geribildiriminin koşulsuz olarak yararlı olduğu anlamına gelmez. Yapay zekâ diyalog sistemlerine aşırı güven üzerine yürütülen bir sistematik derleme, bu bağımlılığın bireylerin bağımsız düşünme ve analiz yapma motivasyonunu azaltabileceğini, bunun da temel bilişsel yeteneklerin zayıflamasına ve otomasyon yanlılığına yol açabileceğini ortaya koymaktadır (Zhai et al., 2024). Aynı çalışmada, diyalog sistemlerine aşırı güvenin öğrencilerin eleştirel düşünme ve problem çözme becerilerini geliştirmesini engellediği, sistemlerin önceden formüle edilmiş yanıtlar sunmasının öğrencilerin kendine özgü düşüncelerini ve bakış açılarını ifade etme özgürlüğünü kısıtlayabileceği belirtilmektedir (Zhai et al., 2024). Benzer bir uyarı, aşırı güvenin öğrencileri, sistem tarafından üretilen yanıtları sorgulamadan kabul eden pasif öğrenicilere dönüştürebileceği ve bunun kaynak niteliğini değerlendirme, bilinçli yargı oluşturma ile özgün fikir üretme gibi becerilerin gelişimini engelleyebileceği yönündedir (Fuchs, 2023).

Deneysel kanıtlar bu endişeleri desteklemektedir. Laboratuvar ortamında yürütülen rastgele bir deneyde, yapay zekâ teknolojilerinin öğrencilerde teknolojiye bağımlılığı ve potansiyel olarak üstbilişsel tembelliği tetikleyebileceği, bunun da öğrencilerin öz düzenleme kapasitesini ve derinlemesine öğrenmeye katılımını engelleyebileceği bulunmuştur. Aynı çalışmada ChatGPT kısa vadeli görev performansını anlamlı biçimde artırabilirken, içsel motivasyonu ve bilgi kazanımı ile transferini artırmadığı görülmüştür (Fan et al., 2024). Bu bulgu, davranışsal ve kısa vadeli bilişsel çıktıların iyileşmesinin, içsel motivasyon ve kalıcı öğrenme ile eşdeğer tutulmaması gerektiğini göstermektedir (Fan et al., 2024). Bu risklere ilişkin daha geniş bir uyarı, ChatGPT'nin pasif biçimde aşırı kullanımının, öğrencilerin deneyimleri üzerine yansıma yoluyla anlam oluşturmasını gerektiren öğrenme çıktılarına ulaşmayı engelleyebileceği ve yüzeysel öğrenmeyi teşvik edebileceği yönündedir (Rasul et al., 2023).

Buna karşılık, genel etki düzeyine ilişkin meta analitik kanıtlar dikkatli yorumlanmalıdır. Geleneksel ve yapay zekâ destekli yaklaşımları karşılaştıran kapsamlı bir meta-analiz, ÜYZ geribildiriminin eğitsel çıktıları geleneksel yöntemlere kıyasla anlamlı biçimde iyileştirebileceğini, ÜYZ'nin kavrayış, zamanındalık ve nesnellik özellikleriyle öğrenci öğrenme ilerlemesi hakkında doğru geribildirim sağlayabildiğini belirtmektedir. Ancak çelişkili sonuçlar da raporlanmıştır. ÜYZ ve ÜYZ dışı geribildirim arasında etkileşimli ve olumsuz duygular ile bilişsel yük ve görsel bilgi işleme açısından anlamlı fark bulunmamıştır (Dong, 2026).

8. Sonuç ve Öneriler

Bu çalışma ile üretken yapay zekâ tarafından sunulan biçimlendirici geribildirim stratejilerini geribildirim kuramları ışığında değerlendirmiş ve ulaşılan temel sonuçlar özetlenmektedir. ÜYZ geribildirimi, geribildirim kuramlarının öngördüğü işlevleri yerine getirme potansiyeli taşımaktadır. Shute'un biçimlendirici geribildirim ilkeleriyle uyumlu algılanmakta, Hattie ve Timperley modelinin özellikle ileri besleme boyutunu ölçeklenebilir kılmakta, süreç odaklı tasarlandığında üstbilişsel yansıma, öz yeterlik ve transfer artışı sağlamaktadır (Zhang et al., 2024; McPherson et al., 2022; Wisniewski et al., 2020; Lourenço & Valente, 2026). Bu yönüyle ÜYZ, biçimlendirici geribildirimin en kronik sorunu olan ölçeklenebilirlik ve zamanındalık kısıtını hafifletmektedir (Meyer et al., 2023).

Olumlu motivasyonel ve duygusal etkiler ampirik olarak desteklenmektedir. ÜYZ geribildirimi görev motivasyonunu ve olumlu duyguları artırmakta, 918 öğrencili bir randomize kontrollü çalışmada katılım ve motivasyon artışı bildirilmekte, yazma motivasyonu, öz yeterlik ve katılım üzerinde olumlu etkiler

göstermekte, memnuniyet ve sahiplenme duygusunu yükseltmekte, öğrencilerin %97'si aracı yeniden kullanmaya istekli olmaktadır (Meyer et al., 2023; Chan et al., 2024; Teng, 2024; Huesca et al., 2025). Programlama eğitiminde ChatGPT desteği, hesaplamalı düşünme becerileri, programlama öz yeterliği ve derse yönelik motivasyonu anlamlı biçimde artırmaktadır (Yılmaz & Yılmaz, 2023). Meta-analitik düzeyde ÜYZ'nin motivasyon ve katılımın bilişsel, davranışsal ve duygusal boyutları üzerinde anlamlı olumlu etkileri olduğu doğrulanmaktadır (Xia et al., 2025).

ÜYZ geribildirimi insan geribildiriminin yerini almamaktadır. Karmaşık görevlerde öğretmen geribildirimi performans kazanımları bakımından daha etkili kalmakta, bazı çalışmalarda öğrenme çıktıları açısından fark bulunmamakta, ÜYZ geribildirimi daha tekrarlı ve pedagojik açıdan daha az zengin bulunmaktadır (Escalante et al., 2023; Pecuchova et al., 2026). Öğrencilerin güveni de insan geribildirimi lehinedir (Winstone et al., 2026). Tasarım tercihleri etkiyi belirlemektedir. Netliği düşünümsellikle birleştiren hibrit geribildirim en fazla revizyona yol açmakta, öğrenci kodunu isteme dâhil eden spesifik geribildirim tercih edilmekte, öğrenciye denetim veren geribildirim düzenlemeleri öğrenme avantajı sağlamaktadır (Alsaiari et al., 2026; Zhang et al., 2024; Chiviacowsky & Wulf, 2002). Bu bulgular, Nicol ve Macfarlane-Dick'in özerkliği ve öz değerlendirmeyi merkeze alan ilkeleriyle örtüşmektedir (Boud & Molloy, 2012; Mulliner & Tucker, 2015). Geribildirim türünün ve odağının dikkat üzerinden çalıştığı yönündeki GMK varsayımı, ÜYZ tasarımı için de geçerlidir. Dikkati görevden benliğe kaydıran geribildirim öğrenmeyi zayıflatabilir (Olencevičius, 2019; Parker et al., 2021). Aşırı bağımlılık riski ciddiye alınmalıdır. Bağımsız düşünme motivasyonunun azalması, pasif öğreniciliğe dönüşme, üstbilişsel tembellik ve içsel motivasyonda artış sağlanamaması ile yüzeysel öğrenme bu risklerin başlıcalarıdır(Zhai et al., 2024; Fuchs, 2023; Fan et al., 2024; Rasul et al., 2023).

Bu doğrultuda şu öneriler geliştirilebilir. ÜYZ geribildirimi, bilgi aktarımı odaklı değil süreç odaklı ve düşünümselliği tetikleyecek biçimde tasarlanmalı, açık değerlendirme ölçütleriyle hizalanmalı ve öğrenciler düşünümsel süreçleri içselleştirdikçe kademeli olarak azaltılmalıdır (Lourenço & Valente, 2026; Winstone et al., 2026). Geribildirim, netliği düşünümsellikle birleştiren hibrit biçimlerde kurgulanmalıdır (Alsaiari et al., 2026). Öğretmen, makine geribildirimini değerlendirme ve yönlendirme rolünü üstlenmeli, ÜYZ insan geribildirimini tamamlayan değil, öğrenme ortamının bütünleyici bir bileşeni olarak konumlandırılmalıdır (Escalante et al., 2023; Xia et al., 2024). Geribildirim tasarımı, ÖBK'nin özerklik, yetkinlik ve ilişkisellik ihtiyaçlarını besleyecek biçimde, öğrenciye denetim ve seçim olanağı tanıyarak yapılandırılmalı ancak aşırı geribildirimin bağımlılık ve özerklik kaybı yaratabileceği göz önünde tutulmalıdır (Annamalai et al., 2024; Chiu, 2024; Al-Smadi et al., 2025). Gelecek araştırmalar, boylamsal ve çok kurumlu tasarımlarla ÜYZ geribildiriminin kalıcı öğrenme, transfer ve içsel motivasyon üzerindeki uzun vadeli etkilerini incelemeli özellikle faillik katılımı gibi etkilenmeyen boyutlara odaklanmalıdır (Le et al., 2026; Xia et al., 2025).

KAYNAKLAR

Alsaiari, O., Baghaei, N., Lodge, J. M., Noroozi, O., Gašević, D., Boden, M., & Khosravi, H. (2026). Directive, metacognitive, or a blend of both? A comparison of AI-generated feedback types on student engagement, confidence, and outcomes. *Computers and Education: Artificial Intelligence*, 100553.

Alshammari, M. T. (2025). An investigation into chatgpt-based instructional feedback on programming projects. In *2025 4th International Conference on Computing and Information Technology (ICCIT)* (pp. 624-628). IEEE.

Al-Smadi, O. A., Ab Rashid, R., Al-Ramahi, R. A., Alqaryouti, M. H., Ugli, H. S. Z., & Vokhidovich, A. N. (2025). Jordanian English language learners' engagement with AI-supported self-regulated learning. *Research in Learning Technology*, *33*, 3377.

Annamalai, N., Bervell, B., Mireku, D. O., & Andoh, R. P. K. (2025). Artificial intelligence in higher education: Modelling students' motivation for continuous use of ChatGPT based on a modified self-determination theory. *Computers and Education: Artificial Intelligence*, *8*, 100346.

Boud, D., & Molloy, E. (2013). Rethinking models of feedback for learning: the challenge of design. *Assessment & Evaluation in higher education*, *38*(6), 698-712.

Brooks, C., Carroll, A., Gillies, R. M., & Hattie, J. (2019). A matrix of feedback for learning. *Australian Journal of Teacher Education (Online)*, *44*(4), 14-32.

Brummer, L., de Boer, H., Mouw, J. M., & Strijbos, J. W. (2024). A meta-analysis of the effects of context, content, and task factors of digitally delivered instructional feedback on learning performance. *Learning Environments Research*, *27*(3), 453-476.

Chan, S. T. S., Lo, N. P. K., & Wong, A. M. H. (2024). Enhancing university level English proficiency with generative AI: Empirical insights into automated feedback and learning outcomes. *Contemporary Educational Technology*, *16*(4), ep541.

Chiu, T. K. (2024). A classification tool to foster self-regulated learning with generative artificial intelligence by applying self-determination theory: a case of ChatGPT: TKF Chiu. *Educational technology research and development*, *72*(4), 2401-2416.

Chiviacowsky, S., & Wulf, G. (2002). Self-controlled feedback: does it enhance learning because performers get feedback when they need it?. *Research quarterly for exercise and sport*, *73*(4), 408-415.

De Vreede, T., Raghavan, M., & De Vreede, G. J. (2021). Design foundations for AI assisted decision making: A self determination theory approach.

Dong, Y. (2026). Generative AI technologies and educational outcomes: a comprehensive meta-analysis comparing traditional and AI-driven approaches. *Humanities and Social Sciences Communications*.

Escalante, J., Pack, A., & Barrett, A. (2023). AI-generated feedback on writing: Insights into efficacy and ENL student preference. *International Journal of Educational Technology in Higher Education*, *20*(1), 57.

Fan, Y., Tang, L., Le, H., Shen, K., Tan, S., Zhao, Y., ... & Gašević, D. (2025). Beware of metacognitive laziness: Effects of generative artificial intelligence on learning motivation, processes, and performance. *British Journal of Educational Technology*, *56*(2), 489-530.

Fuchs, K. (2023, May). Exploring the opportunities and challenges of NLP models in higher education: is Chat GPT a blessing or a curse?. In *Frontiers in education* (Vol. 8, p. 1166682). Frontiers Media SA.

Huesca, G., Elizondo-García, M. E., Aguayo-González, R., Aguayo-Hernández, C. H., González-Buenrostro, T., & Verdugo-Jasso, Y. A. (2025). Evaluating the potential of generative artificial intelligence to innovate feedback processes. *Education Sciences*, *15*(4), 505.

Hysong, S. J. (2009). Meta-analysis: audit & feedback features impact effectiveness on care quality. *Medical care*, *47*(3), 356.

Jablonski, S. (2024). Students' verification and elaboration in outdoor mathematics: The role of digital feedback in MathCityMap. *Digital experiences in mathematics education*, *10*(1), 132-157.

Knaut, J., Altieri, M., Bach, S., Strobl, I., & Dechant, K. (2022). A Theory-Based Approach of Feedback in STACK-Based Moodle Quizzes Taking into Account Self-Regulation and Different Proficiency of Learners. *Int. J. Emerg. Technol. Learn.*, *17*(23), 38-55.

Larasati, S. P., Sukma, D., Karneli, Y., Fikri, M., Amat, M. A. C., & Rismi, R. (2026). AI-driven feedback and its impact on student motivation in online learning. *G-Couns: Jurnal Bimbingan dan Konseling*, *10*(02), 1071-1088.

Larson, E. L., Patel, S. J., Evans, D., & Saiman, L. (2013). Feedback as a strategy to change behaviour: the devil is in the details. *Journal of evaluation in clinical practice*, *19*(2), 230-234.

Le, A. N. N., Nguyen, N. T. Y., & Bich, T. D. T. (2026). BRIDGING SELF-REGULATED LEARNING AND GENERATIVE AI. *Pedagogical Innovation Through Technology-Enhanced Learning Design: Global Case Studies and Implications for Practice*.

Lefevre, D., & Cox, B. (2017). Delayed instructional feedback may be more effective, but is this contrary to learners' preferences?. *British Journal of Educational Technology*, *48*(6), 1357-1367.

Lourenço, A. A., & Valente, S. (2026). Artificial intelligence in learning: an integrative framework for education 4.0.

Maier, U., & Klotz, C. (2022). Personalized feedback in digital learning environments: Classification framework and literature review. *Computers and education: Artificial intelligence*, *3*, 100080.

McPherson, G. E., Blackwell, J., & Hattie, J. (2022). Feedback in music performance teaching. *Frontiers in psychology*, *13*, 891025.

McGowan, A., Anderson, N., & Smith, C. (2025). Use of ChatGPT for Assessment Feedback on a Complex Programming Assessment. In *2025 IEEE Integrated STEM Education Conference (ISEC)* (pp. 1-6). IEEE.

Meyer, J., Jansen, T., Schiller, R., Liebenow, L. W., Steinbach, M., Horbach, A., & Fleckenstein, J. (2024). Using LLMs to bring evidence-based feedback into the classroom: AI-generated feedback increases secondary students' text revision, motivation, and positive emotions. *Computers and Education: Artificial Intelligence*, *6*, 100199.

Mulliner, E., & Tucker, M. (2017). Feedback on feedback practice: perceptions of students and academics. *Assessment & Evaluation in Higher Education*, *42*(2), 266-288.

Nawahdah, M., Sawalha, H., & Jabara, H. (2026). Enhancing programming education with emotion-aware chatbot interfaces: a Wizard-of-Oz study among Arabic-speaking university students. *International Journal of Educational Technology in Higher Education*, *23*(1), 22.

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in higher education*, *31*(2), 199-218.

Olencevicius, S. (2019). Feedback intervention research historical review: From single to multidimensional. *Management-Journal of Contemporary Management Issues*, *24*(1), 55-69.

Parker, S. K., Ward, M. K., & Fisher, G. G. (2021). Can high-quality jobs help workers learn new tricks? A multidisciplinary review of work design for cognition. *Academy of Management Annals*, *15*(2), 406-454.

Pecuchova, J., Benko, L., & Drlik, M. (2026). Reimagining feedback through generative AI in engineering education. *Computers and Education: Artificial Intelligence*, 100574.

Rasul, T., Nair, S., Kalendra, D., Robin, M., de Oliveira Santini, F., Ladeira, W., ... & Heathcote, L. (2023). The role of ChatGPT in higher education: BeneGMKs, challenges, and future research directions. *Journal of Applied Learning & Teaching*, *6*(1), 41-56.

Ruwe, T., & Mayweg-Paus, E. (2023). "Your argumentation is good", says the AI vs humans–The role of feedback providers and personalised language for feedback effectiveness. *Computers and Education: Artificial Intelligence*, *5*, 100189.

Shute, V. J. (2008). Focus on formative feedback. *Review of educational research*, *78*(1), 153-189.

Sun, D., Boudouaia, A., Zhu, C., & Li, Y. (2024). Would ChatGPT-facilitated programming mode impact college students' programming behaviors, performances, and perceptions? An empirical study. *International Journal of Educational Technology in Higher Education*, *21*(1), 14.

Candorcio Rodríguez, N., Sorcinelli, F., & Martínez de Carnero Calzada, F. (2026). Algorithmic Feedback and Human Agency: An Ethical Dialectic for Self-Regulated Learning. Zenodo. https://doi.org/10.5281/zenodo.18377364

Teng, M. F. (2024). "ChatGPT is the companion, not enemies": EFL learners' perceptions and experiences in using ChatGPT for feedback in writing. *Computers and Education: Artificial Intelligence*, *7*, 100270.

Qi, X. I. A., Weijia, L. I., Yiming, Y. A. N. G., & Xiaojing, W. E. N. G. (2025). A systematic review and meta-analysis of the effectiveness of generative artificial intelligence (GenAI) on students' motivation and engagement. *Computers and Education: Artificial Intelligence*, 100455.

Weinhandl, R., Baldinger, S., & Riegler, V. (2025). Design characteristics for discovery learning within digital mathematics learning environments from students' perspectives. *International Journal of Science and Mathematics Education*, *23*(8), 3981-4009.

Winstone, N. E., Gravett, K., Bearman, M., Noble, C., Jensen, L. X., Jones, A., & Nicola-Richmond, K. (2026). The care-full craft of feedback in an age of generative AI. *Assessment & Evaluation in Higher Education*, 1-17.

Wisniewski, B., Zierer, K., & Hattie, J. (2020). The power of feedback revisited: A meta-analysis of educational feedback research. *Frontiers in psychology*, *10*, 3087.

Xia, Q., Weng, X., Ouyang, F., Lin, T. J., & Chiu, T. K. (2024). A scoping review on how generative artificial intelligence transforms assessment in higher education. *International Journal of Educational Technology in Higher Education*, *21*(1), 40.

Yeatman, L., & Hewitt, L. (2021). Feedback: a reflection on the use of Nicol and Macfarlane-Dick's feedback principles to engage learners. *The Law Teacher*, *55*(2), 227-240.

Yilmaz, R., & Yilmaz, F. G. K. (2023). The effect of generative artificial intelligence (AI)-based tool use on students' computational thinking skills, programming self-efficacy and motivation. *Computers and education: Artificial intelligence*, *4*, 100147.

Zhai, C., Wibowo, S., & Li, L. D. (2024). *The effects of over-reliance on AI dialogue systems on students' cognitive abilities: a systematic review. Smart Learn. Environ. 11, 28 (2024)*.

Zhang, Z., Dong, Z., Shi, Y., Price, T., Matsuda, N., & Xu, D. (2024, March). Students' perceptions and preferences of generative artificial intelligence feedback for programming. In *Proceedings of the AAAI Conference on Artificial Intelligence* (Vol. 38, No. 21, pp. 23250-23258).

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ENERGY AND FUEL CONSUMPTION ANALYSIS OF A PLUG-IN HYBRID ELECTRIC VEHICLE UNDER WLTC CONDITIONS USING AVL CRUISE M

Yusuf AKIN
Müjdat FIRAT
Res. Asst., Department of Automotive Engineering, Faculty of Technology, Fırat University, 23119, Elazığ, Türkiye.
Prof. Dr., Graduate School of Natural and Applied Sciences, Fırat University, 23200, Elazığ, Türkiye.
ORCID: Y. AKIN 0009-0001-1188-0643, M. FIRAT 0000-0001-6978-9044

Abstract

In this study, the energy and fuel consumption of a plug-in hybrid electric vehicle (PHEV), whose front axle is driven by an internal combustion engine (ICE) with a belt-driven P0 machine and whose rear axle is driven by a P4 machine, was investigated in AVL CRUISE M. The vehicle model was built on the software's P0+P4 PHEV example model; the ICE fuel map, the loss maps of the electric machines and the road load were parameterised with data from the literature, and user-defined C functions were added to the rule-based energy management strategy and the transmission control. The vehicle was simulated over the WLTC according to the WLTP charge-depleting (CD) and charge-sustaining (CS) test procedure, and the results were weighted with the utility factor. With a fully charged battery, the vehicle completed the low, medium and high phases of the cycle in pure electric mode, and the ICE operated for only 79 s in the extra-high phase; the vehicle stayed within the WLTP speed tolerance in all tests. The CD range, the equivalent all-electric range and the CS fuel consumption were found to be 69.7 km, 48.4 km and 6.56 L/100 km, respectively. In the CS test, the ICE operated mostly at low load (mean specific fuel consumption 272 g/kWh), and charging the battery via the P0 machine required approximately 3.1 kWh of fuel energy per 1 kWh stored. The weighted CO_2 emission and fuel consumption were calculated as 44.5 g/km and 1.85 L/100 km; the weighted values were within the range declared by the manufacturer for model year 2024, while the electric range was about 10–13% higher than the manufacturer's values. The developed model will be used as a reference model to investigate the effect of different operating conditions on energy consumption.

Keywords: Plug-in hybrid electric vehicle, P0+P4 architecture, AVL CRUISE M, WLTP, utility factor, energy management.

AVL CRUISE M KULLANILARAK WLTP KOŞULLARI ALTINDA BİR FİŞLİ HİBRİT ELEKTRİKLİ ARACIN ENERJİ VE YAKIT TÜKETİM ANALİZİ

Özet

Bu çalışmada, ön aksı bir içten yanmalı motor (İYM) ve kayışlı bir P0 makinesi, arka aksı ise bir P4 makinesi tarafından tahrik edilen şarj edilebilir bir hibrit elektrikli aracın (PHEV) enerji ve yakıt tüketimi AVL CRUISE M ortamında incelenmiştir. Yazılımın P0+P4 PHEV örnek modeli temel alınarak oluşturulan araç modelinde İYM yakıt haritası, elektrik makinesi kayıp haritaları ve yol yükü literatürdeki verilerle parametrelendirilmiş; kural tabanlı enerji yönetim stratejisine ve şanzıman kontrolüne kullanıcı tanımlı C fonksiyonları eklenmiştir. Araç, WLTP'nin yük boşaltma (CD) ve yük koruma (CS) test prosedürüne göre WLTC çevrimiyle simüle edilmiş ve sonuçlar kullanım faktörü ile ağırlıklandırılmıştır. Batarya dolu iken araç çevrimin düşük, orta ve yüksek hız fazlarını tamamen elektrikli olarak tamamlamış, İYM yalnızca çok yüksek hız fazında 79 s çalışmıştır; araç tüm testlerde WLTP hız toleransı içinde kalmıştır. CD menzili 69,7 km, eşdeğer tam elektrikli menzil 48,4 km, CS yakıt tüketimi 6,56 L/100 km olarak bulunmuştur. CS testinde İYM'nin çoğunlukla düşük yükte çalıştığı (ortalama özgül yakıt tüketimi 272 g/kWh) ve bataryanın P0 üzerinden şarj edilmesinin, depolanan her 1 kWh için yaklaşık 3,1 kWh yakıt enerjisi gerektirdiği belirlenmiştir. Ağırlıklı CO_2 emisyonu 44,5 g/km, ağırlıklı yakıt tüketimi 1,85 L/100 km olarak hesaplanmış; ağırlıklı değerlerin üreticinin 2024

model yılı için açıkladığı aralıkta kaldığı, elektrikli menzilin ise üretici değerlerinden yaklaşık %10–13 yüksek olduğu görülmüştür. Oluşturulan model, ileride farklı işletme koşullarının enerji tüketimine etkisinin incelenmesi için referans model olarak kullanılacaktır.

Anahtar Kelimeler: Şarj edilebilir hibrit elektrikli araç, P0+P4 mimarisi, AVL CRUISE M, WLTP, kullanım faktörü, enerji yönetimi.

1. GİRİŞ

Ulaştırma sektörü, toplam enerji kullanımının yaklaşık üçte birini oluşturmakta ve karbon emisyonları yoluyla çevre kirliliğinin başlıca kaynaklarından biri olarak kabul edilmektedir [1]. Bu nedenle yeni binek araçlar için CO2 emisyon sınırları giderek sıkılaştırılmaktadır. Avrupa Birliği'nde 2019/631 sayılı Tüzük ile belirlenen filo ortalaması hedefleri, 2023 yılında yapılan değişiklikle 2035 yılından itibaren satılan yeni binek araçlarda %100 CO2 azaltımını öngörecek şekilde güncellenmiştir [2]. Bu düzenlemeler, üreticileri içten yanmalı motorlu (İYM) araçların yanı sıra elektrikli ve hibrit güç aktarma sistemlerine yönelmeye zorlamaktadır.

Hibrit elektrikli araçlar (HEV), bir İYM'yi bir veya daha fazla elektrik makinesi ve bir batarya ile kullanan araçlardır. Güç aktarma organlarının yapısına göre HEV'ler seri, paralel ve seri-paralel (karma) olmak üzere üç temel gruba ayrılmaktadır [3]. Elektrik makinesi gücünün toplam araç gücüne oranı olarak tanımlanan hibritleşme derecesine göre ise mikro, hafif (mild), tam (full) ve şarj edilebilir (plug-in) hibritler şeklinde sınıflandırılmaktadır [4]. Paralel hibritlerde elektrik makinesinin güç aktarma hattındaki konumu P0'dan P4'e kadar adlandırılmaktadır: P0 konumunda makine İYM'ye kayışla bağlı bir marş-jeneratör olarak çalışırken, P4 konumunda İYM'nin tahrik etmediği diğer aksı doğrudan tahrik etmektedir [5]. P4 makinesine sahip araçlarda iki güç kaynağının torku ancak yol üzerinden birleştiği için bu yapı "yol üzerinden paralel" (parallel-through-the-road) hibrit olarak da adlandırılmaktadır [6]. Elektrik makinesinin konumu, rejeneratif frenleme ile geri kazanılabilecek enerjiyi doğrudan etkilemektedir [5].

Şarj edilebilir hibrit elektrikli araçlar (PHEV), bataryalarının elektrik şebekesinden şarj edilebilmesi ve diğer hibritlere göre daha büyük batarya kapasiteleri ile öne çıkmaktadır [7]. Bu araçlarda yaygın olarak kullanılan yük boşaltma/yük koruma (Charge Depleting/Charge Sustaining, CD/CS) stratejisinde batarya önce İYM kapalı tutularak elektrikli sürüşle boşaltılmakta, şarj durumu (SOC) alt sınıra ulaştığında ise araç SOC'yi belirli bir düzeyde tutan yük koruma moduna geçmektedir [4]. Bu iki çalışma modu nedeniyle PHEV'lerin yakıt tüketimi tek bir testle ifade edilememektedir. Dünya Genelinde Uyumlaştırılmış Hafif Araç Test Prosedürü (WLTP) kapsamında PHEV'ler, yük koruma ölçütü sağlanana kadar art arda yapılan CD testlerine ve ayrı bir CS testine tabi tutulmakta; elde edilen sonuçlar, aracın CD menziline bağlı olan kullanım faktörü (utility factor, UF) ile ağırlıklandırılmaktadır [8].

PHEV'lerde güç kaynakları arasındaki paylaşımı belirleyen enerji yönetim stratejileri (EYS), kural tabanlı ve optimizasyon tabanlı olmak üzere iki ana gruba ayrılmaktadır [3]. Kural tabanlı stratejiler, kontrol sinyallerini SOC ve güç talebi gibi büyüklükler için önceden belirlenmiş eşik değerlerine göre hesaplamakta ve gerçek zamanlı uygulamaya uygun bir yapı sunmaktadır. Dinamik programlama gibi optimizasyon tabanlı yöntemler ise çoğunlukla çevrim dışı analizlerde diğer stratejiler için referans oluşturmak amacıyla kullanılmaktadır [9]. CD/CS yaklaşımı basitliği nedeniyle yaygın olarak tercih edilmekle birlikte, araç CS moduna geçtikten sonra iyileştirme payının ortadan kalktığı ve bu yaklaşımın verimlilik açısından sınırlı kaldığı da belirtilmektedir [9].

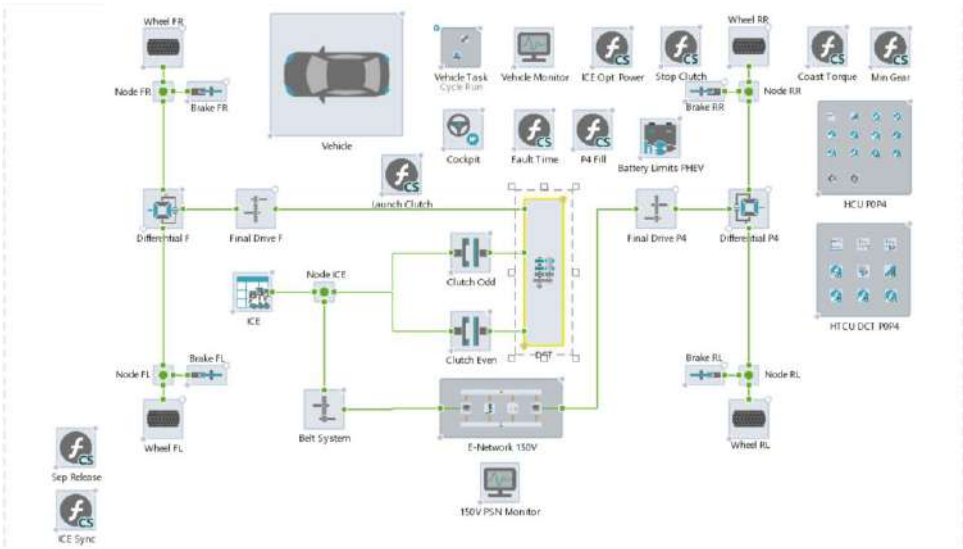
Bu denli karmaşık güç aktarma sistemlerinin fiziksel prototipler üretilmeden önce değerlendirilmesinde sistem simülasyonu yazılımlarından yararlanılmaktadır. ADVISOR, Autonomie, GT-SUITE ve AVL CRUISE bu amaçla kullanılan başlıca araçlar arasında yer almaktadır [10]. AVL CRUISE ile elektrikli bir binek aracın WLTC çevrimindeki enerji tüketimi ve menzili [11], 48 V'luk PHEV konseptlerinde farklı P0–P4 topolojilerinin rejenerasyon potansiyeli incelenmiştir [5]. AVL CRUISE M ise hibrit güç aktarma sistemlerinin sanal kalibrasyon sürecinde model omurgası olarak kullanılmış [12], ayrıca deneysel verilerle parametrelendirilip doğrulanan bir PHEV modelinde enerji yönetim stratejileri kullanıcı tanımlı C fonksiyonları ile uygulanmıştır [13].

Jeep Renegade 4xe, ön akstaki İYM'ye kayışla bağlı bir P0 makinesi ve arka aksı tahrik eden bir P4 makinesi ile seri üretimdeki P0+P4 mimarili PHEV'lere bir örnektir. Bu araçtan esinlenen yol üzerinden paralel bir PHEV modeli, literatürde kural tabanlı enerji ve ısıl yönetimin optimizasyonla kalibrasyonu ile yüksek gerilim bataryasının ısıl davranışı ve yaşlanmasının incelenmesinde kullanılmıştır [6], [14]. Bu çalışmada ise P0+P4 mimarili bir PHEV, AVL CRUISE M ortamında modellenmiş; İYM, elektrik makineleri, batarya, aktarma organları ve yol yükü parametreleri araca göre kalibre edilmiştir. Elde edilen model ile araç, WLTP'nin CD ve CS test prosedürüne göre simüle edilmiş; WLTC çevrimindeki çalışma modları, CD testi boyunca bataryanın şarj durumu ve yakıt tüketimi, CS testinde İYM çalışma noktaları ile güç kaynakları arasındaki enerji paylaşımı incelenmiş ve ağırlıklı yakıt tüketimi ile CO2 emisyonu belirlenmiştir. Oluşturulan model, çalışmanın devamında lastik boyutu ve yuvarlanma direnci, yol eğimi, klima ve diğer elektrikli yardımcı tüketiciler, araç yükü, ortam sıcaklığı ve sürücü davranışının enerji ve yakıt tüketimi üzerindeki etkilerinin incelenmesi için referans model olarak kullanılacaktır.

2. MATERYAL VE YÖNTEM

2.1. Araç ve simülasyon modeli

Çalışmada C-SUV sınıfında, dört silindirli 1,33 L turbo beslemeli benzinli bir İYM ile iki elektrik makinesine sahip P0+P4 mimarili bir PHEV ele alınmıştır. İYM ön aksı altı ileri bir şanzıman üzerinden tahrik etmekte; P0 makinesi İYM'ye kayışla bağlı bir marş-jeneratör olarak çalışmakta, P4 makinesi ise ayrı bir son tahrik oranı üzerinden arka aksı tahrik etmektedir [6]. Araç modeli AVL CRUISE M R2025.1 yazılımında, yazılımla birlikte sunulan P0+P4 mimarili PHEV örnek modeli temel alınarak oluşturulmuştur (Şekil 1). Modelde şanzıman, yazılımın çift kavramalı şanzıman bileşeni altı vites oranıyla kullanılarak temsil edilmiştir. Güç kaynakları arasındaki paylaşım hibrit kontrol ünitesi (HCU), vites değişimleri ise şanzıman kontrol ünitesi (HTCU) tarafından belirlenmekte; sürücü modeli hedef hızı bir PI denetleyici ile izlemektedir. Aracın temel özellikleri Tablo 1'de verilmiştir.



Şekil 1. AVL CRUISE M ortamında oluşturulan P0+P4 PHEV modelinin yapısı

Tablo 1. Simülasyonu yapılan aracın temel özellikleri

Özellik	Değer
Referans kütle	1850 kg (boş kütle 1770 kg + sürücü 80 kg); WLTP test kütlesi yaklaşık 1937 kg
İYM	1,33 L, 4 silindir, turbo benzinli; 95,6 kW (5500 d/d); 270 N·m (1850 d/d)
P0 makinesi (kayışlı marş-jeneratör)	14,7 kW; 48 N·m
P4 makinesi (arka aks)	44 kW; 250 N·m
Batarya	Li-iyon, 96 seri hücre, 31,9 Ah, ortalama açık devre gerilimi yaklaşık 358 V, 11,4 kWh

2.2. Bileşen parametreleri ve yol yükü

Bileşenlere ait üretici ölçüm haritaları kamuya açık olmadığından, İYM yakıt tüketim haritası ile P0 ve P4 makinelerinin kayıp haritaları aynı mimariyi inceleyen çalışmada verilen verim haritalarından türetilmiştir [6]. Bu haritalardan okunan noktalara yarı fiziksel kayıp modelleri en küçük kareler yöntemiyle uydurulmuş ve sonuçlar AVL CRUISE M'e tablo olarak aktarılmıştır. Elde edilen İYM haritasında en yüksek efektif verim yaklaşık %36'dır. Batarya, 96 seri hücreden oluşan ve hücre başına iç direnci 1,02 mΩ olan bir eşdeğer devre modeliyle temsil edilmiş, hücre kapasitesi paket enerjisini üreticinin bildirdiği 11,4 kWh'ye getirecek biçimde 31,9 Ah alınmıştır. Batarya sıcaklığı 25 °C'de sabit tutulmuş, elektrikli yardımcı tüketiciler 300 W sabit güçle temsil edilmiştir. Batarya yönetim sisteminin deşarj gücü sınırı SOC %40'ın üzerinde sürekli 45 kW ve kısa süreli 90 kW olup SOC %30'da 23 ve 45 kW'a, SOC %20'de sıfıra inmektedir. Şarj gücü sınırı ise SOC %30–90 aralığında sürekli 27 kW ve kısa süreli 90 kW olup SOC %95'te sıfıra inmektedir.

2.3. Enerji yönetim stratejisi

HCU kural tabanlı bir strateji uygulamaktadır [9]. Sürüş güç talebi 40 kW'ın altında ve batarya SOC'si alt sınırın (%30) üzerinde olduğu sürece araç yalnızca P4 makinesiyle elektrikli olarak tahrik edilmektedir. Güç talebi 40 kW'ı aştığında İYM, P0 ile çalıştırılarak devreye alınmakta, 30 kW'ın altına düştüğünde ise kapatılmaktadır. SOC alt sınıra indiğinde araç yük koruma moduna geçmekte ve İYM bataryayı P0 makinesi üzerinden şarj etmek için de çalıştırılmaktadır. Şarj, SOC alt ve üst (%35) sınırlarının ortasına, yani %32,5'e çıkana kadar sürdürülmektedir. Şarj sırasında İYM, ilgili devirdeki tam yük gücünün yaklaşık %80'inde, verimli olduğu daha yüksek bir yükte çalıştırılmakta ve sürüş için gerekenden fazla olan güç P0 tarafından elektriğe çevrilmektedir. Ani ve yüksek güç taleplerinde elektrik makineleri İYM'ye tork desteği vermektedir. Frenleme sırasında P0 ve P4 makineleri jeneratör olarak çalışarak rejeneratif frenleme yapmaktadır.

Örnek modelin kontrol mantığında, incelenen aracın verileri ve WLTP'nin uzun test dizisi altında bazı kusurlar ortaya çıkmıştır. Bunların başlıcaları, batarya doluyken frenlemede elektrik makinesinin aracı itmesi, duruşta aracın frene karşı sürünmesi, vites geçişlerinde ve İYM araç hareket hâlindeyken çalıştırılırken oluşan kısa çekiş kayıpları ve İYM kapalıyken krank milinin aktarma organlarınca sürüklenmesidir. Bu kusurlar hazır kontrol modüllerinin içi değiştirilmeden, modüllerin giriş ve çıkış sinyallerine eklenen kullanıcı tanımlı C fonksiyonlarıyla ve modül parametreleriyle giderilmiştir. Enerji yönetiminin C fonksiyonlarıyla uygulanmasına AVL CRUISE M literatüründe de rastlanmaktadır [13]. Hız izleme doğruluğu, AVL CRUISE M'in araç izleme bileşeninin, araç hızının WLTP tolerans bandı (±2 km/h, ±1 s) dışında kaldığı süreyi toplayan çıktısıyla izlenmiştir.

2.4. Test prosedürü ve hesaplama yöntemi

Simülasyonlar WLTP'de tanımlanan 3. sınıf WLTC çevrimi (1800 s, yaklaşık 23,3 km) ile gerçekleştirilmiştir [8]. CD testinde batarya SOC'si %99,5 ile başlatılmış; her çevrim bir öncekinin bittiği SOC değerinden başlatılarak çevrimler art arda tekrarlanmıştır. Batarya enerji değişiminin (ΔE) çevrimin enerji ihtiyacının (tekerlekteki pozitif çekiş enerjisi, 3,89 kWh) %4'ünün altına indiği ilk çevrim onay çevrimi, bir önceki çevrim ise geçiş çevrimi olarak kabul edilmiş ve CD menzili (R_{CDC}) geçiş çevrimi dahil CD çevrimlerinin toplam

mesafesi olarak belirlenmiştir. CS testi %30, %32 ve %34 başlangıç SOC değerleriyle tekrarlanmıştır. Bu üç testten yakıt tüketiminin ΔE ile değişimini veren düzeltme katsayısı doğrusal regresyonla belirlenmiş ve ΔE'si sıfıra en yakın test bu katsayıyla ΔE = 0'a düzeltilmiştir. Ağırlıklı CO2 emisyonu

$$M_w = \Sigma\, UF_j \cdot M_{CD,j} + (1 - \Sigma\, UF_j) \cdot M_{CS} \qquad (2)$$

eşitliğiyle hesaplanmıştır. Burada $M_{CD,j}$, j. CD çevriminin CO2 emisyonu; M_{CS}, düzeltilmiş CS emisyonu; UF_j ise j. çevrimin sonundaki toplam mesafeye (d) bağlı kullanım faktörünün o çevrimdeki artışıdır:

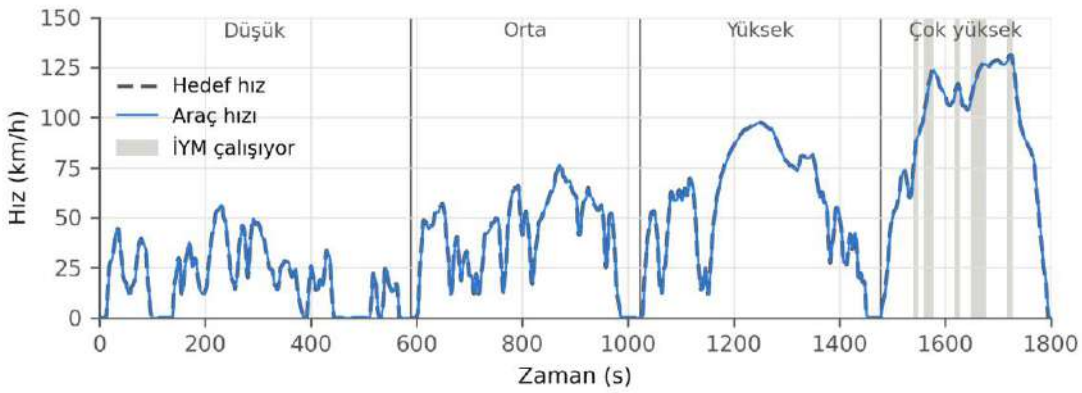
$$UF(d) = 1 - \exp[\, -\Sigma_{i=1..10}\, k_i \cdot (d/800)^i \,] \qquad (3)$$

k_i katsayıları ilgili tüzükte verilmiştir [8]. Eşdeğer tam elektrikli menzil $EAER = R_{CDC} \cdot (M_{CS} - M_{CD,ort})/M_{CS}$ bağıntısıyla hesaplanmıştır. Yakıt tüketimi, CO2 emisyonundan karbon dengesiyle, yakıtın karbon kütle oranı 0,876 ve yoğunluğu 748 kg/m³ alınarak belirlenmiştir.

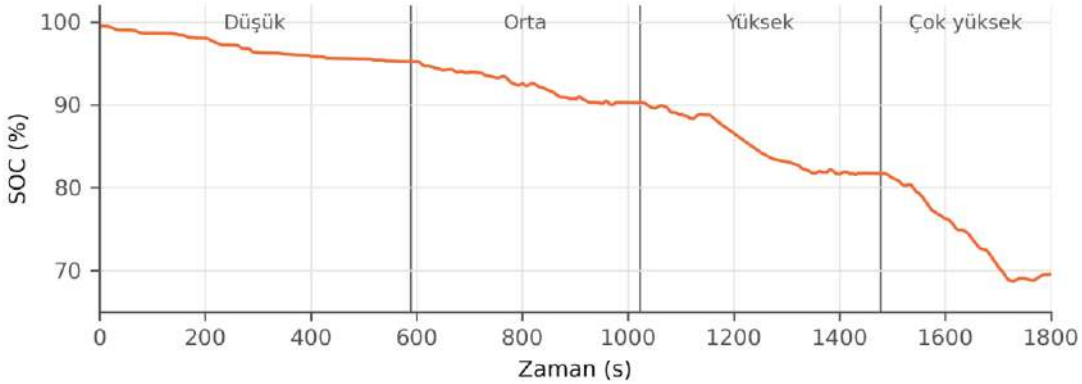
3. BULGULAR

3.1. WLTC çevriminde çalışma modları

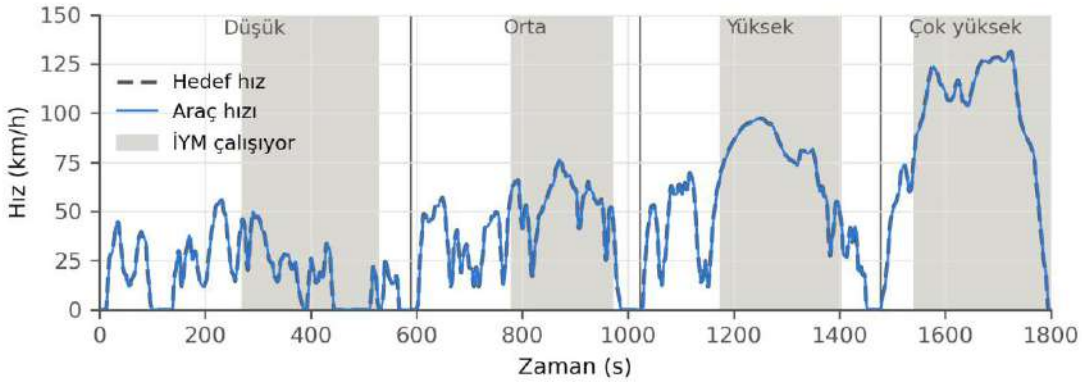
Şekil 2'de CD testinin ilk ve son (onay) çevrimlerine ait sonuçlar verilmiştir. Hedef ve gerçek hız eğrilerinin neredeyse üst üste çakışması, aracın hedef hızı yakından izlediğini göstermektedir; tolerans bandı dışında geçen süre CD testinin dört çevriminde ve üç CS testinde sıfırdır. Batarya dolu iken araç düşük, orta ve yüksek hız fazlarını tamamen elektrikli olarak tamamlamış; İYM yalnızca çok yüksek hız fazındaki, güç talebinin 40 kW eşiğini aştığı ivmelenmelerde beş kısa aralıkta devreye girmiştir (toplam 79 s). Bu çevrimde SOC %99,5'ten %69,5'e inmiştir. SOC düşüşü düşük ve orta hız fazlarında sırasıyla 4,3 ve 4,9 puan iken, yüksek ve çok yüksek hız fazlarında 8,5 ve 12,2 puana çıkmaktadır; bu durum, artan hız ile birlikte aerodinamik direncin ve dolayısıyla çekiş enerjisi ihtiyacının artmasıyla açıklanabilir. SOC'nin alt sınıra yakın olduğu onay çevriminde ise (Şekil 2c) araç yük koruma modunda çalışmış ve İYM çevrimin 946 s'sinde devrede kalmıştır. İYM'nin uzun çalışma blokları, SOC %30'a indiğinde bataryanın İYM ile şarj edilmesinden kaynaklanmakta; düşük hız fazındaki duruş süresinin yaklaşık yarısında İYM'nin çalışmaya devam ettiği görülmektedir. Ayrı yapılan CS testinde (başlangıç SOC %32) İYM 945 s çalışmıştır.



(a)



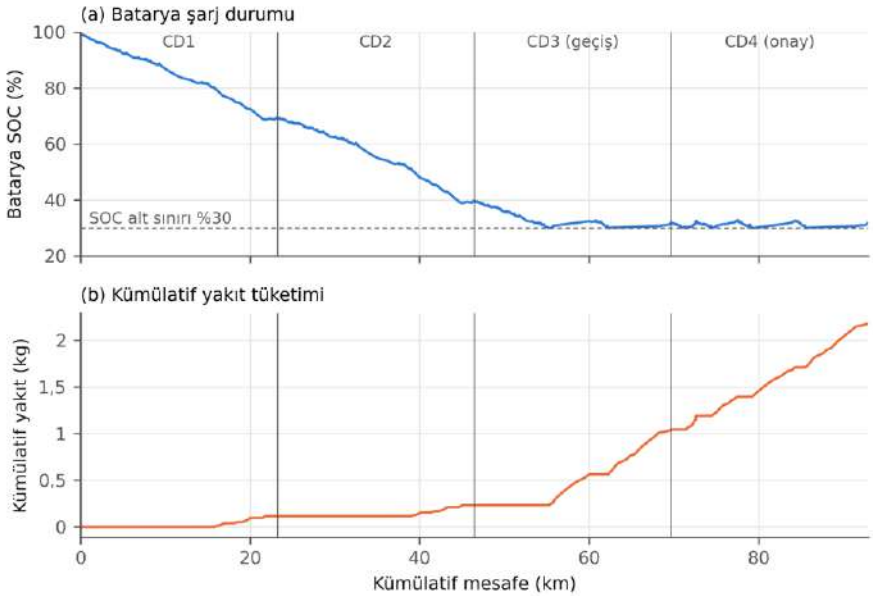
(b)



Şekil 2. CD testinde (a) 1. çevrimde hedef ve gerçek araç hızı ile İYM'nin çalıştığı aralıklar, (b) 1. çevrimde batarya SOC değişimi, (c) 4. (onay) çevrimde hedef ve gerçek araç hızı ile İYM'nin çalıştığı aralıklar

3.2. Yük boşaltma (CD) testi

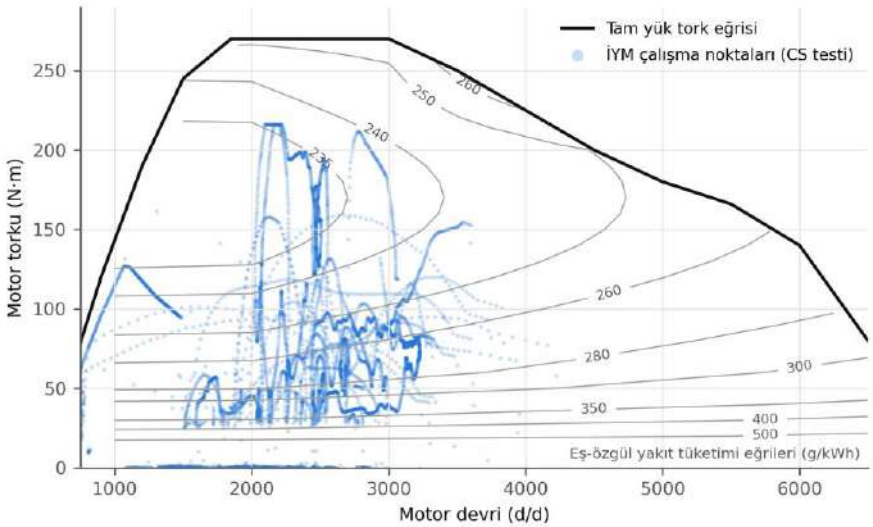
Şekil 3'te CD testi boyunca SOC'nin ve kümülatif yakıt tüketiminin değişimi, Tablo 2'de ise çevrim sonuçları verilmiştir. İlk iki çevrimde SOC %99,5'ten %39,8'e düşmüş ve bu çevrimlerin her birinde yalnızca 116 g yakıt tüketilmiştir (16,1 g/km CO_2). Üçüncü çevrimde SOC %30 alt sınırına çevrimin 1106. saniyesinde ulaşılmış ve araç çevrim içinde yük koruma moduna geçmiştir. Bu çevrimde |ΔE| çevrim enerji ihtiyacının (3,89 kWh) %22'si olduğundan çevrim geçiş çevrimi kabul edilmiş; dördüncü çevrimde |ΔE| çevrim enerji ihtiyacının %0,13'üne inerek yük koruma koşulunun sağlandığı doğrulanmıştır. Buna göre CD menzili 69,7 km, CD testi boyunca bataryadan çekilen enerji 7,95 kWh olarak bulunmuştur. Bataryanın enerji tüketimi ilk çevrimde 15,8 kWh/100 km, ikinci çevrimde 14,6 kWh/100 km olmuştur. İlk çevrimdeki tüketimin biraz daha yüksek olması, batarya tam doluyken (SOC> %90) şarj gücü sınırlandığı için ilk kilometrelerde rejeneratif frenlemenin kısıtlanmasından kaynaklanmaktadır.



Şekil 3. CD testi boyunca (a) batarya SOC değişimi ve (b) kümülatif yakıt tüketimi

3.3. Yük koruma (CS) testinde İYM çalışma noktaları

Şekil 4'te CS testindeki İYM çalışma noktaları özgül yakıt tüketimi haritası üzerinde gösterilmiştir. İYM'nin zaman ağırlıklı ortalama çalışma noktası yaklaşık 2280 d/d ve 76 N·m olup, çalışma süresinin yalnızca %11'inde tork 150 N·m'yi aşmıştır. Bunun sonucunda İYM'nin çevrim ortalaması özgül yakıt tüketimi 272 g/kWh olmuş ve haritanın en düşük değerinin (yaklaşık 230 g/kWh) belirgin biçimde üzerinde kalmıştır. Çalışma noktalarının büyük ölçüde 30–100 N·m aralığında toplanması, mevcut kural tabanlı stratejinin İYM'yi çoğunlukla düşük yükte, verimin düşük olduğu bölgede çalıştırdığını göstermektedir.

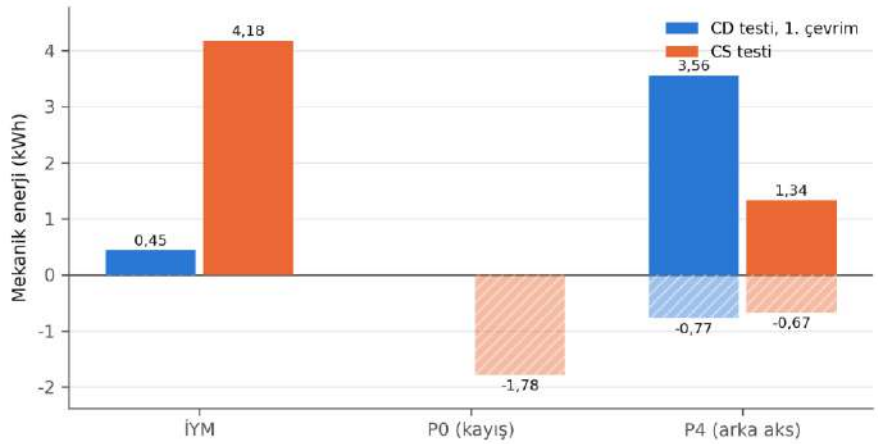


Şekil 4. CS testinde İYM çalışma noktalarının eş-özgül yakıt tüketimi eğrileri üzerindeki dağılımı

3.4. Güç kaynakları arasındaki enerji paylaşımı

Şekil 5'te CD testinin ilk çevrimi ve CS testi için İYM ile P0 ve P4 makinelerinin pozitif (tahrik) ve negatif (jeneratör çalışması ve rejeneratif frenleme) mekanik enerjileri karşılaştırılmıştır. CD çevriminde tahrik enerjisinin büyük kısmını P4 makinesi (3,56 kWh) karşılarken İYM'nin katkısı 0,45 kWh ile sınırlı kalmıştır.

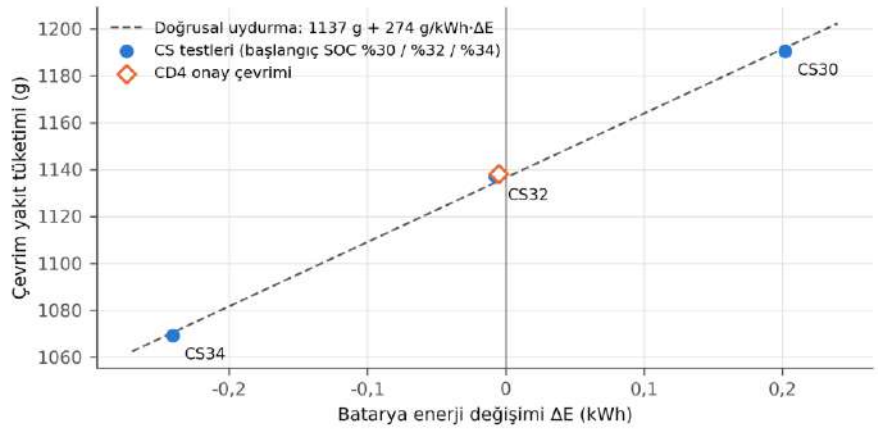
CS testinde ise İYM 4,18 kWh mekanik iş üretmiş; bunun 1,78 kWh'lik kısmı P0 makinesi tarafından elektriğe dönüştürülerek bataryaya aktarılmış, P4 makinesi ise 1,34 kWh tahrik sağlamıştır. P4'ün rejeneratif frenleme ile geri kazandığı enerji CD çevriminde 0,77 kWh, CS testinde 0,67 kWh olmuştur. CS testinde İYM enerjisinin önemli bir kısmının P0–batarya–P4 yolu üzerinden aktarılması, her dönüşümde oluşan kayıplar nedeniyle CS yakıt tüketimini artıran bir etken olarak değerlendirilmektedir.



Şekil 5. CD testi 1. çevrim ve CS testinde güç kaynaklarının mekanik enerjileri (pozitif: tahrik; negatif, taralı: jeneratör çalışması ve rejeneratif frenleme)

3.5. Ağırlıklı yakıt tüketimi ve CO2 emisyonu

Şekil 6'da CS testlerinde çevrim yakıt tüketiminin batarya enerji değişimiyle ilişkisi verilmiştir. Doğrusal regresyonla düzeltme katsayısı 274 g/kWh olarak bulunmuştur. Üç nokta neredeyse bir doğru üzerinde yer almaktadır ($R^2 = 0,999$): eğim, bataryanın şarj edildiği yönde (CS30–CS32 arası) 255 g/kWh, boşaldığı yönde (CS32–CS34 arası) 291 g/kWh'tir. Onay çevrimi (CD4) de bu doğrunun yakınındadır. Dolayısıyla düzeltme katsayısı başlangıç SOC'sinden büyük ölçüde bağımsız olarak belirlenebilmektedir. Şarj yönündeki eğime göre bataryaya depolanan her 1 kWh enerji için yaklaşık 3,1 kWh yakıt enerjisi harcanmaktadır; bu sonuç, P0 üzerinden yapılan şarjın yakıttan bataryaya yaklaşık %32 verimle gerçekleştiğini ve maliyetli olduğunu göstermektedir. ΔE'si sıfıra en yakın CS testi (CS32, −0,007 kWh) bu katsayıyla düzeltildiğinde CS yakıt tüketimi 6,56 L/100 km (157,5 g/km CO_2) olarak bulunmuştur; düzeltme yalnızca yaklaşık 2 g yakıta karşılık geldiğinden katsayıdaki belirsizlik bu sonucu etkilememektedir.



Şekil 6. CS testlerinde çevrim yakıt tüketiminin batarya enerji değişimine (ΔE) göre değişimi

Ağırlıklı sonuçlar Tablo 2'de özetlenmiştir. Ağırlıklı CO_2 emisyonu 44,5 g/km, ağırlıklı yakıt tüketimi 1,85 L/100 km ve eşdeğer tam elektrikli menzil 48,4 km olarak hesaplanmıştır. Üreticinin açıkladığı değerler 2023

model yılı için 49–52 g/km, 2,1–2,3 L/100 km ve 43–44 km, 2024 model yılı için 41–45 g/km, 1,8–1,9 L/100 km ve yaklaşık 43 km'dir [15], [16]. Buna göre modelin ağırlıklı değerleri 2024 model yılı aralığında, 2023 model yılı aralığının ise altında kalmakta, elektrikli menzil ise üretici değerlerinin yaklaşık %10–13 üzerinde bulunmaktadır.

Tablo 2. WLTP CD ve CS testi sonuçları ile ağırlıklı değerler

Çevrim	SOC (%)	ΔE (kWh)	Yakıt (g)	CO2 (g/km)	UF artışı
CD1	99,5 → 69,5	−3,67	116	16,1	0,512
CD2	69,5 → 39,8	−3,40	116	16,1	0,222
CD3 (geçiş)	39,8 → 32,0	−0,87	811	112,1	0,104
CD4 (onay)	32,0 → 32,0	−0,01	1138	157,4	–
CS (düzeltilmiş)	32 → 32	0	1139	157,5	0,163
CD menzili R_{CDC}					**69,7 km**
Eşdeğer tam elektrikli menzil (EAER)					**48,4 km**
Ağırlıklı CO2 emisyonu					**44,5 g/km**
Ağırlıklı yakıt tüketimi					**1,85 L/100 km**

4. TARTIŞMA

Modelin ağırlıklı CO_2 emisyonu (44,5 g/km) ve yakıt tüketimi (1,85 L/100 km) üreticinin 2024 model yılı için açıkladığı aralıktadır. Buna karşılık eşdeğer tam elektrikli menzil (48,4 km) üretici değerlerinden yaklaşık %10–13 yüksektir. Ağırlıklı CO_2'nin düşük, menzilin yüksek çıkması ortak bir nedene işaret etmektedir: modelin enerji yönetim stratejisinde soğuk çalıştırma, katalizör ısıtma ve ısıl yönetim için İYM'yi çalıştıran kurallar bulunmamaktadır. Modelde CD testinde İYM yalnızca güç talebi 40 kW'ı aştığında çalışmaktadır. Gerçek araçta bu tür kurallar CD testinde de İYM'yi bir süre çalıştırarak CO_2 değerini artırır ve elektrikli menzili kısaltır. Ayrıca simülasyonlarda kullanılan referans kütle (1850 kg) WLTP test kütlesinden (yaklaşık 1937 kg) yaklaşık 87 kg düşüktür ve bu fark ağırlıklı CO_2 değerini yaklaşık 2,1 g/km düşürmektedir. Üretici değerlerinin iki model yılı arasında belirgin biçimde değişmesi de bu değerlerin donanım ve kalibrasyon farklarına duyarlı olduğunu göstermektedir. Ağırlıklı değerde CS testinin payı ($1 - \Sigma UF_j = 0{,}163$) küçük olmakla birlikte, CS emisyonu ilk iki CD çevriminin yaklaşık 9,8 katı olduğundan ağırlıklı CO_2 emisyonunun yarıdan fazlası CS testinden gelmektedir.

CS yakıt tüketimini artıran ilk etken, İYM'nin çoğunlukla düşük yükte çalışmasıdır (Şekil 4). Çevrim ortalaması özgül yakıt tüketimi (272 g/kWh) haritanın en düşük değerinden yaklaşık %18 yüksektir. İkinci etken, bataryanın P0 makinesi üzerinden şarj edilmesidir: CS testinde İYM'nin ürettiği işin 1,78 kWh'lik kısmı P0'da elektriğe dönüştürülmüş ve sonra P4 üzerinden yeniden mekanik enerjiye çevrilmiştir (Şekil 5). Bu çift dönüşüm nedeniyle bataryaya depolanan her 1 kWh için yaklaşık 3,1 kWh yakıt enerjisi harcanmaktadır (Şekil 6). Bu bulgular, kural tabanlı stratejide İYM'nin çalışma noktalarının daha verimli bir yük bölgesine kaydırılmasıyla CS tüketiminin azaltılabileceğine işaret etmektedir. Üçüncü olarak, İYM yakıt haritası ile elektrik makinelerinin kayıp haritaları üretici ölçümleri yerine literatürdeki bir araştırma modelinden türetilmiştir [6] ve şanzıman, yazılımın çift kavramalı şanzıman bileşeniyle temsil edilmiştir; bu yaklaşımlar da sonuçlarda belirli bir belirsizlik oluşturmaktadır.

Sonuçları etkileyen bir diğer model özelliği, batarya yönetim sisteminin şarj gücü sınırıdır. Örnek modelden devralınan sınır SOC %85'te sıfıra indiği için batarya dolu iken başlayan ilk CD çevriminde rejeneratif frenleme büyük ölçüde engelleniyordu. Şarj gücünün bu kadar düşük bir SOC değerinde sıfırlanması gerçek araç davranışını yansıtmadığından sınır SOC %90–95 aralığına taşınmıştır. Bu düzenlemenin yapıldığı ara model sürümünde ilk çevrimde P4'ün geri kazandığı enerji 0,20 kWh'ten 0,60 kWh'e çıkmış, eşdeğer elektrikli

menzil 1,9 km artmıştır. Bu sonuç, batarya yönetim sistemi parametrelerinin, özellikle tam şarjla başlayan sürüşlerde, PHEV'in elektrikli menzili üzerinde belirgin bir etkisi olduğunu göstermektedir. Üretici tarafından uygulanan gerçek şarj gücü sınırları bilinmediğinden bu parametre ileriki çalışmalarda duyarlılık analiziyle ayrıca incelenecektir.

Çalışmanın sınırlılıkları da göz önünde bulundurulmalıdır. Simülasyonlar sabit batarya sıcaklığında (25 °C), yardımcı tüketiciler 300 W sabit güçle temsil edilerek ve yalnızca WLTC çevrimiyle yapılmıştır. İYM'nin soğuk çalışma ve ısınma davranışı ile bataryanın sıcaklığa bağlı davranışı modelde yer almamaktadır. Örnek modelin kontrol mantığındaki kusurlar (Bölüm 2.3) giderilmeden önce araç hızı bazı çevrimlerde tolerans bandının dışına çıkmıştır. Bu düzeltmeler esas olarak test geçerliliğini sağlamış ve sonuçları az değiştirmiştir. Tek önemli istisna, İYM kapalıyken krank milinin aktarma organlarınca sürüklenmesinin giderilmesidir: bu düzeltmeyle İYM'nin ilk CD çevrimindeki çalışma süresi 102 s'den 79 s'ye inmiş ve eşdeğer elektrikli menzil 45,3 km'den 48,4 km'ye çıkmıştır. Bu sonuç, kontrol mantığındaki küçük bir ayrıntının bile fiziğe aykırı bir davranışa yol açtığında PHEV'in elektrikli menzilini belirgin biçimde etkileyebildiğini göstermektedir.

5. SONUÇ

Bu çalışmada P0+P4 mimarili bir PHEV, AVL CRUISE M ortamında modellenmiş ve WLTP CD/CS test prosedürüne göre simüle edilmiştir. Elde edilen başlıca sonuçlar şunlardır:

(i) Batarya dolu iken araç WLTC'nin düşük, orta ve yüksek hız fazlarını tamamen elektrikli olarak tamamlamış; İYM yalnızca çok yüksek hız fazında, toplam 79 s çalışmıştır. CD menzili 69,7 km, eşdeğer tam elektrikli menzil 48,4 km olarak bulunmuştur.

(ii) CS testinde İYM çevrimin 945 s'sinde çalışmış, ancak çoğunlukla düşük yükte kalmış ve ortalama özgül yakıt tüketimi 272 g/kWh olmuştur. CS yakıt tüketimi 6,56 L/100 km (157,5 g/km CO_2) olarak belirlenmiştir.

(iii) P0 makinesi üzerinden yapılan şarj, depolanan her 1 kWh için yaklaşık 3,1 kWh yakıt enerjisi gerektirmekte olup CS tüketimini artıran başlıca etkenlerden biridir. Üç CS testi neredeyse aynı doğru üzerinde yer aldığından (R^2 = 0,999) CS düzeltme katsayısı (274 g/kWh) güvenilir biçimde belirlenmiştir.

(iv) Ağırlıklı CO_2 emisyonu 44,5 g/km ve ağırlıklı yakıt tüketimi 1,85 L/100 km olarak hesaplanmıştır. Bu değerler üreticinin 2024 model yılı aralığındadır, elektrikli menzil ise üretici değerlerinden yaklaşık %10–13 yüksektir. Farkın olası nedeni, modelde soğuk çalıştırma ve katalizör ısıtma kurallarının bulunmamasıdır.

(v) Örnek modelin kontrol mantığındaki kusurlar C fonksiyonlarıyla giderilerek araç tüm CD ve CS testlerinde WLTP hız toleransı içinde tutulmuştur. Bu düzeltmelerden kapalı İYM'nin sürüklenmesinin giderilmesi, eşdeğer elektrikli menzili 3,1 km artırmıştır.

Çalışmanın devamında lastik boyutu ve yuvarlanma direnci, yol eğimi, klima ve yardımcı tüketiciler, araç yükü, ortam sıcaklığı ve sürücü davranışının enerji ve yakıt tüketimi üzerindeki etkileri bu referans model üzerinden incelenecektir.

KAYNAKLAR

[1] I. Husain, *Electric and hybrid vehicles: design fundamentals*, Third Edition. Boca Raton London New York: CRC Press, Taylor & Francis Group, 2021.

[2] "REGULATION (EU) 2019/ 631 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - of 17 April 2019 - setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443 / 2009 and (EU) No 510 / 2011".

[3] K. Çağatay Bayindir, M. A. Gözüküçük, ve A. Teke, "A comprehensive overview of hybrid electric vehicle: Powertrain configurations, powertrain control techniques and electronic control units", *Energy Convers. Manag.*, c. 52, sy. 2, ss. 1305-1313, Şub. 2011, doi: 10.1016/j.enconman.2010.09.028.

[4] L. Tribioli ve G. Bella, "Automotive hybrid electric systems: Design, modeling, and energy management", içinde *Hybrid Technologies for Power Generation*, Elsevier, 2022, ss. 279-312. doi: 10.1016/B978-0-12-823793-9.00010-3.
[5] P. Kapus, M. Brendel, G. Teuschl, ve T. Pels, "48-V Plug-in Hybrid Vehicles for Inner-city Zero Emission", *ATZ Worldw.*, c. 121, sy. 10, ss. 26-33, Eki. 2019, doi: 10.1007/s38311-019-0108-1.
[6] P. G. Anselma, M. Del Prete, ve G. Belingardi, "Battery High Temperature Sensitive Optimization-Based Calibration of Energy and Thermal Management for a Parallel-through-the-Road Plug-in Hybrid Electric Vehicle", *Appl. Sci.*, c. 11, sy. 18, s. 8593, Eyl. 2021, doi: 10.3390/app11188593.
[7] B. Subhash ve S. Kalakotla, "Plug-in hybrid electric vehicle system and its future advanced technology", içinde *Advanced Technologies in Electric Vehicles*, Elsevier, 2024, ss. 57-81. doi: 10.1016/B978-0-443-18999-9.00021-1.
[8] "Commission Regulation (EU) 2017/ of 1 June 2017 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information, amending Directive 2007/46/EC of the European Parliament and of the Council, Commission Regulation (EC) No 692/2008 and Commission Regulation (EU) No 1230/2012 and repealing Commission Regulation (EC) No 692/2008".
[9] C. M. Martinez, X. Hu, D. Cao, E. Velenis, B. Gao, ve M. Wellers, "Energy Management in Plug-in Hybrid Electric Vehicles: Recent Progress and a Connected Vehicles Perspective", *IEEE Trans. Veh. Technol.*, c. 66, sy. 6, ss. 4534-4549, Haz. 2017, doi: 10.1109/TVT.2016.2582721.
[10] E. M. Szumska ve A. Skuza, "Simulation and Modeling Programs for Electric and Hybrid Vehicles: A Review and Case Study of AVL Cruise for Energy Consumption Analysis", *Transp. Commun.*, c. 12, sy. 1, ss. 1-12, Nis. 2024, doi: 10.26552/tac.C.2024.1.1.
[11] C. C. Cioroianu, D. G. Marinescu, A. Iorga, ve A. R. Sibiceanu, "Simulation of an electric vehicle model on the new WLTC test cycle using AVL CRUISE software", *IOP Conf. Ser. Mater. Sci. Eng.*, c. 252, s. 012060, Eki. 2017, doi: 10.1088/1757-899X/252/1/012060.
[12] R. Merl, C. Jung, A. Huss, ve K. Klumaier, "Innovative Solutions for the Calibration of Hybrid Drives", *ATZ Worldw.*, c. 122, sy. 5, ss. 38-43, May. 2020, doi: 10.1007/s38311-020-0225-x.
[13] C. Beatrice, C. Capasso, S. Doulgeris, Z. Samaras, ve O. Veneri, "Hybrid storage system management for hybrid electric vehicles under real operating conditions", *Appl. Energy*, c. 354, s. 122170, Oca. 2024, doi: 10.1016/j.apenergy.2023.122170.
[14] M. Del Prete, P. G. Anselma, ve G. Belingardi, "Identifying Critical Use Cases for a Plug-in Hybrid Electric Vehicle Battery Pack from Thermal and Ageing Perspectives", program adı: SAE Powertrains, Fuels & Lubricants Digital Summit, Live Online, Pennsylvania, United States, Eyl. 2021, ss. 2021-01-1251. doi: 10.4271/2021-01-1251.

[15] Üretici teknik föyü (2023). Jeep Renegade PHEV 4xe, model yılı 2023: fiyat listesi ve teknik veriler. FCA Poland S.A.

[16] Üretici teknik föyü (2025). Jeep Renegade, model yılı 2024: fiyat listesi ve teknik veriler (01.01.2025). Slovenya.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

EFFECTS OF CRUDE BORAGE OIL BLENDING AND DIMETHYL CARBONATE ADDITION ON EXHAUST EMISSIONS OF A SINGLE-CYLINDER DIESEL ENGINE

Hanbey Hazar
Vedat Arslantatar
Huseyin Sevinc
0000-0001-7699-0088, Firat University, Faculty of Technology, Department of Automotive Engineering, Elazig, Türkiye.
0009-0003-0337-8156, Firat University, Faculty of Technology, Department of Automotive Engineering, Elazig, Türkiye.
0000-0001-7513-3412, Firat University, Faculty of Technology, Department of Automotive Engineering, Elazig, Türkiye.

Abstract

Investigating alternative fuels is essential for diversifying energy resources and reducing reliance on petroleum-derived fuels. However, their emission characteristics require evaluation before their wider application in diesel engines. Fuel additives offer a potential means of improving the combustion and emission characteristics of alternative fuels, thereby facilitating their utilization in conventional diesel engines. This study investigated the effects of crude borage oil blending and dimethyl carbonate (DMC) addition on carbon monoxide (CO), unburned hydrocarbon (HC), and nitrogen oxide (NO_X) emissions. Diesel blends containing 10%, 20%, and 30% crude borage oil, designated H10, H20, and H30, respectively, were tested alongside neat diesel (D100) and their DMC-containing counterparts. Experiments were performed using a single-cylinder, direct-injection, air-cooled diesel engine at 2000 rpm under loads of 1, 1.5, 2, 2.5, and 3 kW. Mean percentage changes were calculated by averaging the relative changes at the five loads, using D100 as the reference for borage oil blends and the corresponding additive-free blend for DMC addition. Compared with D100, H10, H20, and H30 increased CO by averages of 10.19%, 23.75%, and 35.90%, respectively. The corresponding increases were 9.56%, 25.76%, and 35.16% for HC and 5.70%, 12.26%, and 20.17% for NO_X. Adding DMC to H10, H20, and H30 reduced CO by averages of 6.82%, 8.12%, and 8.43%, respectively, and HC by 6.45%, 7.80%, and 7.27%. However, NO_X increased by averages of 3.43%, 4.48%, and 5.02%, respectively. Thus, increasing the crude borage oil fraction progressively increased the average relative emissions of all three pollutants. DMC partially mitigated CO and HC increases but introduced an additional NO_X penalty. These findings highlight the importance of evaluating both blend composition and additive use when assessing the emission implications of crude vegetable oil utilization in diesel engines.

Keywords: Crude borage oil; Dimethyl carbonate; Diesel engine; Exhaust emissions.

Introduction

The growing demand for sustainable energy resources and the environmental impacts of petroleum-derived fuels have intensified research into alternative fuels for compression ignition (CI) engines. Although alternative powertrain technologies are becoming increasingly widespread, conventional diesel engines continue to play an important role in transportation, agriculture, and stationary power generation. Consequently, improving the environmental characteristics of fuels compatible with existing diesel engines remains a relevant research objective. Vegetable oils have attracted considerable attention as potential alternatives because of their renewable origin and availability from various agricultural feedstocks. However, their direct utilization in diesel engines presents several challenges associated with relatively high viscosity, low volatility, and different combustion characteristics compared with conventional diesel fuel. These properties may adversely affect fuel atomization, air–fuel mixing, and combustion completeness, potentially increasing exhaust emissions. Blending vegetable oils with diesel fuel is therefore considered a practical

approach to improving their applicability without requiring extensive fuel processing (Wan Osman, Rosli, Mazli, & Samsuri, 2024).

Among vegetable-derived feedstocks, borage (*Borago officinalis* L.) oil represents an interesting alternative due to its distinctive fatty acid composition. Borage seed oil contains substantial proportions of unsaturated fatty acids, particularly linoleic, oleic, and gamma-linolenic acids. Salari et al. investigated the fatty acid composition of borage oil and highlighted its high unsaturated fatty acid content, which was influenced by cultivation conditions (Salari, Khalesro, Heidari, & Zareei, 2025). From a fuel perspective, the molecular structure and degree of unsaturation of vegetable oils are relevant to their physicochemical properties and combustion behavior. Knothe previously examined the fuel characteristics of methyl esters derived from borage and black currant oils, identifying the effects of highly unsaturated fatty acid components on fuel quality and oxidation stability (Knothe, 2013). However, findings obtained from chemically converted methyl esters cannot be directly generalized to crude vegetable oils because of differences in their molecular structures and physical properties. Therefore, the emission characteristics of crude borage oil blended directly with diesel fuel require further experimental investigation.

Oxygenated fuel additives offer another approach to modifying the combustion and emission characteristics of vegetable oil–diesel blends. Among these additives, dimethyl carbonate (DMC) has received attention because of its high oxygen content, approximately 53% by mass, and the absence of carbon–carbon bonds in its molecular structure. These characteristics may promote fuel oxidation and suppress the formation of carbonaceous combustion products. Furthermore, its relatively low viscosity and high volatility compared with vegetable oils can influence the physical properties of fuel blends. Aguado-Deblas et al. investigated diesel–DMC–vegetable oil blends containing sunflower and castor oils and reported improvements in fuel properties and substantial reductions in smoke emissions (Aguado-Deblas et al., 2021). Nevertheless, the relatively low heating value of DMC may influence fuel consumption and combustion performance, indicating that its effects depend on the overall blend composition and operating conditions.

Recent experimental investigations have further demonstrated the potential of DMC in alternative diesel fuel formulations. Gülüm (Gülüm, 2023) evaluated the addition of DMC to diesel–corn oil blends and reported reductions in CO, HC, and smoke emissions, although certain engine performance parameters deteriorated. O'Connell et al. (O'Connell, Stümpfl, Höß, & Lechner, 2025) investigated DMC and polyoxymethylene dimethyl ethers as additives for industrial diesel engines, emphasizing their effects on injection behavior, material compatibility, and exhaust emissions. Di et al. (Di et al., 2025) examined the effects of DMC concentration and engine load on regulated and unregulated emissions and found that particulate emissions could be reduced considerably, whereas NO_X emissions exhibited a non-monotonic response to DMC addition. More recently, Di et al. (Di et al., 2026) compared different ester-based oxygenates in diesel engines and demonstrated that their molecular structures and oxygen contents influenced combustion phasing and pollutant formation. These findings indicate that the environmental benefits of oxygenated additives cannot be evaluated solely through their oxygen content, since combustion temperature, fuel characteristics, and engine operating conditions may produce different emission responses.

Although previous studies have investigated DMC in combination with conventional diesel, biodiesel, and several vegetable oils, its application to crude borage oil–diesel blends remains insufficiently documented. In particular, the combined influence of increasing crude borage oil concentration and DMC addition on CO, HC, and NO_X emissions requires systematic evaluation. Accordingly, the present study experimentally investigates diesel blends containing 10%, 20%, and 30% crude borage oil, together with their DMC-containing counterparts, in a single-cylinder, direct-injection diesel engine. Experiments were conducted at a constant engine speed of 2000 rpm under five loads ranging from 1 to 3 kW. The emission effects of crude borage oil were evaluated relative to neat diesel, while the effects of DMC were determined relative to the corresponding additive-free blends. This approach enables the individual contributions of crude borage oil concentration and DMC addition to be distinguished and provides an assessment of the trade-offs among CO, HC, and NO_X emissions.

Materials and Methods

Test Fuels and Blend Preparation

Commercial diesel fuel (D100), crude borage oil (Borago officinalis L.), and dimethyl carbonate (DMC) were used in the experimental investigation. Crude borage oil was utilized without chemical conversion into biodiesel. Three binary fuel blends containing 10%, 20%, and 30% crude borage oil were designated H10, H20, and H30, respectively. Additional ternary blends were formulated by incorporating DMC into the corresponding diesel–borage oil mixtures and were designated H10DMC, H20DMC, and H30DMC.
DMC was added to the fuel blends at a constant concentration of 10% by volume. All fuel components were mixed using a magnetic stirrer for 20 minutes to ensure homogeneous blending. The investigated fuel formulations are summarized in Table 1.

Table 1. Fuel formulations investigated in the experiments.

Fuel code	Diesel (vol.%)	Crude borage oil (vol.%)	DMC (vol.%)
D100	100	0	0
H10	90	10	0
H20	80	20	0
H30	70	30	0
H10DMC	80	10	10
H20DMC	70	20	10
H30DMC	60	30	10

Experimental Setup
The experiments were conducted using a single-cylinder, four-stroke, direct-injection, air-cooled diesel engine. The engine was operated at a constant speed of 2000 rpm, while the applied load was varied between 1 and 3 kW. An adjustable loading system was used to establish the required operating conditions. Exhaust emissions were measured using an exhaust gas analyzer. The investigated parameters were carbon monoxide (CO), unburned hydrocarbons (HC), and nitrogen oxides (NO_X). CO emissions were expressed as volume percentage (vol.%), whereas HC and NO_X concentrations were recorded in parts per million (ppm). A schematic representation of the experimental arrangement is presented in Fig. 1.

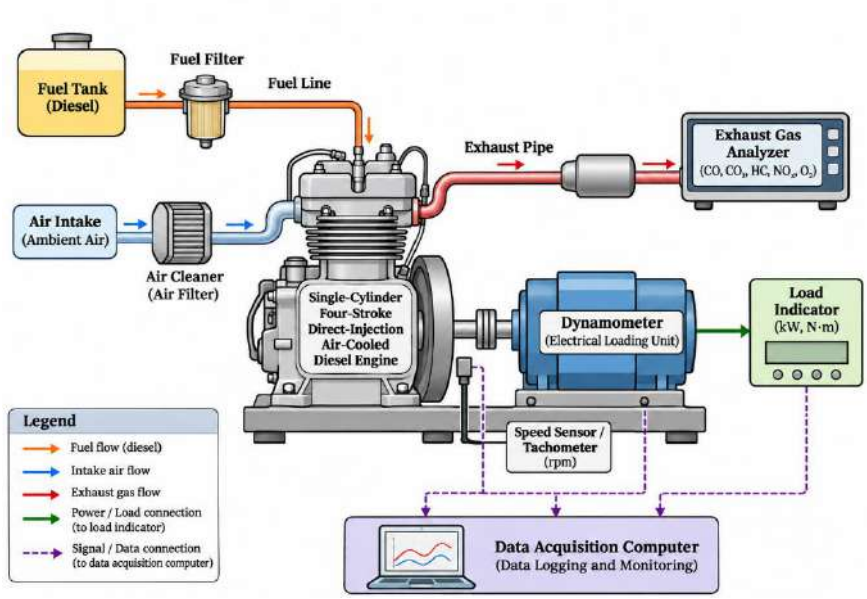


Figure. 1. Schematic representation of the experimental diesel engine test setup.

Experimental Procedure
The experiments were performed at a constant engine speed of 2000 rpm under five load conditions: 1, 1.5, 2, 2.5, and 3 kW. Each fuel formulation was tested under the same operating conditions to ensure comparability

of the emission results. Before the experiments, the engine was operated under no-load idling conditions for 20 minutes to reach stable operating conditions. At each operating point, exhaust emission measurements were recorded when the fluctuations in the measured values became minimal.

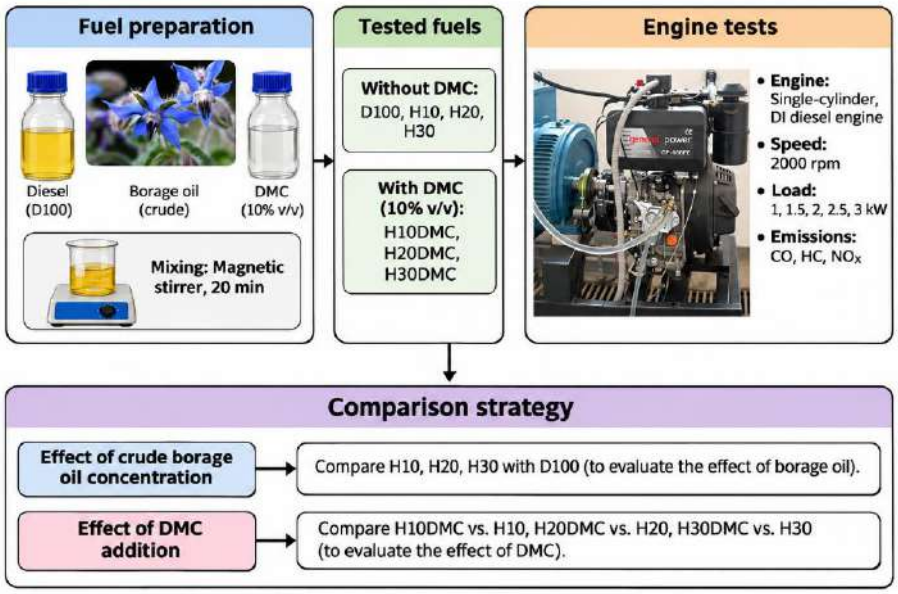


Figure. 2. Experimental workflow and comparison strategy for evaluating the effects of crude borage oil and DMC addition.

Measurements were repeated three times for each test condition, and the arithmetic mean of these measurements was used for the evaluation of the emission results. The experimental procedure involved two main comparisons. First, the effects of increasing crude borage oil concentration were evaluated by comparing H10, H20, and H30 with D100. Subsequently, the influence of DMC addition was examined by comparing H10DMC, H20DMC, and H30DMC with their corresponding additive-free blends. The experimental workflow and comparison strategy are illustrated in Fig. 2.

Findings and Discussion

Carbon Monoxide (CO) Emissions

The variation in CO emissions with engine load for the investigated fuel blends is presented in Fig. 3. For all tested fuels, CO emissions initially decreased as the engine load increased from 1 to 1.5 kW, followed by a progressive increase at higher loads. The lowest CO concentration for D100 was recorded at 1.5 kW (0.029 vol.%), whereas the highest value was observed at 3 kW (0.175 vol.%). The initial reduction may be attributed to improved combustion conditions as the engine transitions from low to moderate loads. However, at higher loads, increased fuel delivery and locally fuel-rich combustion regions may restrict complete oxidation of carbon-containing species, resulting in higher CO concentrations.

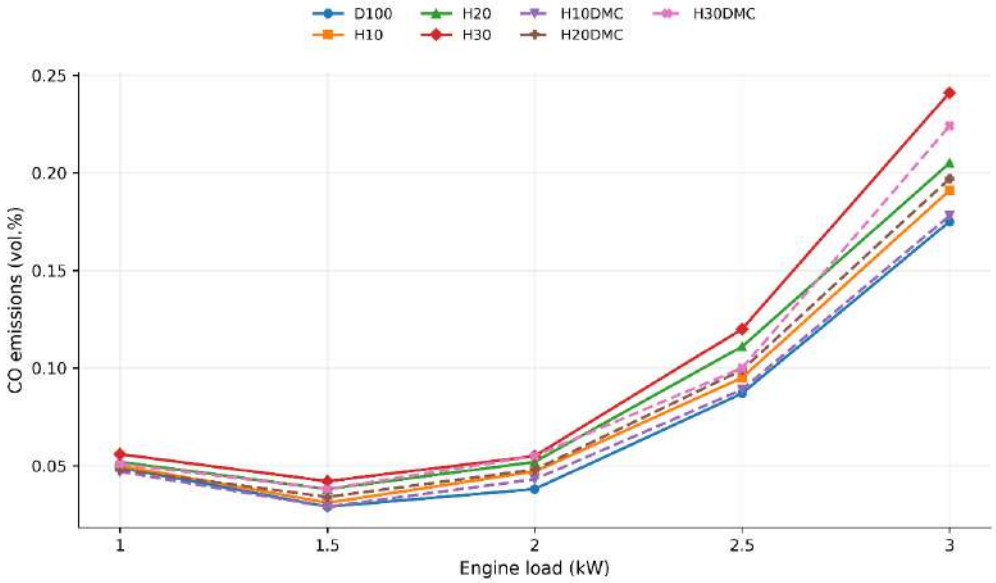


Figure. 3. Variation of CO emissions with engine load for the investigated fuel blends.

Increasing the crude borage oil fraction consistently increased CO emissions compared with D100. The average increases across the five engine loads were 10.19%, 23.75%, and 35.90% for H10, H20, and H30, respectively. The highest CO concentration (0.241 vol.%) was obtained with H30 at 3 kW, representing an increase of 37.71% relative to D100 at the same load. This behavior may be associated with the relatively high viscosity and low volatility generally characteristic of crude vegetable oils, which can adversely affect fuel atomization, evaporation, and air–fuel mixing. Consequently, increasing the vegetable oil fraction may promote incomplete oxidation, particularly under high-load conditions.

The incorporation of 10% DMC reduced CO emissions for all three borage oil blend groups on average. Compared with their corresponding additive-free blends, H10DMC, H20DMC, and H30DMC exhibited average reductions of 6.82%, 8.12%, and 8.43%, respectively. The most pronounced individual reduction was observed for H30DMC at 2.5 kW, where CO decreased from 0.120 to 0.100 vol.%. Nevertheless, the reduction was load-dependent, and no change was observed between H30 and H30DMC at 2 kW. The overall improvement may be related to the high oxygen content of DMC, which can facilitate CO oxidation in locally oxygen-deficient regions. In addition, the relatively low viscosity and high volatility of DMC may favorably influence the atomization and evaporation characteristics of the blends. Similar reductions in CO emissions following DMC addition to diesel–corn oil blends were reported by Gülüm (Gülüm, 2023). However, the DMC-containing borage oil blends still exhibited higher average relative CO emissions than D100, indicating that DMC only partially compensated for the adverse effects associated with increasing crude borage oil concentration.

Unburned Hydrocarbon (HC) Emissions

Figure 4 illustrates the variation in HC emissions with engine load for the investigated fuels. Similar to CO emissions, HC concentrations generally decreased from 1 to 1.5 kW and subsequently increased with increasing load. For D100, HC emissions decreased from 17 ppm at 1 kW to 14 ppm at 1.5 kW before increasing to 21 ppm at 3 kW. This behavior suggests that combustion completeness was more favorable at intermediate loads, whereas higher fuel delivery at elevated loads may have increased the formation of locally rich or incompletely burned fuel regions.

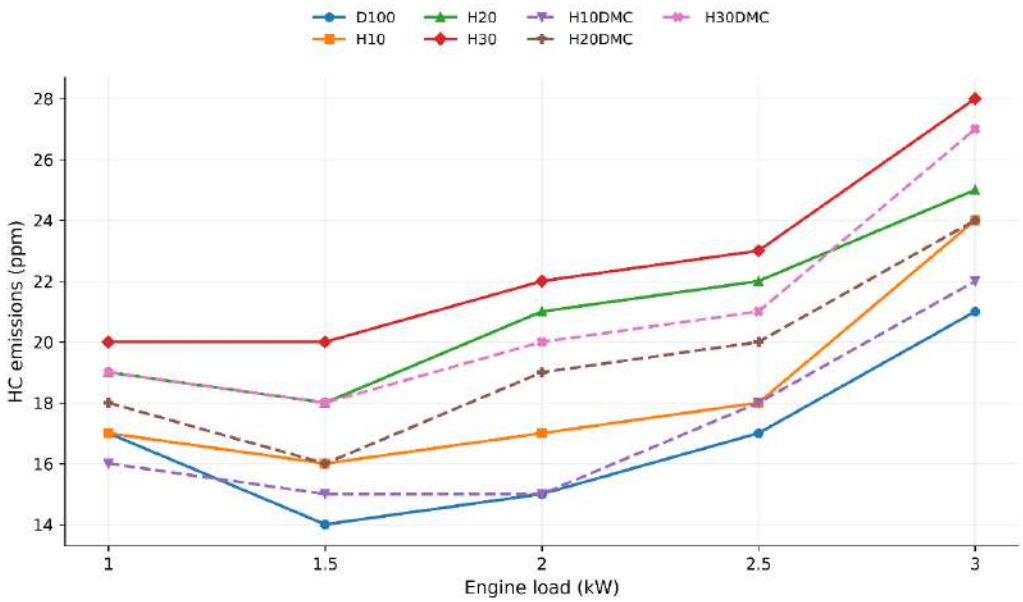


Figure. 4. Variation of HC emissions with engine load for the investigated fuel blends.

Crude borage oil addition increased HC emissions, and the magnitude of this increase became more pronounced as the oil concentration increased. Compared with D100, the average HC increases were 9.56%, 25.76%, and 35.16% for H10, H20, and H30, respectively. At 3 kW, HC concentrations reached 24, 25, and 28 ppm for these blends, compared with 21 ppm for D100. The increased HC concentrations may be attributed to the deterioration of fuel spray characteristics and incomplete evaporation associated with higher crude vegetable oil contents. Such conditions can reduce fuel–air mixing uniformity and increase the possibility of unburned fuel remaining in the combustion chamber.

DMC addition generally improved the HC emission characteristics of the borage oil blends. Average reductions of 6.45%, 7.80%, and 7.27% were obtained for H10DMC, H20DMC, and H30DMC, respectively, relative to their additive-free counterparts. The beneficial effect was observed over most engine loads, although H10 and H10DMC produced identical HC concentrations at 2.5 kW. The reduction in HC emissions may be associated with improved fuel oxidation due to the oxygen supplied by DMC and its potential influence on fuel evaporation and mixing. These findings are consistent with the reductions in HC emissions reported for DMC-containing diesel–vegetable oil formulations (Gülüm, 2023). Nevertheless, the relatively moderate reductions observed in this study indicate that oxygen enrichment alone may not completely overcome the combustion limitations associated with crude borage oil. Overall, increasing the borage oil concentration increased HC emissions, while DMC addition provided a partial improvement in combustion completeness.

Nitrogen Oxide (NO_X) Emissions

The effects of engine load and fuel composition on NO_X emissions are illustrated in Fig. 5. Unlike CO and HC emissions, NO_X concentrations increased with engine load up to 2.5 kW and subsequently decreased at 3 kW for all investigated fuels. For D100, NO_X concentrations increased from 386 ppm at 1 kW to 569 ppm at 2.5 kW before decreasing to 479 ppm at the maximum load. This trend may be associated with changes in combustion temperature, local oxygen availability, and combustion duration as the engine load increases. The decrease observed at 3 kW may reflect changes in the local air–fuel ratio and combustion characteristics under high-load operation.

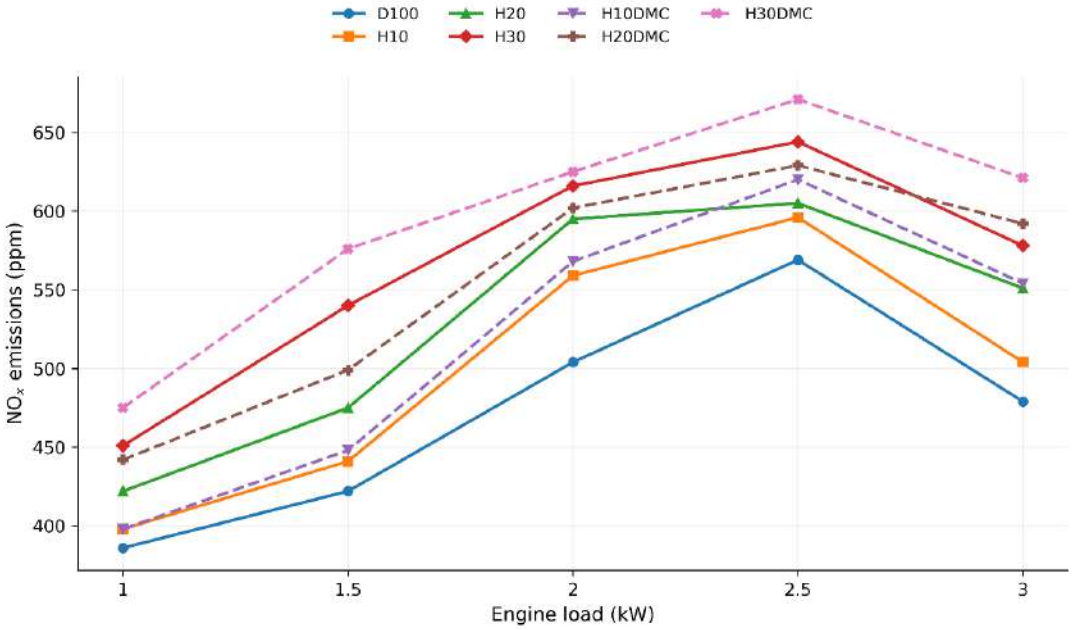


Figure. 5. Variation of NO_X emissions with engine load for the investigated fuel blends.

Increasing the crude borage oil fraction resulted in progressively higher NO_X emissions. Compared with D100, the average increases were 5.70%, 12.26%, and 20.17% for H10, H20, and H30, respectively. At 2.5 kW, NO_X concentrations reached 596, 605, and 644 ppm for H10, H20, and H30, compared with 569 ppm for D100. The higher NO_X concentrations may be associated with changes in local combustion temperature, oxygen availability, and combustion phasing resulting from differences in fuel composition and physical properties. However, since in-cylinder temperature and heat-release characteristics were not directly evaluated, the individual contributions of these mechanisms cannot be conclusively identified.

In contrast to its beneficial effects on CO and HC emissions, DMC addition caused a further increase in NO_X concentrations. Compared with the corresponding additive-free blends, average NO_X increases of 3.43%, 4.48%, and 5.02% were obtained for H10DMC, H20DMC, and H30DMC, respectively. The highest NO_X concentration of the study was recorded for H30DMC at 2.5 kW (671 ppm). The additional oxygen introduced by DMC may enhance oxidation reactions and potentially influence local combustion temperatures, thereby promoting conditions favorable to NO_X formation. Nevertheless, the influence of DMC on NO_X is highly dependent on fuel composition and engine operating conditions. Di et al. reported a non-monotonic NO_X response to DMC addition, while subsequent investigations demonstrated that oxygenated fuel molecular structure can influence combustion phasing and emission formation (Di et al., 2025). Therefore, the NO_X increases observed in the present study should be interpreted as specific to the investigated fuel formulations and operating conditions.

Conclusion and Recommendations

This study experimentally investigated the effects of crude borage oil blending and 10% dimethyl carbonate (DMC) addition on CO, HC, and NO_X emissions in a single-cylinder diesel engine operating at 2000 rpm under different load conditions. The main conclusions are summarized as follows:

- Increasing the crude borage oil concentration from 10% to 30% progressively increased exhaust emissions. Compared with D100, the average increases ranged from 10.19% to 35.90% for CO, 9.56% to 35.16% for HC, and 5.70% to 20.17% for NO_X.
- DMC addition improved the emission characteristics of the borage oil blends by reducing CO and HC emissions by 6.82–8.43% and 6.45–7.80%, respectively, compared with the corresponding additive-free blends.

- Despite these improvements, DMC addition increased NO_X emissions by 3.43–5.02%, indicating a trade-off between reducing incomplete combustion products and limiting nitrogen oxide formation.
- Although DMC partially mitigated the adverse emission effects of crude borage oil, the investigated blends generally exhibited higher emissions than conventional diesel fuel.

Overall, the findings demonstrate that DMC has potential as an oxygenated additive for improving the CO and HC emission characteristics of crude vegetable oil–diesel blends. However, optimizing the blend composition is essential to minimize the associated NO_X penalty. Future studies should investigate different DMC concentrations and evaluate fuel properties, engine performance, and combustion characteristics to determine more favorable operating conditions and blend formulations.

Thanks and Information Note
The authors gratefully acknowledge the financial support provided by the Scientific Research Projects Coordination Unit (BAP) of Fırat University under Project No. TEKF.25.15.

References

Aguado-Deblas, L., Hidalgo-Carrillo, J., Bautista, F. M., Luna, C., Calero, J., Posadillo, A., … Estévez, R. (2021). Evaluation of Dimethyl Carbonate as Alternative Biofuel. Performance and Smoke Emissions of a Diesel Engine Fueled with Diesel/Dimethyl Carbonate/Straight Vegetable Oil Triple Blends. *Sustainability*, *13*(4), 1749. https://doi.org/10.3390/su13041749

Di, Y., Huang, X., Jiang, P., Ying, G., Chen, X., Jiang, Z., & Lu, J. (2026). Experimental Study and Modeling the Effect of Ester-Based Oxygenates on Combustion and Emission of a Diesel Engine. *Journal of Energy Engineering*, *152*(4). https://doi.org/10.1061/JLEED9.EYENG-6650

Di, Y., Jiang, Z., Ying, G., Chen, X., Lu, J., & Wang, C. (2025). Effects of DMC and operating load on regulated and unregulated emissions of a diesel engine. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *47*(1), 9966–9980. https://doi.org/10.1080/15567036.2025.2494851

Gülüm, M. (2023). Effect of adding dimethyl carbonate and gasoline to diesel fuel + corn oil blend on performance and combustion characteristics of a diesel engine. *Environmental Science and Pollution Research*, *31*(27), 38926–38939. https://doi.org/10.1007/s11356-023-27121-y

Knothe, G. (2013). Fuel properties of methyl esters of borage and black currant oils containing methyl γ-linolenate. *European Journal of Lipid Science and Technology*, *115*(8), 901–908. https://doi.org/10.1002/ejlt.201300061

O'Connell, N., Stümpfl, D., Höß, R., & Lechner, R. (2025). Potential of DMC and PODE as Fuel Additives for Industrial Diesel Engines. *Fuels*, *6*(2), 44. https://doi.org/10.3390/fuels6020044

Salari, F., Khalesro, S., Heidari, G., & Zareei, S. (2025). Fertilizer type and intercropping influence the metabolic and nutritional profiles of borage and peanut. *Scientific Reports*, *15*(1), 38596. https://doi.org/10.1038/s41598-025-22446-9

Wan Osman, W. N. A., Rosli, M. H., Mazli, W. N. A., & Samsuri, S. (2024). Comparative review of biodiesel production and purification. *Carbon Capture Science & Technology*, *13*, 100264. https://doi.org/10.1016/j.ccst.2024.100264

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

EXPERIMENTAL EVALUATION OF GASEOUS EMISSIONS FROM A DIESEL ENGINE FUELED WITH CRUDE GARLIC OIL BLENDS AND DIETHYL ETHER

Hanbey Hazar
Vedat Arslantatar
Huseyin Sevinc
0000-0001-7699-0088, Firat University, Faculty of Technology, Department of Automotive Engineering, Elazig, Türkiye.
0009-0003-0337-8156, Firat University, Faculty of Technology, Department of Automotive Engineering, Elazig, Türkiye.
0000-0001-7513-3412, Firat University, Faculty of Technology, Department of Automotive Engineering, Elazig, Türkiye.

Abstract

Exploring alternative fuels and suitable additives can support fuel diversification while addressing the emission challenges of diesel engines. Evaluating their combined effects is therefore important for identifying blends with favorable emission characteristics. This study experimentally investigated the effects of crude garlic oil and diethyl ether (DEE) on carbon monoxide (CO), unburned hydrocarbon (HC), and nitrogen oxide (NO_X) emissions. Diesel blends containing 10%, 20%, and 30% crude garlic oil were designated S10, S20, and S30, respectively. Their counterparts containing a fixed DEE proportion of 5% were also tested and compared with neat diesel (D100). Experiments were conducted using a single-cylinder, direct-injection, air-cooled diesel engine at a constant speed of 2000 rpm and loads of 1, 1.5, 2, 2.5, and 3 kW. Average percentage changes were determined as the arithmetic means of the relative changes at the five loads. Compared with D100, S10, S20, and S30 reduced CO by averages of 9.60%, 18.86%, and 30.58%, respectively, and HC by 7.82%, 16.39%, and 28.27%. Their average NO_X increases were 7.77%, 13.49%, and 18.24%, respectively, indicating a greater NO_X penalty as the garlic oil fraction increased. Relative to the corresponding DEE-free blends, adding 5% DEE further reduced CO by averages of 9.71%, 9.51%, and 8.12% and HC by 8.12%, 8.10%, and 6.30% for S10, S20, and S30, respectively. However, DEE increased NO_X by averages of 4.51%, 3.06%, and 3.67%, respectively. DEE reduced CO at every tested load, whereas HC decreased or remained unchanged. Overall, increasing the garlic oil fraction strengthened the average CO and HC reductions but increased NO_X. DEE provided additional average CO and HC reductions, accompanied by a further NO_X increase, highlighting the need to balance competing emission outcomes.

Keywords: Crude garlic oil; Diethyl ether; Diesel engine; Exhaust emissions.

Introduction

Compression ignition (CI) engines remain essential in transportation, agricultural machinery, and stationary power generation because of their high thermal efficiency, reliability, and durability. Nevertheless, their dependence on petroleum-derived fuels and the formation of harmful exhaust pollutants have encouraged the investigation of alternative fuel formulations. Among the available approaches, blending conventional diesel with fuels derived from biological resources provides an opportunity to diversify fuel sources while maintaining compatibility with existing engine technologies. However, the environmental benefits of alternative fuels are strongly influenced by their chemical composition, physical properties, and combustion behavior. Therefore, evaluating individual fuel components and their combined effects on exhaust emissions is essential for developing more effective fuel formulations (Yuksel, 2024).
Garlic (*Allium sativum* L.) is an agricultural product containing various biologically active compounds, particularly organosulfur constituents. Garlic-derived oils have attracted attention because of their distinctive chemical composition, although their properties can vary considerably depending on the extraction and processing methods. Zhang et al. (Zhang et al., 2025) emphasized that garlic oil composition is strongly

affected by production conditions and identified several sulfur-containing compounds, including diallyl sulfide, diallyl disulfide, and diallyl trisulfide, as characteristic constituents of garlic oil preparations. Such compositional characteristics make garlic-derived oils an interesting subject for alternative fuel investigations. However, the properties of a particular crude garlic oil cannot be established solely from general compositional information, and its suitability for diesel engine applications requires experimental evaluation.

Recent research has begun to examine the potential of garlic-derived fuels in compression ignition engines. Yuksel (Yuksel, 2024) experimentally investigated garlic methyl ester (GME) and its diesel blends under different engine loads, considering the effects of fuel composition and preheating on engine performance and exhaust emissions. The study demonstrated that garlic-derived fuel could influence CO, HC, and NO_X emissions and highlighted the importance of fuel processing conditions. Nevertheless, garlic methyl ester is chemically different from crude garlic oil because transesterification modifies the original fuel constituents. Consequently, the emission characteristics reported for garlic-derived biodiesel cannot be directly extended to the use of unconverted crude garlic oil. This distinction creates a basis for investigating the direct incorporation of crude garlic oil into diesel fuel.

Fuel additives represent an additional strategy for modifying the combustion characteristics of alternative fuel blends. Among oxygenated additives, diethyl ether (DEE) has attracted considerable attention because of its high cetane number, low viscosity, high volatility, and oxygen-containing molecular structure. These properties can influence ignition behavior, fuel evaporation, and air–fuel mixing, potentially improving combustion completeness. Aguado-Deblas et al. (Aguado-Deblas et al., 2020) investigated diesel–vegetable oil–DEE blends and demonstrated the potential of DEE to improve blend properties and reduce pollutant emissions. Similarly, Mohammed et al. (Mohammed, Atnaw, Ramaya, & Alemayehu, 2023) reviewed the application of ether-based additives in compression ignition engines and highlighted their potential to improve combustion characteristics. Nevertheless, the influence of DEE on exhaust emissions depends on the fuel composition and operating conditions, and improvements in individual pollutants do not necessarily imply an overall reduction in emissions.

Recent investigations have further emphasized the importance of optimizing oxygenated fuel formulations. Ooi et al. (Ooi et al., 2024) evaluated diesel–palm oil biodiesel–ethanol–DEE blends and demonstrated that additive concentration and engine load significantly influenced CO, unburned hydrocarbon, and NO_X emissions. Youssef and Ibrahim (Youssef & Ibrahim, 2024) investigated DEE-containing diesel–biodiesel blends and reported improvements in engine performance and reductions in NO_X emissions under the investigated conditions. Furthermore, Sonawane and Agarwal (Sonawane & Agarwal, 2025) experimentally examined DEE–diesel blends under different injection timings and exhaust gas recirculation rates, highlighting the strong relationship between fuel properties, combustion conditions, and emission formation. Collectively, these findings indicate that DEE can provide beneficial emission characteristics, although its effects cannot be generalized across different fuels and operating conditions.

Despite the growing interest in oxygenated additives and unconventional plant-derived fuels, experimental information concerning the combined use of crude garlic oil and DEE in diesel engines remains limited. In particular, the influence of increasing crude garlic oil concentration and the additional effect of a fixed DEE proportion on gaseous exhaust emissions require systematic investigation. Therefore, the present study experimentally evaluates diesel blends containing 10%, 20%, and 30% crude garlic oil, designated S10, S20, and S30, respectively, together with their counterparts containing 5% DEE. Experiments were conducted using a single-cylinder, direct-injection, air-cooled diesel engine at a constant speed of 2000 rpm under loads of 1, 1.5, 2, 2.5, and 3 kW. The effects of crude garlic oil were evaluated relative to neat diesel, whereas those of DEE were assessed using the corresponding additive-free blends as references. By separately examining these effects, the study aims to clarify the relationships between fuel composition and CO, HC, and NOX emissions and identify the potential trade-offs associated with crude garlic oil and DEE utilization.

Materials and Methods

Test Fuels and Blend Preparation

Commercial diesel fuel (D100), crude garlic oil (Allium sativum L.), and diethyl ether (DEE) were used to prepare the experimental fuel blends. Crude garlic oil was incorporated directly into diesel fuel without conversion into biodiesel. Three binary fuel blends were prepared by incorporating 10%, 20%, and 30% crude garlic oil into diesel fuel on a volumetric basis and were designated S10, S20, and S30, respectively. For the DEE-containing formulations, 5 vol.% of the diesel fraction was replaced with DEE while maintaining the corresponding crude garlic oil concentration. Accordingly, S10DEE, S20DEE, and S30DEE contained 5 vol.% DEE. The prepared fuel mixtures were homogenized using a magnetic stirrer for 20 minutes. The detailed volumetric compositions of the investigated fuels are presented in Table 1.

Table 1. Fuel formulations investigated in the experiments.

Fuel code	Diesel (vol.%)	Crude garlic oil (vol.%)	DEE (vol.%)
D100	100	0	0
S10	90	10	0
S20	80	20	0
S30	70	30	0
S10DEE	85	10	5
S20DEE	75	20	5
S30DEE	65	30	5

Experimental Setup

The experimental tests were carried out on a single-cylinder, four-stroke diesel engine equipped with a direct fuel injection system and air cooling. Engine loading was controlled through an adjustable load unit, allowing the operating conditions to be varied while maintaining a constant rotational speed of 2000 rpm. Five load levels, ranging from 1 to 3 kW at 0.5 kW intervals, were selected to examine the emission response under different operating conditions. The exhaust gas composition was monitored using a gas emission analyzer, with particular emphasis on CO, HC, and NO_X. The measured CO concentrations were expressed in volume percentage (vol.%), whereas HC and NO_X values were reported in parts per million (ppm). An overview of the engine test arrangement is presented in Fig. 1, while the exhaust gas analyzer used for emission measurements is shown in Fig. 2.

Figure. 1. Photograph of the experimental diesel engine test setup.

Figure. 2. Photograph of the exhaust gas analyzer used for the measurement of exhaust emissions.

Experimental Procedure

Before conducting the experiments, the engine was operated under no-load idling conditions for 20 minutes to reach stable operating conditions. Subsequently, the engine speed was maintained at 2000 rpm, and the applied load was gradually adjusted to the predetermined values.

Exhaust emission measurements were recorded at each operating point when fluctuations in the measured parameters became minimal. Each measurement was repeated three times under the same operating conditions, and the arithmetic mean was used to determine the representative emission values.

The experimental investigation consisted of two comparison stages. In the first stage, the effects of crude garlic oil concentration were evaluated by comparing S10, S20, and S30 with D100. In the second stage, the influence of DEE addition was investigated by comparing S10DEE, S20DEE, and S30DEE with their corresponding DEE-free blends. This approach allowed the effects of garlic oil concentration and DEE addition to be evaluated separately.

Findings and Discussion

Carbon Monoxide (CO) Emissions

Figure 3 presents the variation in CO emissions with engine load for diesel, crude garlic oil blends, and their DEE-containing counterparts. A similar load-dependent trend was observed for all investigated fuels. CO concentrations decreased between 1 and 1.5 kW, followed by a marked increase as the load approached 3 kW. For D100, the minimum CO concentration was measured at 1.5 kW (0.029 vol.%), while the maximum value reached 0.175 vol.% at 3 kW. The initial reduction may be associated with more favorable combustion conditions at moderate loads. Conversely, the increase at higher loads can be related to increased fuel delivery and the development of locally fuel-rich regions, which may limit the complete conversion of CO into CO_2.

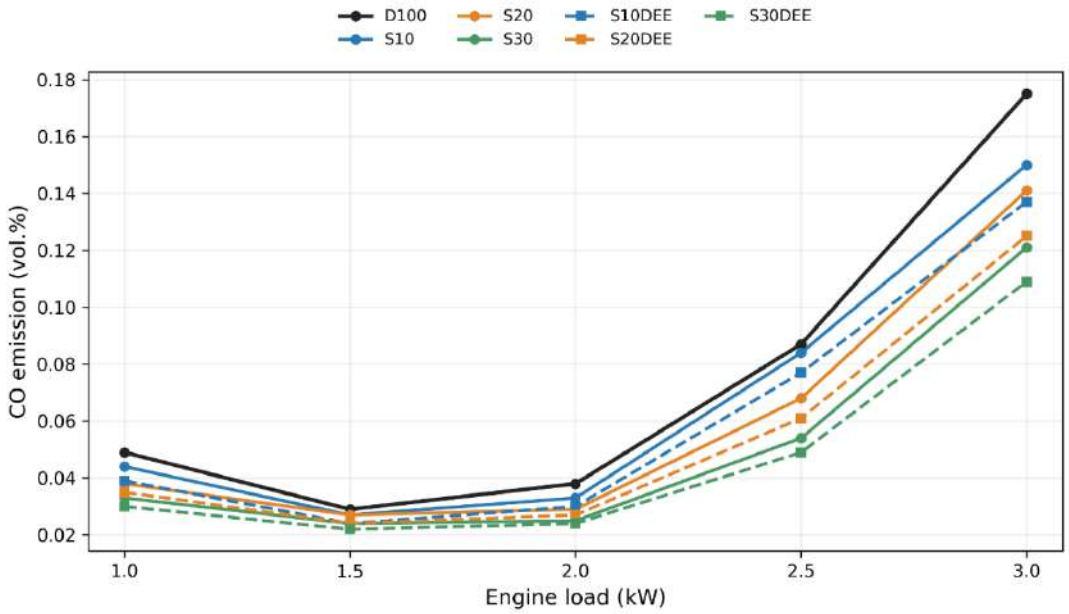


Figure. 3. Variation of CO emissions with engine load for crude garlic oil–diesel blends with and without DEE addition.

The addition of crude garlic oil resulted in lower CO concentrations compared with D100, with reductions generally becoming more pronounced as the garlic oil proportion increased. The average decreases were 9.60%, 18.86%, and 30.58% for S10, S20, and S30, respectively. At 2.5 kW, CO emissions decreased from 0.087 vol.% for D100 to 0.054 vol.% for S30, corresponding to a reduction of 37.93%. These findings suggest that the incorporation of crude garlic oil modified the combustion process in a manner favorable to CO oxidation under the investigated conditions. However, without detailed fuel characterization and in-cylinder combustion measurements, the contribution of individual physicochemical properties cannot be conclusively established. Yuksel (Yuksel, 2024) also reported reductions in CO emissions using garlic-derived methyl ester fuels, although the chemical differences between methyl esters and crude garlic oil should be considered when comparing these results.

The addition of 5% DEE provided further CO reductions at every investigated operating point. Relative to the corresponding additive-free blends, the average decreases were 9.71%, 9.51%, and 8.12% for S10DEE, S20DEE, and S30DEE, respectively. The lowest CO concentration of the study was obtained with S30DEE at 1.5 kW (0.022 vol.%). The favorable influence of DEE may be associated with its oxygen-containing structure, high volatility, and low viscosity, which can contribute to improved fuel evaporation and air–fuel mixing. Aguado-Deblas et al. (Aguado-Deblas et al., 2020) also emphasized the favorable physicochemical characteristics of DEE in diesel–vegetable oil formulations. Overall, the results indicate that both increasing crude garlic oil concentration and introducing DEE contributed to lower CO emissions, although the magnitude of these improvements varied with engine load.

Unburned Hydrocarbon (HC) Emissions

The relationship between engine load and HC emissions is illustrated in Fig. 4. For conventional diesel fuel, HC emissions initially decreased from 17 ppm at 1 kW to 14 ppm at 1.5 kW, subsequently increasing to 21 ppm at 3 kW. A broadly similar pattern was observed for the alternative fuel blends, with the highest HC concentrations generally recorded at maximum load. This behavior may reflect the combined effects of fuel evaporation, combustion chamber temperature distribution, and local air–fuel mixture formation. At higher loads, increased fuel delivery may favor the persistence of incompletely oxidized hydrocarbons in regions where sufficient oxygen or residence time is unavailable.

Increasing the crude garlic oil concentration generally decreased HC emissions throughout the investigated load range. Compared with D100, S10, S20, and S30 exhibited average reductions of 7.82%, 16.39%, and

28.27%, respectively. At the maximum engine load, HC emissions decreased from 21 ppm for D100 to 18, 17, and 15 ppm for S10, S20, and S30, respectively. The reduction became more pronounced at higher garlic oil concentrations, suggesting more favorable conditions for hydrocarbon oxidation. Nevertheless, the response was not uniform at every operating point, as identical HC concentrations of 15 ppm were recorded for D100 and S10 at 2 kW. The overall trend is consistent with findings reported for garlic methyl ester fuels (Yuksel, 2024), although differences in chemical composition and fuel processing prevent direct mechanistic equivalence.

DEE incorporation further improved the HC emission characteristics of the investigated blends. Compared with S10, S20, and S30, the corresponding DEE-containing fuels produced average reductions of 8.12%, 8.10%, and 6.30%, respectively. The maximum individual reduction associated with DEE was observed for S10 at 2 kW, where HC emissions decreased from 15 to 12 ppm, corresponding to a 20% reduction. However, DEE did not reduce HC emissions at every operating point; several comparisons produced unchanged concentrations. The lowest HC value of 10 ppm was obtained with S30DEE at both 1.5 and 2 kW. The additional reductions may be related to the favorable evaporation characteristics and ignition-promoting properties of DEE, which can affect mixture preparation and combustion completeness. Similar considerations regarding the role of DEE in modifying fuel behavior have been discussed in previous investigations [3,5]. These findings demonstrate that DEE can complement the HC reduction associated with crude garlic oil, although its effectiveness depends on the fuel composition and operating condition.

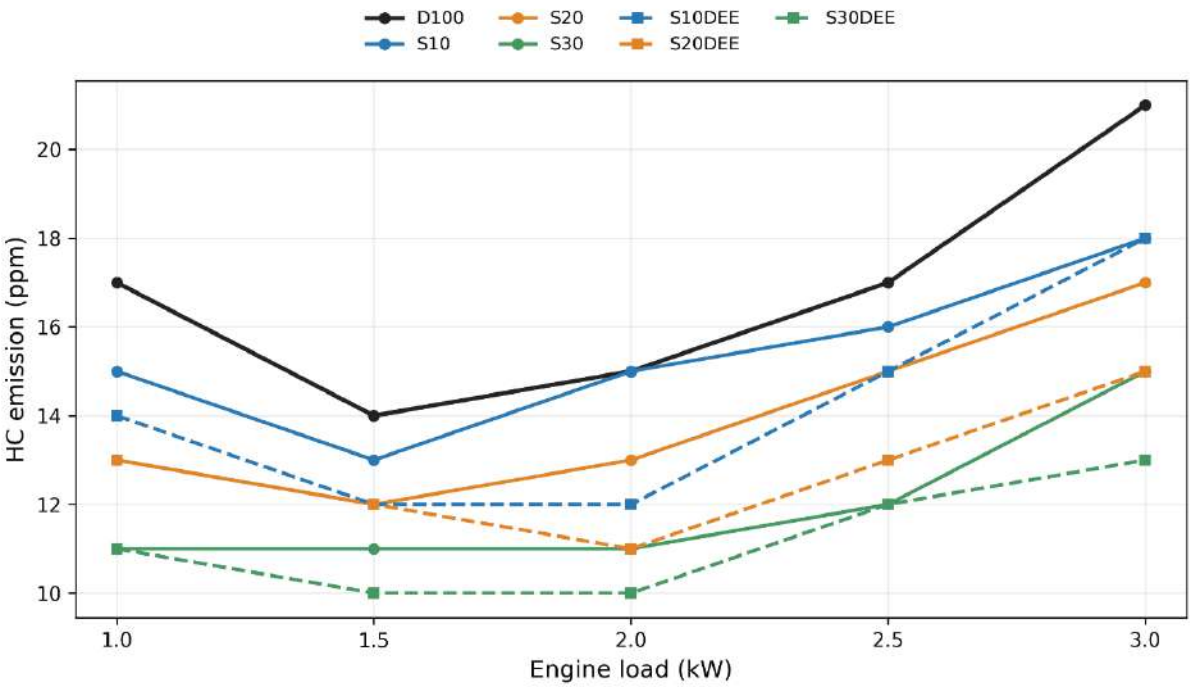


Figure. 4. Variation of HC emissions with engine load for crude garlic oil–diesel blends with and without DEE addition.

Nitrogen Oxide (NO_X) Emissions

Figure 5 illustrates the variation in NO_X emissions for the investigated fuel formulations. Unlike CO and HC, NO_X concentrations increased with engine load up to 2.5 kW and subsequently decreased at 3 kW for all tested fuels. For D100, NO_X increased from 386 ppm at 1 kW to 569 ppm at 2.5 kW before declining to 479 ppm at maximum load. This behavior may be associated with changes in local combustion temperature, oxygen availability, and combustion phasing. Although increasing engine load generally enhances thermal conditions favorable to NO_X formation, the reduction at 3 kW suggests that other factors, including changes in local mixture composition and combustion characteristics, may also influence its formation.

Crude garlic oil addition increased NO_X concentrations relative to D100 at every operating point. The average increases were 7.77%, 13.49%, and 18.24% for S10, S20, and S30, respectively. At 2.5 kW, NO_X concentrations increased from 569 ppm for D100 to 589, 630, and 666 ppm for the corresponding garlic oil blends. The increasing NO_X tendency may indicate changes in combustion characteristics that promote nitrogen oxide formation. In particular, improved fuel oxidation may coexist with local thermal conditions favorable to NO_X production, potentially explaining the simultaneous reductions in CO and HC. However, since combustion temperature and heat-release characteristics were not directly measured, such interpretations remain plausible mechanisms rather than experimentally confirmed explanations. A comparable tendency involving reduced CO and HC emissions accompanied by increased NO_X was reported by Yuksel (Yuksel, 2024) for garlic-derived methyl ester fuels.

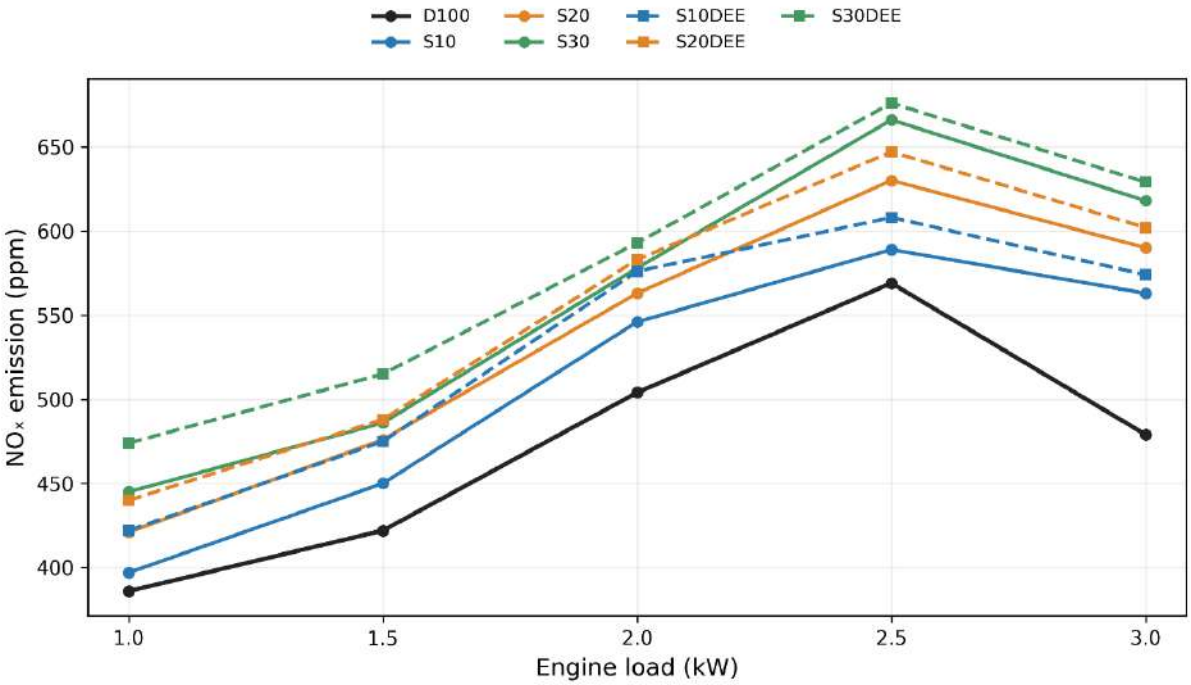


Figure. 5. Variation of NOX emissions with engine load for crude garlic oil–diesel blends with and without DEE addition.

The incorporation of DEE introduced an additional NO_X increase across all tested loads. Compared with the respective DEE-free formulations, S10DEE, S20DEE, and S30DEE exhibited average increases of 4.51%, 3.06%, and 3.67%, respectively. The highest NO_X concentration of 676 ppm was recorded for S30DEE at 2.5 kW. The observed increase may be associated with changes in ignition behavior, oxygen availability, and local combustion temperature resulting from DEE incorporation. Nevertheless, the influence of DEE on NO_X emissions is not necessarily uniform across different fuel systems. Ooi et al. [5] demonstrated that engine load and oxygenated additive concentration are important variables when optimizing the emission characteristics of DEE-containing fuels. Therefore, the additional NO_X formation observed in the present study highlights the need to consider the specific fuel formulation and operating conditions when assessing the environmental implications of DEE addition.

Conclusion and Recommendations

This study experimentally examined the effects of crude garlic oil blending and 5% diethyl ether (DEE) addition on CO, HC, and NO_X emissions in a single-cylinder diesel engine operating at 2000 rpm under five different load conditions. The main findings are summarized as follows:

- Increasing the crude garlic oil concentration from 10% to 30% progressively reduced CO and HC emissions. Compared with D100, the average reductions ranged from 9.60% to 30.58% for CO and from 7.82% to 28.27% for HC.
- Crude garlic oil addition increased NO_X emissions, with average increases of 7.77%, 13.49%, and 18.24% for S10, S20, and S30, respectively.
-
- Incorporating 5% DEE provided additional average reductions of 8.12–9.71% in CO and 6.30–8.12% in HC emissions compared with the corresponding DEE-free blends.
- Despite these improvements, DEE addition increased NO_X emissions by 3.06–4.51%, indicating a trade-off between reducing CO and HC emissions and controlling NO_X formation.

Overall, the results demonstrate that crude garlic oil–diesel blends, particularly when combined with DEE, offer potential for reducing CO and HC emissions. However, the associated increase in NO_X emissions limits their overall environmental benefits. Future studies should focus on optimizing garlic oil and DEE concentrations, characterizing fuel properties, and investigating combustion parameters and NO_X mitigation strategies to achieve a more balanced emission profile.

Thanks and Information Note

The authors gratefully acknowledge the financial support provided by the Scientific Research Projects Coordination Unit (BAP) of Fırat University under Project No. TEKF.25.15.

References

Aguado-Deblas, L., Hidalgo-Carrillo, J., Bautista, F. M., Luna, D., Luna, C., Calero, J., … Estevez, R. (2020). Diethyl Ether as an Oxygenated Additive for Fossil Diesel/Vegetable Oil Blends: Evaluation of Performance and Emission Quality of Triple Blends on a Diesel Engine. *Energies*, *13*(7), 1542. https://doi.org/10.3390/en13071542

Mohammed, A. S., Atnaw, S. M., Ramaya, A. V., & Alemayehu, G. (2023). A comprehensive review on the effect of ethers, antioxidants, and cetane improver additives on biodiesel-diesel blend in CI engine performance and emission characteristics. *Journal of the Energy Institute*, *108*, 101227. https://doi.org/10.1016/j.joei.2023.101227

Ooi, J. B., Chan, X. L., Jaliliantabar, F., Tan, B. T., Wang, X., Song, C. P., … Hung, Y. M. (2024). Experimental study of quaternary blends with diesel/palm-oil biodiesel/ethanol/diethyl ether for optimum performance and emissions in a light-duty diesel engine using response surface methodology. *Energy*, *301*, 131782. https://doi.org/10.1016/j.energy.2024.131782

Sonawane, U., & Agarwal, A. K. (2025). Influence of Exhaust Gas Recirculation and Fuel Injection Timings on a Diethyl Ether–Diesel Blend-Fueled Compression Ignition Engine. *ASME Open Journal of Engineering*, *4*. https://doi.org/10.1115/1.4068299

Youssef, A., & Ibrahim, A. (2024). A numerical investigation on enhancing the performance of a diesel engine fuelled with diesel-biodiesel blend using a diethyl ether as an additive. *Engineering Reports*, *6*(11). https://doi.org/10.1002/eng2.12915

Yuksel, T. (2024). Experimental investigation of the emission and performance of preheated and unheated garlic methyl ester fuels and diesel fuel in a diesel engine. *Process Safety and Environmental Protection*, *185*, 239–255. https://doi.org/10.1016/j.psep.2024.03.012

Zhang, S., Duan, H., Zhao, J., Guo, Y., Wang, L., & Yan, W. (2025). Discussion on the safety of garlic oil as a raw material for health food. *Agricultural Products Processing and Storage*, *1*(1), 28. https://doi.org/10.1007/s44462-025-00034-4

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

DEVELOPMENT OF A GENERALIZABLE MACHINE LEARNING SURROGATE FOR OFF-DESIGN PERFORMANCE PREDICTION OF ORGANIC RANKINE CYCLES

Uğur ACAR
Assistant Prof., 0000-0002-6387-8641, Osmaniye Korkut Ata University, Faculty of Engineering and Natural Sciences, Department of Mechanical Engineering, Osmaniye, Türkiye.

Abstract

Organic Rankine cycle (ORC) models are repeatedly evaluated in the simulation and design of integrated energy systems. Detailed off-design calculations become computationally demanding when heat-exchanger rating, hydraulic feedback and turbine performance are solved within an operating-point search. This study develops a capacity-aware machine learning surrogate that represents a family of ORC designs through a single five-input formulation. A subcritical R1233zd(E) reference model established eight development designs between 50 and 1000 kW and five intermediate designs reserved for assessment, generating 8224 operating-point evaluations. The inputs comprise nominal capacity, hot- and cold-stream inlet temperatures, and both stream flow ratios relative to their capacity-specific design values. The sampling campaign combines a wide Latin-hypercube design, adaptive boundary enrichment and an independent stratified hold-out. The surrogate consists of a cost-sensitive operability classifier followed by fourteen target-specific regressors. On the 2080-point hold-out, the selected shallow multilayer perceptron produced two false-feasible predictions, corresponding to 0.41% of genuinely infeasible points, with 87.97% feasible recall and 93.78% balanced accuracy. Separately, regression assessment on the 1588 genuinely feasible hold-out points yielded coefficients of determination of 0.96–0.99 and normalized root-mean-square errors of 2.60–6.55% for net power, heat duties, working-fluid flow, evaporating pressure and stream outlet temperatures. At five intermediate capacities excluded from model development, the classifier produced no false-feasible predictions and achieved 93.84% balanced accuracy. Median absolute relative error in net power increased from 8.62% at trained capacities to 12.42% at intermediate capacities, quantifying the interpolation penalty. Condensing pressure and turbine efficiency were the most difficult regression targets. The results support capacity interpolation within the specified design family and provide a reusable surrogate framework for repeated ORC performance evaluation.

Keywords: Organic Rankine cycle; surrogate modeling; machine learning; off-design performance; operability classification; capacity interpolation

1 Introduction

Organic Rankine cycles convert low- and medium-temperature thermal energy into mechanical or electrical power and are frequently considered for waste-heat recovery, geothermal applications and solar-driven energy systems. Their performance depends on both the heat source and the heat sink. A design-point calculation alone therefore provides limited information about operation under changing stream temperatures and flow rates. Off-design studies must account for the interaction between the cycle state, turbine behavior and heat-exchanger capability. Manente et al. [1] demonstrated the importance of component performance and operating strategy in ORC off-design modeling, while Walraven et al. [2,3] showed that heat-exchanger configuration and pressure losses affect the cycle design and its achievable performance.

Resolving these interactions repeatedly can become costly when an ORC is embedded in an integrated **energy-**

system model. Each operating condition may require several trial cycle states, heat-exchanger rating calculations and feasibility checks before an acceptable operating point is obtained. The repeated nature of this task motivates a surrogate that learns the input–output behavior of the reference calculation. Artificial neural networks have already been used to represent thermal equipment, including cooling towers [4,5], and data-driven models have also supported the design and optimization of solar thermal collectors [6]. These applications demonstrate the usefulness of replacing repeated component calculations with trained input–output mappings.

Machine learning has also been applied directly to ORCs. Wang et al. [7] developed neural-network and support-vector-regression models for thermal and exergy efficiency using a database covering several cycle configurations and working fluids. Feng et al. [8] investigated an automatically controlled 3 kW ORC and developed performance predictions from experimental operating data. At the component level, Du et al. [9] used deep learning to predict turbine aerodynamic fields and performance under off-design conditions. These studies address different prediction tasks and show that ORC surrogate modeling extends beyond a single choice of learning algorithm.

Related work has also addressed the physical and computational structure of the off-design problem. Oh et al. [10] developed a deterministic ORC simulation model driven by external boundary conditions and able to identify operational failures. Serafino et al. [11] used nested Kriging surrogates in robust ORC design optimization under uncertain conditions. For the present application, the specific requirement is to represent the operating behavior of a capacity-parametrized family whose heat exchangers are sized separately and then held fixed during off-design operation. A model trained for one member of that family does not, by itself, establish interpolation to other nominal capacities. This motivates treating capacity as an explicit input and testing capacities that are absent from model development.

The present study combines a detailed ORC reference model with a two-stage, capacity-aware surrogate. Eight nominal designs from 50 to 1000 kW define the development family. Their operating data are sampled over external stream conditions, supplemented near the learned operability boundary, and used to train a classifier and target-specific regressors. A separate hold-out contains both the trained capacities and five intermediate designs. The contributions are the common representation of differently sized ORC designs using nominal capacity and normalized stream flows, an operability gate selected with particular attention to false-feasible decisions, and a direct assessment of interpolation to capacities not used in training. The reference model, data-generation procedure and validation results are presented below.

2 Materials and methods

Figure 1 summarizes the workflow. Nominal sizing establishes the capacity family; the reference model then generates development and hold-out data. The classifier learns whether the dispatch procedure identifies feasible operation, while the regressors learn the corresponding operating quantities. Model selection uses internal development partitions, and the final assessment uses the independently generated hold-out.

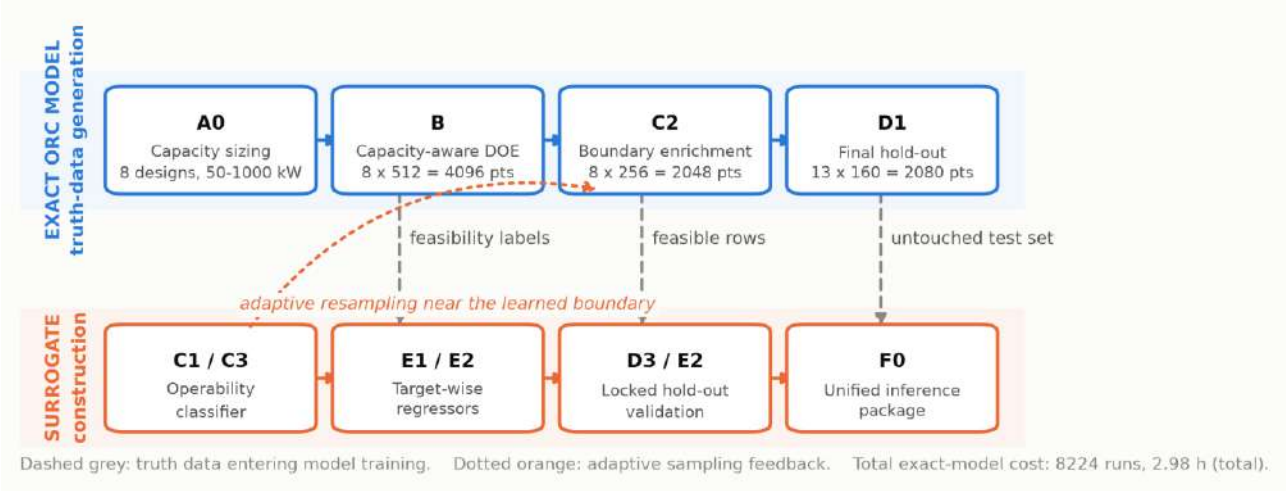


Fig. 1. Construction of the capacity-aware ORC surrogate. A0 establishes the nominal design family; B and C2 provide development data; D1 supplies the independent hold-out; C1/C3 and E1/E2 denote classifier and regression development, D3/E2 validation, and F0 the inference package.

2.1 Reference ORC model

The reference system is a subcritical ORC using R1233zd(E), Syltherm 800 as the hot-stream fluid and water as the coolant. Each nominal design has its own evaporator and condenser geometry, which remains fixed during off-design evaluation. The main specifications are listed in Table 1, and the cycle and surrogate interface are shown in Fig. 2. Thermophysical properties are evaluated through tabulated data generated using CoolProp [12], with interpolation during repeated calculations. The R1233zd(E) thermal-conductivity treatment uses the background correlation of Perkins et al. [13]. Syltherm properties are provided by the dedicated temperature-dependent property function used in the reference model.

Table 1. Fixed reference-model specifications shared by the nominal capacity family.

Parameter	Value
Working fluid	R1233zd(E)
Hot-stream fluid	Syltherm 800
Cold-stream fluid	Water
Hot-stream inlet pressure	10.0 bar
Cold-stream inlet pressure	2.0 bar
Design evaporating pressure	10.7 bar
Design condensing pressure	2.0 bar
Pump isentropic efficiency	0.80
Turbine nominal isentropic efficiency	0.85

Parameter	Value
Turbine off-design efficiency model	Velocity-ratio and corrected mass-flow corrections, Eq. (7)
Turbine isentropic efficiency bounds	0.30 - 0.90
Maximum turbine pressure ratio	8.0
Maximum reduced evaporating pressure	0.85
Shell-side boiling correlation	Palen-Mostinski
Shell-side condensation correlation	Nusselt film + Kern bundle correction
Shell-side single-phase correlation	Bell-Delaware / Hagen-number formulation
Tube-side single-phase correlation	Gnielinski-type (turbulent), Nu = 3.66 (laminar)
Dispatch evaporating-pressure levels	15 discrete factors, 0.60 - 1.50 of design
Design hot-stream inlet temperature	160 °C
Design cold-stream inlet temperature	27 °C
Wall and fouling resistances	Neglected

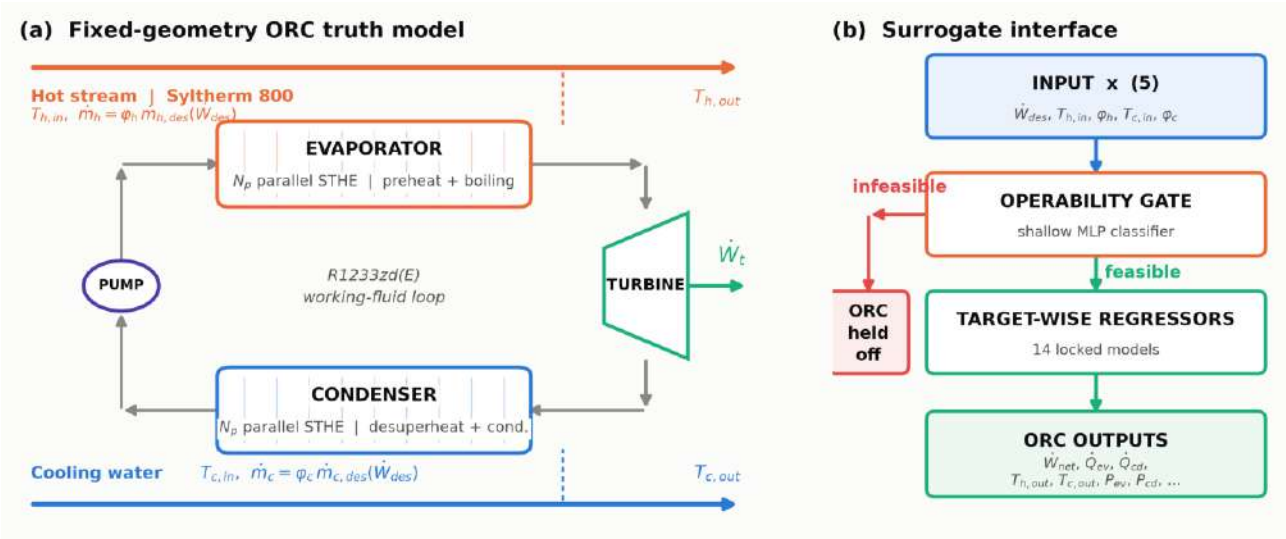


Fig. 2. (a) R1233zd(E) reference cycle with parallel shell-and-tube evaporator and condenser modules. (b) Surrogate interface: the five inputs enter an operability gate, followed by target-specific regression for accepted conditions.

2.1.1 Cycle thermodynamics

States 1–4 are, respectively, saturated liquid at the condenser outlet, the pump discharge, saturated vapor at

the turbine inlet, and the turbine exhaust. Pump and turbine outlet enthalpies follow from their isentropic efficiencies:

$$h_2 = h_1 + \frac{h_{2s}-h_1}{\eta_p}, h_4 = h_3 - \eta_t(h_3 - h_{4s}) \quad (1)$$

Here, h denotes specific enthalpy, subscript s identifies an isentropic outlet state, and η_p and η_t are the pump and turbine efficiencies. The nominal turbine efficiency is 0.85, while the pump efficiency is 0.80. Working-fluid pressure losses are included when determining pump discharge and turbine exhaust conditions. The cycle power and heat-transfer rates are

$$\dot{W}_{net} = \dot{m}_{orc}[(h_3 - h_4) - (h_2 - h_1)]$$

$$\dot{Q}_{ev} = \dot{m}_{orc}(h_3 - h_2), \dot{Q}_{cd} = \dot{m}_{orc}(h_4 - h_1) \quad (2)$$

where $\dot{m}_{orc}$ is the working-fluid mass flow. For nominal sizing, the mass flow is obtained from the required net cycle power:

$$\dot{m}_{orc,des} = \frac{\dot{W}_{des}}{(h_3-h_4)-(h_2-h_1)} \quad (3)$$

The cycle net power is turbine shaft power $\dot{W}_t$ minus ORC feed-pump power; the net cycle thermal efficiency is $\eta_{th} = \dot{W}_{net}/\dot{Q}_{ev}$. The thermodynamic calculation checks pressure ordering, positive net power, subcritical operation and the cycle energy balance. External hot- and cold-stream pumping and other system auxiliaries are outside this definition of cycle net power.

2.1.2 Heat-exchanger representation

The evaporator and condenser are represented as shell-and-tube trains of identical modules in parallel. The evaporator is divided into preheating and boiling zones, and the condenser into desuperheating and condensation zones. The area requirement is evaluated by summing the zone contributions:

$$A_{req} = \sum_z \frac{\dot{Q}_z}{U_z \Delta T_{lm,z}}, \Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} \quad (4)$$

In Eq. (4), U is the zone overall heat-transfer coefficient, ΔT_{lm} is the logarithmic mean temperature difference, and ΔT_1 and ΔT_2 are the terminal temperature differences; z indexes the heat-transfer zones. The implemented cases neglect wall and fouling resistances. Shell-side single-phase heat transfer and pressure drop use the Bell–Delaware/Hagen-number treatment described by Walraven et al. [2]. Tube-side heat transfer uses $Nu = 3.66$ for laminar flow and a Gnielinski-type expression with smooth-tube friction factors for turbulent flow.

Shell-side boiling follows the Palen–Mostinski formulation reported by Calise et al. [14]:

$$h_b = h_{nb}F_bF_c + h_{natural}, h_{nb} = 0.00417(q'')^{0.7}P_{crit}F_p$$

$$F_p = 1.8P_r^{0.17} + 4P_r^{1.2} + 10P_r^{10} \quad (5)$$

The local heat flux q'' is expressed in W m^{-2}, P_{crit} in the h_{nb} expression is in bar, and $P_r = P/P_{crit}$ is the reduced pressure. The bundle and pure-fluid factors are $F_b = 1.5$ and $F_c = 1.0$, and $h_{natural} = 250$ W m^{-2} K^{-1}. The shell-side condensation coefficient combines the horizontal-tube Nusselt expression with the Kern

tube-row correction [14,15]:

$$h_{cd} = 0.728\left[\frac{\rho_l(\rho_l-\rho_v)g h_{fg} k_l^3}{\mu_l(T_{sat}-T_{wall})d_o}\right]^{1/4} N_{row}^{-1/6} \qquad (6)$$

Here, ρ_l and ρ_v are liquid and vapor densities, k_l and μ_l are liquid thermal conductivity and viscosity, h_{fg} is latent heat, d_o is tube outer diameter, and N_{row} is the number of tube rows. g is gravitational acceleration, and T_{sat} and T_{wall} are saturation and wall temperatures. The tube count and parallel-module arrangement are selected by a constrained geometry search subject to tube-length, shell-diameter, heat-transfer-area and positive-approach criteria. Cycle states and calculated pressure losses are updated through hydraulic feedback during sizing. The accepted geometry is subsequently frozen for rating calculations.

2.1.3 Turbine off-design treatment and dispatch

Turbine efficiency varies with the operating state rather than remaining fixed at its nominal value. A reduced-order correction structure, adapted from the off-design approach of Manente et al. [1], is used:

$$\eta_t = min\left(0.90, max\left(0.30, \eta_{t,des} F_{VR} F_m\right)\right)$$

$$F_{VR} = max\left(0, 2r_{VR} - r_{VR}^2\right), r_{VR} = \sqrt{\frac{\Delta h_{is,des}}{\Delta h_{is}}}$$

$$r_m = \frac{\dot{m}_{corr}}{\dot{m}_{corr,des}}, \dot{m}_{corr} = \frac{\dot{m}_{orc}\sqrt{T_{t,in}}}{P_{t,in}}, \Pi_t = \frac{P_{t,in}}{P_{t,out}} \qquad (7)$$

Here, Δh_{is} is the isentropic enthalpy drop, r_{VR} is its design-referenced velocity-ratio proxy, and r_m is the corrected mass-flow ratio. Turbine pressure ratio Π_t uses the actual inlet and outlet pressures. In the corrected-flow expression, turbine inlet temperature $T_{t,in}$ is in K, inlet pressure $P_{t,in}$ is in Pa, and ORC mass flow is in kg s^{-1}. The subscript des denotes the nominal design. F_m is obtained by linear interpolation of the adopted tabulated curve as a function of r_m. The resulting turbine efficiency is bounded between 0.30 and 0.90.

Off-design operation is determined by a power-oriented, ordered search over evaporating pressure, condensing pressure and working-fluid flow candidates. The procedure favors productive feasible operation while reducing the cost of repeated evaluation. Candidates undergo a thermodynamic prescreen and fast heat-exchanger rating; a selected feasible point is checked using the full rating settings and locally refined in working-fluid flow. Feasibility requires acceptable heat-exchanger area and approach conditions, positive cycle net power, subcritical operation and a turbine pressure ratio no greater than eight. If no acceptable point is found by the dispatch procedure, the input condition is labeled infeasible. These labels define the classification task used in this study.

2.2 Capacity-parametrized design family

Eight nominal net capacities are used for model development: 50, 100, 150, 250, 350, 500, 750 and 1000 kW. Each is sized at a hot-stream inlet temperature of 160 °C, a coolant inlet temperature of 27 °C, and nominal evaporating and condensing pressures of 10.7 and 2.0 bar. Stream design flows scale from the 250 kW reference values of 30 kg s^{-1} for Syltherm 800 and 100 kg s^{-1} for water. The heat-exchanger search is performed separately at each capacity, so the resulting family contains different physical module arrangements rather than a single geometry with a rescaled power label. Table 2 and Fig. 3 summarize the nominal family.

Table 2. Nominal cycle quantities for the eight designs used in model development.

$\dot{W}_{des}$ [kW]	$\dot{m}_{h,des}$ [kg s^{-1}]	$\dot{m}_{c,des}$ [kg s^{-1}]	$\dot{m}_{orc,des}$ [kg s^{-1}]	$\dot{Q}_{ev,des}$ [MW]	$\dot{Q}_{cd,des}$ [MW]	$\eta_{th,des}$ [%]
50	6	20	1.94	0.43	0.38	11.53
100	12	40	3.98	0.89	0.79	11.24
150	18	60	6.24	1.4	1.25	10.74
250	30	100	11.04	2.47	2.22	10.12
350	42	140	16.35	3.66	3.31	9.57
500	60	200	22.44	5.02	4.52	9.96
750	90	300	36.51	8.17	7.42	9.18
1000	120	400	46.86	10.49	9.49	9.54

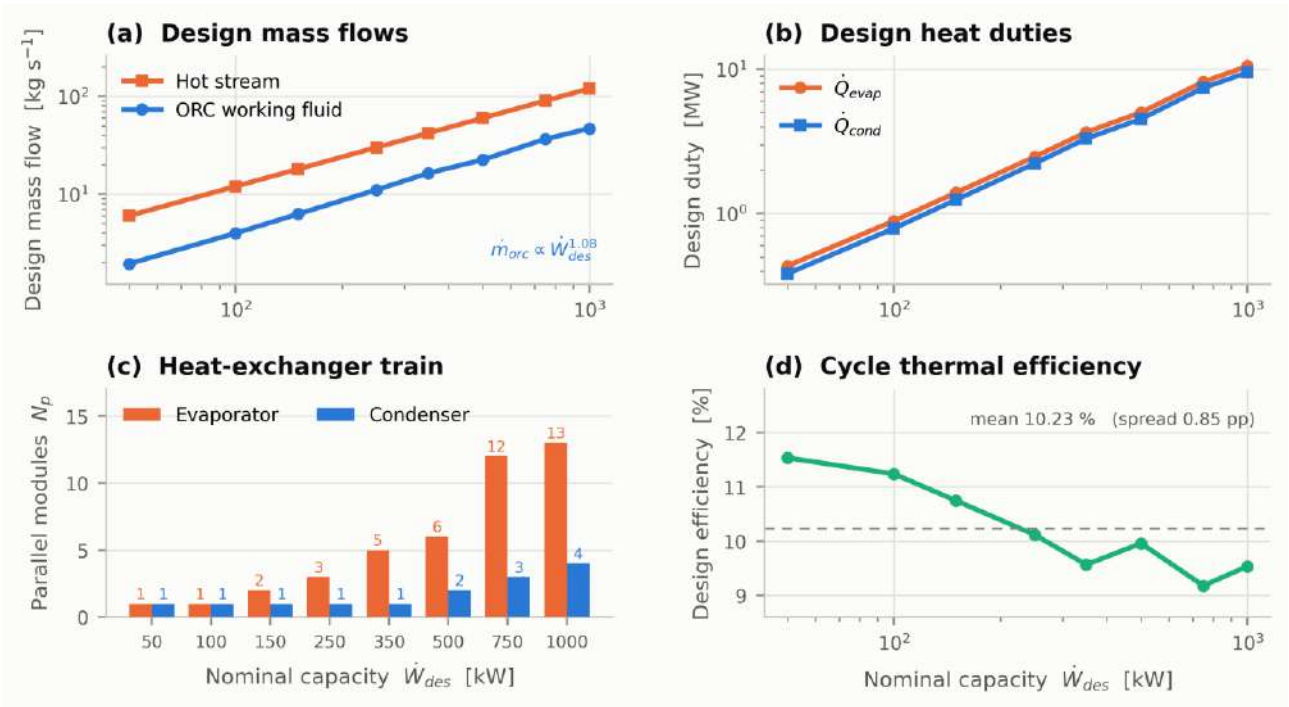


Fig. 3. Nominal design family: (a) hot-stream and ORC mass flows; (b) evaporator and condenser duties; (c) numbers of parallel modules; and (d) cycle thermal efficiency. Each capacity is sized separately using the common design procedure.

Five additional capacities—75, 200, 425, 600 and 850 kW—are sized using the same procedure and reserved for the final hold-out. Their operating points are excluded from classifier and regressor development. The study therefore distinguishes prediction within a trained capacity from interpolation to an intermediate member of

the same design family.

2.3 Surrogate inputs and outputs

The common input vector contains nominal capacity, the two stream inlet temperatures and the two design-referenced stream flow ratios. Feature standardization is also defined below:

$$\boldsymbol{x} = \left[\dot{\boldsymbol{W}}_{\boldsymbol{des}}, \boldsymbol{T}_{\boldsymbol{h,in}}, \boldsymbol{\varphi}_{\boldsymbol{h}}, \boldsymbol{T}_{\boldsymbol{c,in}}, \boldsymbol{\varphi}_{\boldsymbol{c}}\right]^{\boldsymbol{T}}$$

$$\boldsymbol{\varphi}_{\boldsymbol{h}} = \frac{\dot{\boldsymbol{m}}_{\boldsymbol{h}}}{\dot{\boldsymbol{m}}_{\boldsymbol{h,des}}(\dot{\boldsymbol{W}}_{\boldsymbol{des}})}, \boldsymbol{\varphi}_{\boldsymbol{c}} = \frac{\dot{\boldsymbol{m}}_{\boldsymbol{c}}}{\dot{\boldsymbol{m}}_{\boldsymbol{c,des}}(\dot{\boldsymbol{W}}_{\boldsymbol{des}})}$$

$$\boldsymbol{z}_{\boldsymbol{k}}^{(\boldsymbol{a})} = \frac{\boldsymbol{x}_{\boldsymbol{k}} - \boldsymbol{\mu}_{\boldsymbol{k}}^{(\boldsymbol{a})}}{\boldsymbol{\sigma}_{\boldsymbol{k}}^{(\boldsymbol{a})}}, \boldsymbol{a} \in \{\boldsymbol{c}, \boldsymbol{r}\} \qquad (8)$$

Capacity is expressed in kW, stream inlet temperatures in °C, and flow ratios are dimensionless. The capacity-specific design flows are $\dot{\boldsymbol{m}}_{\boldsymbol{h,des}} = \boldsymbol{0.12}\dot{\boldsymbol{W}}_{\boldsymbol{des}}$ and $\dot{\boldsymbol{m}}_{\boldsymbol{c,des}} = \boldsymbol{0.40}\dot{\boldsymbol{W}}_{\boldsymbol{des}}$ in kg s^{-1} when $\dot{\boldsymbol{W}}_{\boldsymbol{des}}$ is in kW. Temperatures specify the thermal boundary conditions, while flow ratios describe relative loading across capacities. In Eq. (8), $\boldsymbol{k}$ indexes the five inputs and $\boldsymbol{a} = \boldsymbol{c}$ or $\boldsymbol{a} = \boldsymbol{r}$ identifies classification or regression. The feature means $\boldsymbol{\mu}_{\boldsymbol{k}}^{(\boldsymbol{c})}$ and standard deviations $\boldsymbol{\sigma}_{\boldsymbol{k}}^{(\boldsymbol{c})}$ are computed over all 6144 B+C2 development points; the separate regression statistics $\boldsymbol{\mu}_{\boldsymbol{k}}^{(\boldsymbol{r})}$ and $\boldsymbol{\sigma}_{\boldsymbol{k}}^{(\boldsymbol{r})}$ use the 5346 feasible development points. These statistics are retained for inference, and D is excluded from their calculation.

The classifier first evaluates operability. Regressors are then applied only when the classifier accepts the input:

$$\boldsymbol{g}(\boldsymbol{x}) = \begin{cases} \boldsymbol{1}, & \boldsymbol{s}(\boldsymbol{z}^{(\boldsymbol{c})}) \geq \boldsymbol{\tau} \\ \boldsymbol{0}, & \boldsymbol{s}(\boldsymbol{z}^{(\boldsymbol{c})}) < \boldsymbol{\tau} \end{cases}$$

$$\hat{\boldsymbol{y}}_{\boldsymbol{j}} = \boldsymbol{\mu}_{\boldsymbol{y,j}} + \boldsymbol{\sigma}_{\boldsymbol{y,j}}\boldsymbol{f}_{\boldsymbol{j}}(\boldsymbol{z}^{(\boldsymbol{r})}), \boldsymbol{g}(\boldsymbol{x}) = \boldsymbol{1} \qquad (9)$$

Here, $\boldsymbol{s}$ is the classifier score, $\boldsymbol{\tau}$ is its selected threshold, and $\boldsymbol{f}_{\boldsymbol{j}}$ predicts the standardized value of target $\boldsymbol{j}$. The target mean $\boldsymbol{\mu}_{\boldsymbol{y,j}}$ and standard deviation $\boldsymbol{\sigma}_{\boldsymbol{y,j}}$ restore each prediction to its original unit. The fourteen targets are net power, evaporator and condenser duties, ORC mass flow, hot- and cold-stream outlet temperatures, evaporating and condensing pressures, turbine pressure ratio, turbine isentropic efficiency, net cycle efficiency, and the ratios $\boldsymbol{W}_{\boldsymbol{net}}/\dot{\boldsymbol{W}}_{\boldsymbol{des}}$, $\dot{\boldsymbol{Q}}_{\boldsymbol{ev}}/\dot{\boldsymbol{W}}_{\boldsymbol{des}}$ and $\dot{\boldsymbol{Q}}_{\boldsymbol{cd}}/\dot{\boldsymbol{W}}_{\boldsymbol{des}}$. All three ratios use nominal net capacity as the denominator, with consistent power units. Targets are modeled individually. Rejected inputs return unavailable regression values and correspond to an OFF decision in the intended system-level use.

2.4 Sampling campaign

The five-dimensional envelope is given in Table 3. Nominal capacity takes the specified discrete design values during data generation; the other four inputs vary continuously within their ranges. The campaign consists of three blocks, summarized in Table 4.

Table 3. Sampling envelope. Stream flow ratios refer to the capacity-specific design values.

Quantity	Symbol	Unit	Range
Nominal capacity	$\dot{\boldsymbol{W}}_{\boldsymbol{des}}$	kW	50, 100, 150, 250, 350, 500, 750, 1000 (training)

Quantity	Symbol	Unit	Range
			75, 200, 425, 600, 850 (intermediate, hold-out only)
Hot-stream inlet temperature	$T_{h,in}$	°C	80 - 300
Hot-stream flow ratio	φ_h	-	0.05 - 3.00
Cold-stream inlet temperature	$T_{c,in}$	°C	5 - 40
Cold-stream flow ratio	φ_c	-	0.05 - 3.00

Block B contains 512 Latin-hypercube sampling (LHS) points per training capacity, giving 4096 evaluations in the wide design of experiments (DOE). This exposes the classifier to both feasible and infeasible conditions. Block C2 provides one adaptive enrichment stage. A preliminary classifier scores a candidate pool of 200000 points; boundary-focused candidates are retained with capacity balance and diversity, and 256 points per training capacity are evaluated, giving 2048 additional reference calculations.

Block D is a separate stratified hold-out with 160 points at each of the thirteen capacities, giving 2080 points. Per capacity, 64 points sample the global envelope, 48 sample a thermal-transition region, 32 stress low hot-stream flow, and 16 stress condenser operation. The thermal-transition region uses hot-inlet temperatures of 95–175 °C and hot-flow ratios of 0.05–2.20. The low-hot-flow stratum uses 110–300 °C and hot-flow ratios of 0.05–0.45. The condenser-stress stratum uses hot-inlet temperatures of 110–230 °C, hot-flow ratios of 0.10–1.50, cold-inlet temperatures of 30–40 °C and cold-flow ratios of 0.05–0.90. Other stratum bounds follow Table 3. D is not used for threshold tuning, model selection or regressor training.

Table 4. Reference-data composition and accumulated evaluation time. Time columns use the logged per-point elapsed times.

Block	Sampling	Points	Feasible	Feasible %	Outer-call errors	Median time (s)	Total time (h)	Use
B	LHS, 8 × 512	4096	3402	83.1	0	0.87	1.04	Development
C2	Adaptive, 8 × 256	2048	1944	94.9	0	2.27	1.23	Development
D	Stratified, 13 × 160	2080	1588	76.3	0	1.29	0.71	Final hold-out
Total	—	8224	6934	84.3	0	-	2.98	—

The campaign comprises 8224 reference-model calls, with no recorded outer-call errors. Feasible and infeasible outcomes are both retained for classification. The sum of logged per-point elapsed times is 2.979 h, corresponding to a mean of 1.304 s per point; these are accumulated evaluation times rather than the wall-clock duration of the parallel campaign.

2.5 Operability classifier

The B and C2 development blocks contain 6144 labeled points, of which 5346 are feasible and 798 infeasible. They are divided approximately 70/15/15 into training, validation and internal test subsets with class and capacity stratification. Seven candidate approaches are compared: a hot-temperature threshold, quadratic logistic regression, a decision tree, a bagged-tree ensemble, LogitBoost gradient boosting, an RBF support-vector machine and a shallow multilayer perceptron (MLP). The bagged and boosted ensembles contain 200 and 180 learners, respectively, and the MLP has hidden layers of 14 and 10 units.

The learned classifiers use an asymmetric cost that assigns false-feasible decisions twenty times the cost of false-infeasible decisions. Score thresholds are tuned on the validation subset using

$$\boldsymbol{J(\tau) = 20FFR(\tau) + \left[1 - R_f(\tau)\right] + 0.25[1 - BA(\tau)]} \quad (10)$$

Here, FFR is the false-feasible rate, $\boldsymbol{R_f}$ is feasible recall and BA is balanced accuracy. The rates in Eqs. (10) and (11) are fractions; reported values are expressed as percentages. Candidate ranking prioritizes lower validation FFR, followed by feasible recall and balanced accuracy. This favors a conservative operability gate. The internal test compares the selected model with the other candidates after selection; final results are obtained on D.

2.6 Regression and assessment metrics

Regression development uses only the 5346 feasible B+C2 points, with an approximately 70/15/15 capacity-balanced split shared by all candidate families and targets. Six model families are trained separately for every target: linear ridge regression, quadratic ridge regression, a regression tree, bagged trees, LSBoost gradient boosting and a shallow MLP. The bagged ensemble uses 250 learners and a minimum leaf size of six; the boosted ensemble uses 250 learners, a learning rate of 0.08 and a maximum of 48 splits. The regression MLP has hidden layers of 24 and 12 units. Each target is standardized using its mean and standard deviation over the 5346 feasible development points. The model family is selected separately for each target by validation normalized root-mean-square error (NRMSE) before final hold-out assessment. Predictions are transformed back to original units before calculating the assessment metrics.

Classification metrics use feasible operation as the positive class. TP and TN count correctly classified feasible and infeasible points, respectively; FP counts infeasible points accepted by the gate, and FN counts feasible points rejected by it. FFR, feasible recall, infeasible recall and balanced accuracy are

$$\boldsymbol{FFR = \frac{FP}{FP+TN}, R_f = \frac{TP}{TP+FN}}$$

$$\boldsymbol{R_i = \frac{TN}{TN+FP}, BA = \frac{R_f+R_i}{2}} \quad (11)$$

Thus, FFR is calculated among reference-infeasible points, and $\boldsymbol{R_i}$ denotes infeasible recall. Regression is assessed separately on the 1588 reference-feasible points in D, including trained and intermediate capacities. For $\boldsymbol{n}$ actual values $\boldsymbol{y_i}$, predictions $\boldsymbol{\hat{y}_i}$ and residuals $\boldsymbol{e_i = \hat{y}_i - y_i}$, the mean absolute error (MAE), root-mean-square error (RMSE) and mean absolute percentage error (MAPE) are

$$\boldsymbol{MAE = \frac{1}{n}\sum_{i=1}^{n} |e_i|, RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}}$$

$$\boldsymbol{MAPE = \frac{100}{n}\sum_{i=1}^{n} \left|\frac{e_i}{y_i}\right|} \quad (12)$$

$$\boldsymbol{NRMSE}(\%) = \mathbf{100}\frac{\boldsymbol{RMSE}}{\boldsymbol{Q_{95}(y) - Q_{05}(y)}}$$

$$\boldsymbol{R^2} = \mathbf{1} - \frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (13)$$

NRMSE is expressed as a percentage in Eq. (13) and normalized by the difference between the 95th and 5th percentiles of the target values in the evaluated subset. MAPE is reported for nonzero targets. Temperature accuracy is additionally interpreted through errors in °C. Classification uses all D points, while regression assessment uses the reference-feasible subset.

3 Results and discussion

3.1 Nominal design family

All eight nominal capacities produced designs satisfying the adopted thermal and geometrical acceptance checks. Table 2 shows increasing ORC flow and heat duties with capacity. Working-fluid flow follows an approximately linear power law, $\boldsymbol{m_{orc} \propto W_{des}^{1.08}}$. Evaporator/condenser design duties increase from 0.43/0.38 MW at 50 kW to 10.49/9.49 MW at 1000 kW. These values define the reference family represented by the surrogate.

Figure 3 shows that the physical module arrangements also change. The evaporator train grows from one parallel module at the two smallest capacities to thirteen at 1000 kW; the condenser increases from one to four modules. Design thermal efficiency ranges from 9.18% to 11.53%, with a mean of 10.23%. Consequently, the family is not described by identical equipment and a constant efficiency multiplied by capacity. The surrogate must represent both the operating-condition response and the differences between designs produced by the common sizing procedure.

3.2 Operability across capacities

In the wide B sample, 83.1% of operating points are feasible, with per-capacity fractions between 81.1% and 84.6%. Figure 4 projects the four-dimensional operating envelope onto the hot-temperature/hot-flow plane. Cold-side conditions also vary within each panel, so the plot shows the distribution of observed labels rather than a boundary at a single fixed coolant condition. Nevertheless, the similar patterns across capacities support the use of design-referenced stream flows as common inputs.

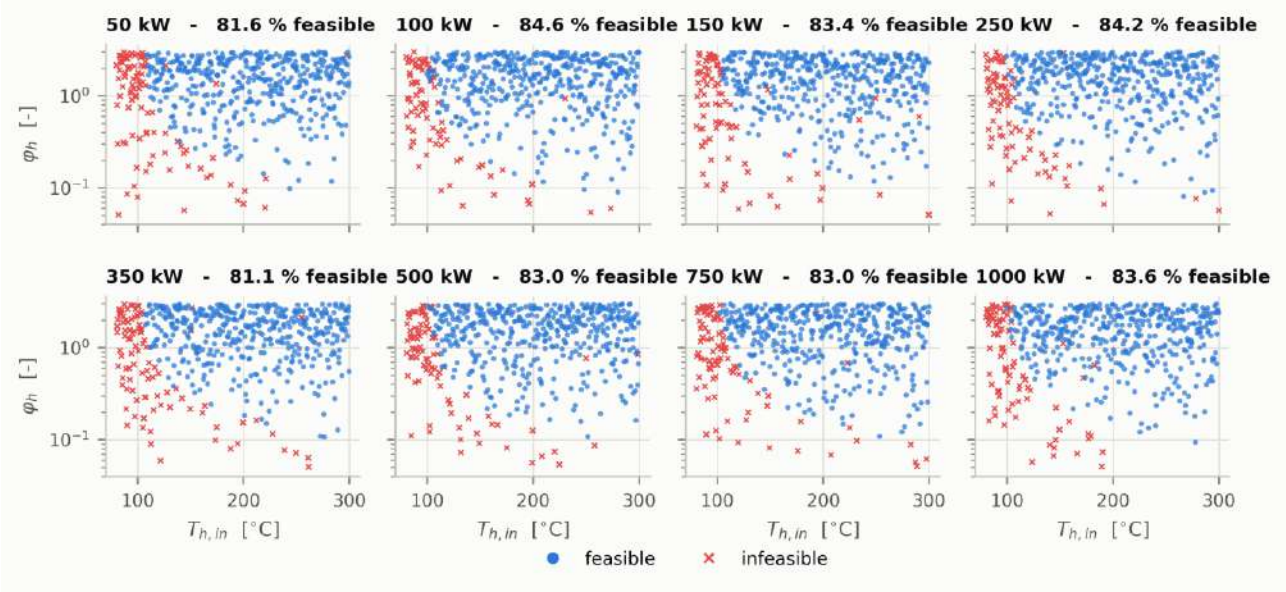


Fig. 4. Projection of the wide-DOE feasibility labels onto hot-inlet temperature and hot-flow ratio for the eight development capacities. Each panel contains 512 points; cold-side conditions vary within the sampled envelope.

The lowest hot-inlet temperatures are associated with infeasible operation: only 0.5% of the 373 B points below 100 °C are feasible, and none are feasible below 90 °C in this sample. Above 120 °C, feasible fraction rises to 95.4%. Low hot-flow ratios form another important transition region. These trends are consistent with the thermal-source requirements of the dispatch calculation and motivate targeted sampling near the operability transition.

Figure 5 compares sample composition across B, C2 and D. The enrichment block contains 94.9% feasible points, whereas the deliberately stress-stratified hold-out contains 76.3%. These fractions reflect the different sampling procedures. Intermediate capacities appear only in D, so their results provide a capacity-interpolation assessment independently of the development blocks.

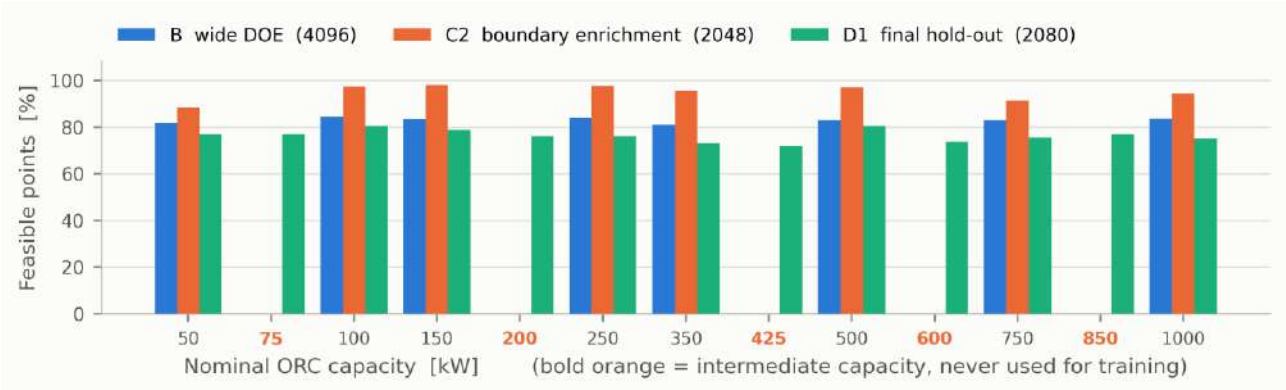


Fig. 5. Feasible fraction by nominal capacity for the wide DOE, boundary enrichment and final hold-out. Orange capacity labels identify the intermediate designs appearing only in the hold-out. The blocks use different sampling distributions.

3.3 Operability Gate Performance

The validation ranking selected the shallow MLP as the operability gate. Table 5 and Fig. 6 compare candidate performance on the separate internal test subset of 920 points. The decision tree achieves the highest recall, 96.63%, and balanced accuracy, 94.11%, but also the highest false-feasible rate, 8.40%. The quadratic logistic model has no false-feasible predictions in this subset but retains only 57.93% feasible recall. The selected MLP combines zero false-feasible predictions with 86.64% feasible recall and 93.32% balanced accuracy. These results illustrate the distinction between high aggregate accuracy and the more conservative decision behavior required of the gate.

Table 5. Candidate classifiers on the internal test subset of 920 development points. Model selection used the validation subset.

Classifier	False-feasible rate [%]	Feasible recall [%]	Infeasible recall [%]	Balanced accuracy [%]	F1 [-]
Decision tree	8.4	96.63	91.6	94.11	0.977
Shallow MLP (selected)	0.0	86.64	100.0	93.32	0.928
Gradient boosting	0.84	85.39	99.16	92.28	0.921
Bagged trees	0.84	83.02	99.16	91.09	0.907
RBF-SVM	1.68	65.42	98.32	81.87	0.79
Quadratic logistic	0.0	57.93	100.0	78.96	0.734
Hot-temperature threshold	0.84	2.0	99.16	50.58	0.039

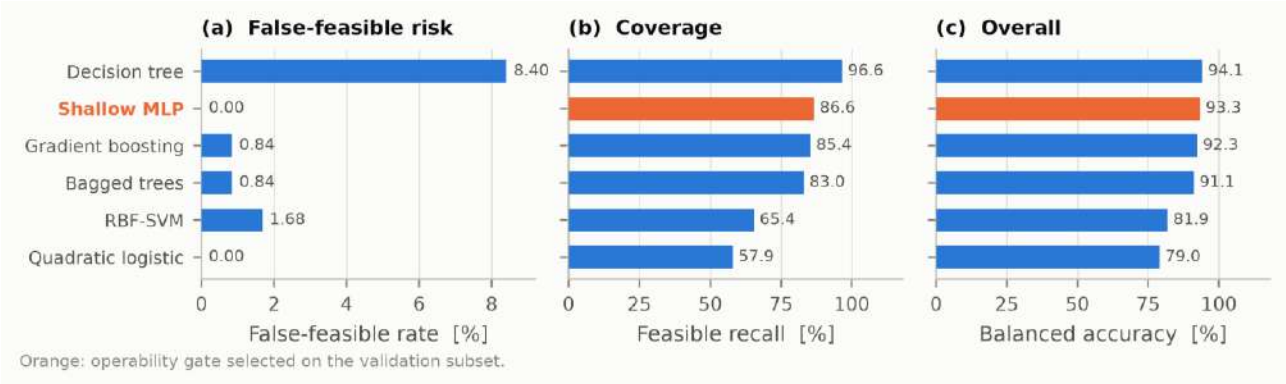


Fig. 6. Classifier performance on the internal test subset. Orange identifies the MLP selected using validation results. The hot-temperature-threshold baseline is included in Table 5 but omitted from this plot.

On the final 2080-point hold-out, the selected gate produces 1397 true-feasible, 490 true-infeasible, 191 false-infeasible and two false-feasible decisions (Table 6). The false-feasible rate is therefore 0.41%, feasible recall is 87.97%, and balanced accuracy is 93.78%. Both false-feasible decisions occur at 1000 kW. No false-feasible decisions are observed at the other capacities in this hold-out.

Table 6. Selected operability gate on the independent final hold-out. Capacity-type and stress-stratum rows are

separate breakdowns of the same hold-out.

Subset	n	TP	FP	TN	FN	False-feasible [%]	Feasible recall [%]	Balanced accuracy [%]
All hold-out points	2080	1397	2	490	191	0.41	87.97	93.78
Training capacities (8)	1280	870	2	291	117	0.68	88.15	93.73
Intermediate capacities (5, untrained)	800	527	0	199	74	0.0	87.69	93.84
Global wide envelope	832	652	0	142	38	0.0	94.49	97.25
Thermal transition	624	384	0	174	66	0.0	85.33	92.67
Low hot-flow stress	416	227	2	131	56	1.5	80.21	89.35
Condenser stress	208	134	0	43	31	0.0	81.21	90.61

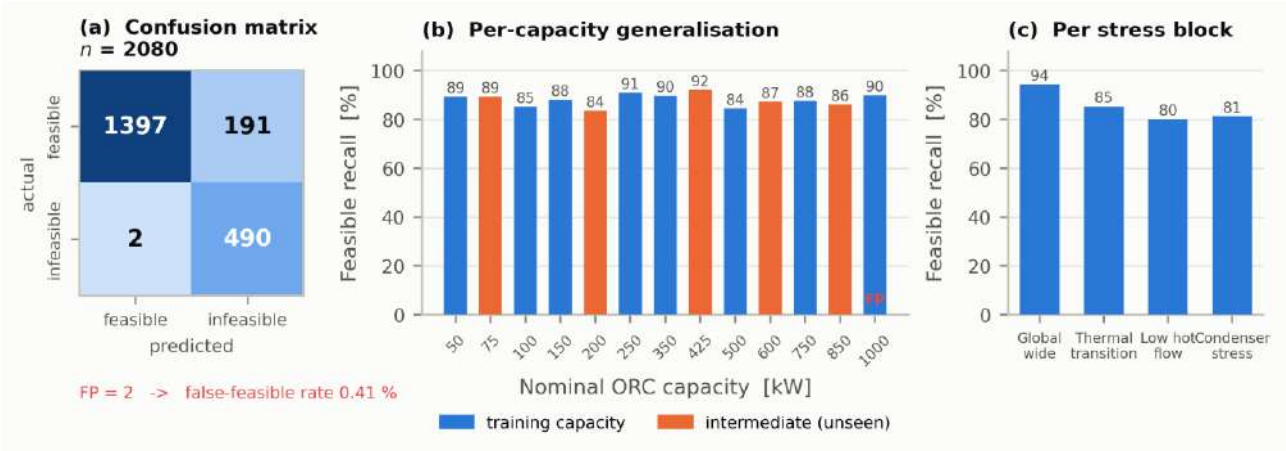


Fig. 7. Selected operability gate on the independent hold-out: (a) confusion matrix; (b) feasible recall by capacity; and (c) feasible recall by stress stratum. Orange bars identify intermediate capacities absent from development.

The stratum-level results in Fig. 7 show 94.49% feasible recall in the global envelope, compared with 85.33% in the thermal-transition region, 80.21% under low hot-stream flow and 81.21% under condenser stress. The gate is therefore more conservative in the deliberately stressed regions. This behavior is consistent with the cost-sensitive selection objective: low false-feasible exposure is obtained at the expense of rejecting a proportion of reference-feasible points.

3.4 Regression accuracy

Table 7 reports the selected target-specific models on the 1588 genuinely feasible hold-out points. Figure 8 shows their predictions for the principal power, heat-duty, flow and temperature outputs. Net power reaches R^2 = 0.9608 with NRMSE = 6.55%; evaporator and condenser duties reach R^2 = 0.9730 and 0.9751 with

NRMSE = 5.31% and 5.03%. Working-fluid flow reaches R^2 = 0.9716 and NRMSE = 5.39%. These results cover both the capacity dependence and the variation caused by external operating conditions.

Table 7. Selected regressors on the 1588 genuinely feasible final hold-out points. MAE and RMSE use the unit shown for each target.

Target	Selected model	MAE	RMSE	NRMSE [%]	MAPE [%]	R^2 [—]
$\dot{W}_{net}$ (W)	Shallow MLP	31360.0	52160.0	6.55	16.63	0.961
$\dot{Q}_{ev}$ (W)	Shallow MLP	255500.0	424800.0	5.31	11.64	0.973
$\dot{Q}_{cd}$ (W)	Shallow MLP	222400.0	366600.0	5.03	12.03	0.975
$\dot{m}_{orc}$ (kg s^{-1})	Shallow MLP	1.138	1.925	5.39	11.44	0.972
$T_{h,out}$ (°C)	Shallow MLP	4.042	7.707	4.16	3.63	0.98
$T_{c,out}$ (°C)	Gradient boosting	0.514	0.9156	2.6	1.88	0.993
P_{ev} (Pa)	Gradient boosting	14200.0	31610.0	4.19	1.52	0.978
P_{cd} (Pa)	Gradient boosting	8326.0	19080.0	11.93	3.1	0.855
Π_t (—)	Gradient boosting	0.2229	0.3404	8.34	5.93	0.9
η_t (—)	Gradient boosting	0.02503	0.0432	21.26	3.71	0.682
η_{th} (—)	Gradient boosting	0.003146	0.005482	9.08	4.86	0.897
$\dot{W}_{net}/\dot{W}_{des}$ (—)	Gradient boosting	0.0554	0.08247	8.84	11.96	0.928
$\dot{Q}_{ev}/\dot{W}_{des}$ (—)	Gradient boosting	0.4713	0.687	9.78	7.71	0.917
$\dot{Q}_{cd}/\dot{W}_{des}$ (—)	Gradient boosting	0.4286	0.6273	10.22	7.75	0.91

NRMSE is normalized by Q95 − Q05. The three fraction targets use nominal net capacity as the denominator; efficiencies and ratios are dimensionless.

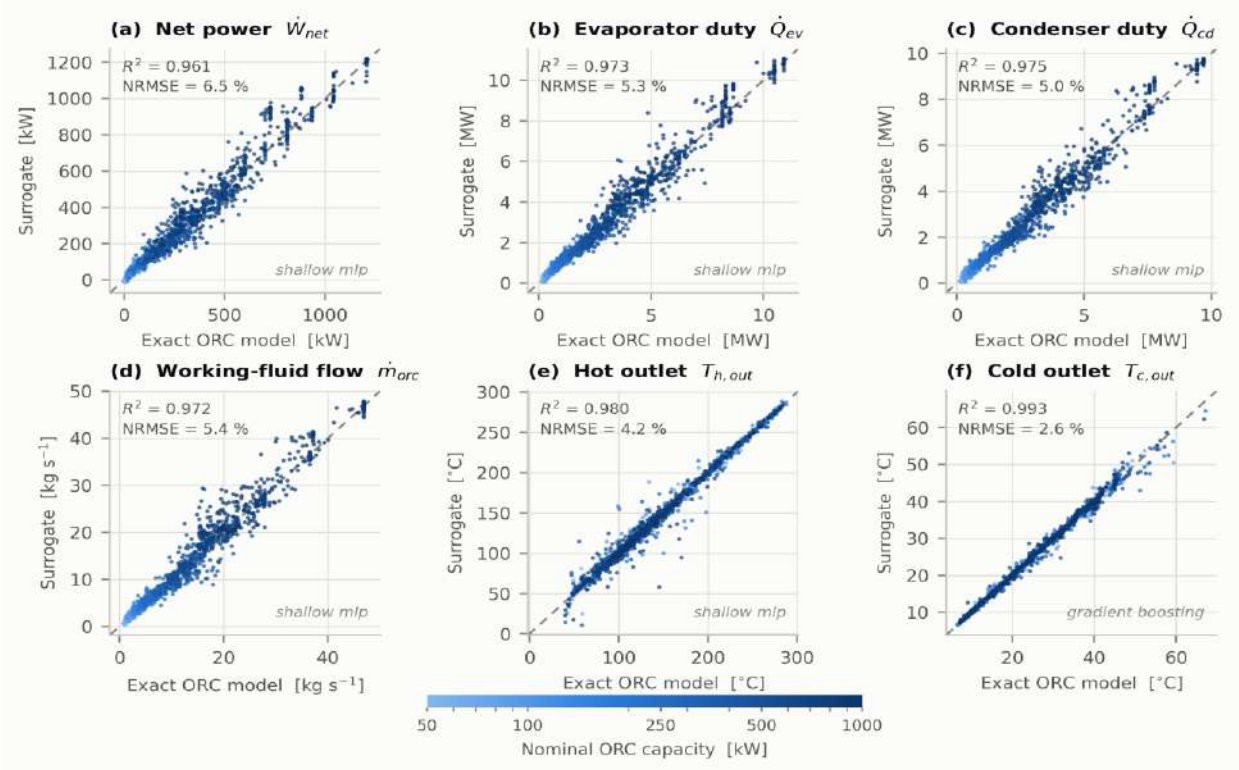


Fig. 8. Regression predictions against reference values for six primary targets on the 1588 genuinely feasible hold-out points. Color represents nominal capacity. The dashed diagonal denotes equal predicted and reference values.

Temperature predictions are particularly useful for an ORC interface to a larger thermal system. The hot-stream outlet has MAE = 4.04 °C and R^2 = 0.9799, while coolant outlet temperature has MAE = 0.51 °C and R^2 = 0.9934. Evaporating pressure is also reproduced well, with R^2 = 0.9778 and MAPE = 1.52%. The reported errors quantify agreement with the reference model under the sampled conditions.

The pressure and turbine targets in Fig. 9 are more demanding. Condensing pressure has R^2 = 0.8554 and NRMSE = 11.93%; turbine isentropic efficiency has R^2 = 0.6817 and NRMSE = 21.26%. Discrete dispatch pressure levels produce vertical bands in the parity plot because the reference values lie on the horizontal axis. The turbine efficiency also depends on the nonlinear operating-state corrections. These features help explain why a smooth prediction of energy quantities is easier than recovering the selected pressure level and its associated turbine state. In physical terms, condensing-pressure MAPE is 3.10%, and turbine-efficiency MAE is 0.025.

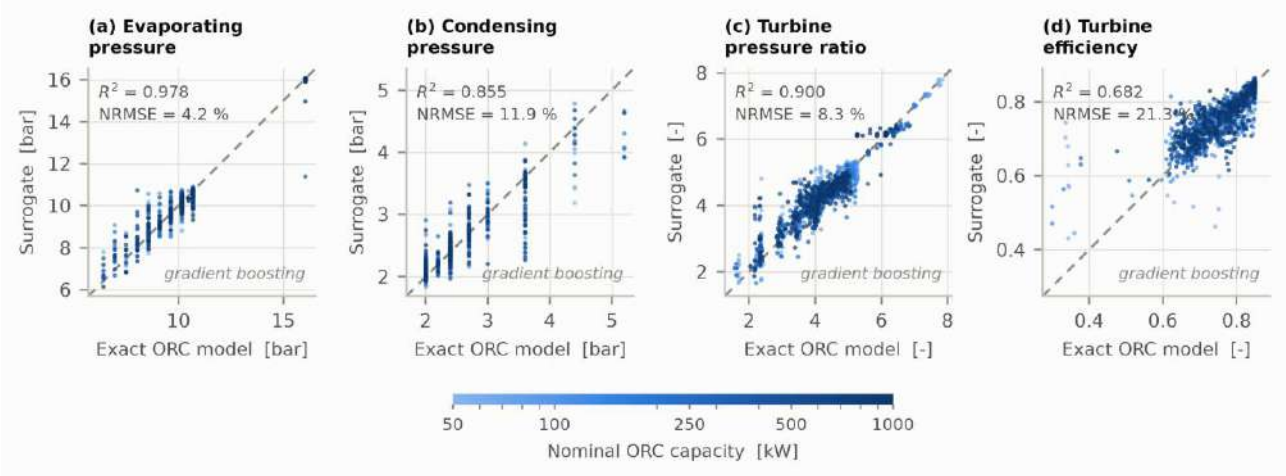


Fig. 9. Regression predictions for evaporating pressure, condensing pressure, turbine pressure ratio and turbine isentropic efficiency on the genuinely feasible hold-out. Discrete reference pressure levels produce vertical bands.

Net-power MAPE is 16.63%, higher than its NRMSE of 6.55%. Low-output part-load points can contribute strongly to a percentage metric because their actual power is small. Accordingly, the relative metric should be considered together with the absolute MAE of 31.36 kW and with capacity-resolved results, rather than interpreted as a uniform error at all operating points. The regression figures remain conditional on reference-feasible operation, as defined in Section 2.6.

3.5 Interpolation to intermediate capacities

The hold-out includes 800 points at the five capacities excluded from development. Their classifier results are close to those obtained at trained capacities: intermediate-capacity feasible recall and balanced accuracy are 87.69% and 93.84%, compared with 88.15% and 93.73% at trained capacities. No false-feasible decisions are observed in the intermediate-capacity subset. These results support interpolation of the learned operability behavior to the five tested designs.

The regression comparison in Fig. 10 shows a measurable interpolation penalty. Median absolute relative error increases from 8.62% to 12.42% for net power, from 6.98% to 9.65% for evaporator duty, and from 6.04% to 9.22% for ORC flow when moving from trained to intermediate capacities. The corresponding hot-outlet-temperature percentages are 1.61% and 1.78%; temperature performance is principally interpreted through the °C errors reported above. The energy and flow results show that intermediate-capacity prediction is more difficult, while remaining useful as a quantified interpolation task within the design family.

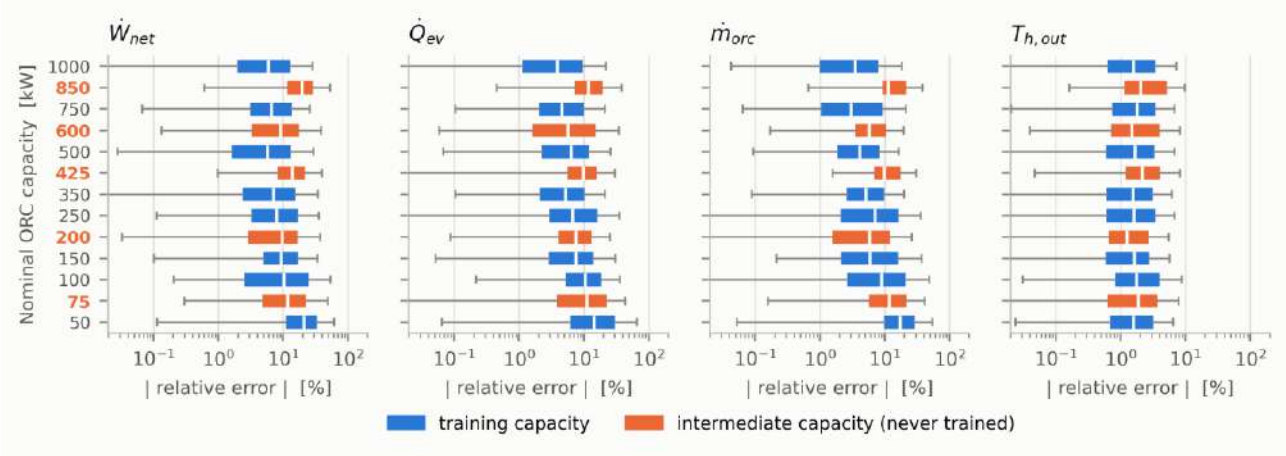


Fig. 10. Absolute relative error by capacity for four targets. Boxes span the interquartile range, the white line marks the median, whiskers extend to the most extreme observations within 1.5 interquartile ranges, and outliers are omitted. Orange boxes identify intermediate capacities.

The comparison is stronger than evaluating only new operating points at the original eight capacities. Entire capacity values are absent from development, and their geometries are generated separately by the same sizing procedure. The result therefore demonstrates capacity interpolation at the tested intermediate designs, rather than only interpolation among operating conditions of a single machine.

3.6 Target-specific model selection

Table 8 and Fig. 11 compare all six regression families. The shallow MLP is selected for net power, both heat duties, ORC flow and hot-stream outlet temperature. Gradient boosting is selected for coolant outlet temperature, the pressure and turbine targets, cycle efficiency and the capacity-normalized ratios. The preferred family therefore varies with the target, supporting target-specific selection rather than imposing one regression algorithm on the complete output set.

Table 8. Final hold-out NRMSE (%) for each regression family and target. Selection was based on validation performance.

Target	Linear ridge	Quadratic ridge	Regression tree	Bagged trees	Gradient boosting	Shallow MLP
$\dot{W}_{net}$	16.81	12.09	8.52	7.45	6.3	6.55
$\dot{Q}_{ev}$	13.94	10.37	7.63	7.0	6.02	5.31
$\dot{Q}_{cd}$	13.51	10.11	7.59	6.87	5.97	5.03
$\dot{m}_{orc}$	13.21	10.14	7.94	7.03	6.27	5.39
$T_{h,out}$	16.21	10.42	6.89	5.03	4.26	4.16

Target	Linear ridge	Quadratic ridge	Regression tree	Bagged trees	Gradient boosting	Shallow MLP
$T_{c,out}$	10.15	7.55	4.11	3.8	2.6	2.89
P_{ev}	23.61	17.59	5.23	5.39	4.19	7.08
P_{cd}	28.23	25.37	15.05	13.76	11.93	12.27
Π_t	22.82	18.05	10.75	9.9	8.34	9.45
η_t	34.31	30.96	23.89	21.37	21.26	23.55
η_{th}	24.19	19.12	13.46	11.8	9.08	10.26
$\dot{W}_{net}/\dot{W}_{des}$	25.28	17.33	11.38	9.79	8.84	9.65
$\dot{Q}_{ev}/\dot{W}_{des}$	26.58	19.17	12.77	10.91	9.78	10.09
$\dot{Q}_{cd}/\dot{W}_{des}$	26.76	19.49	12.88	11.24	10.22	10.81

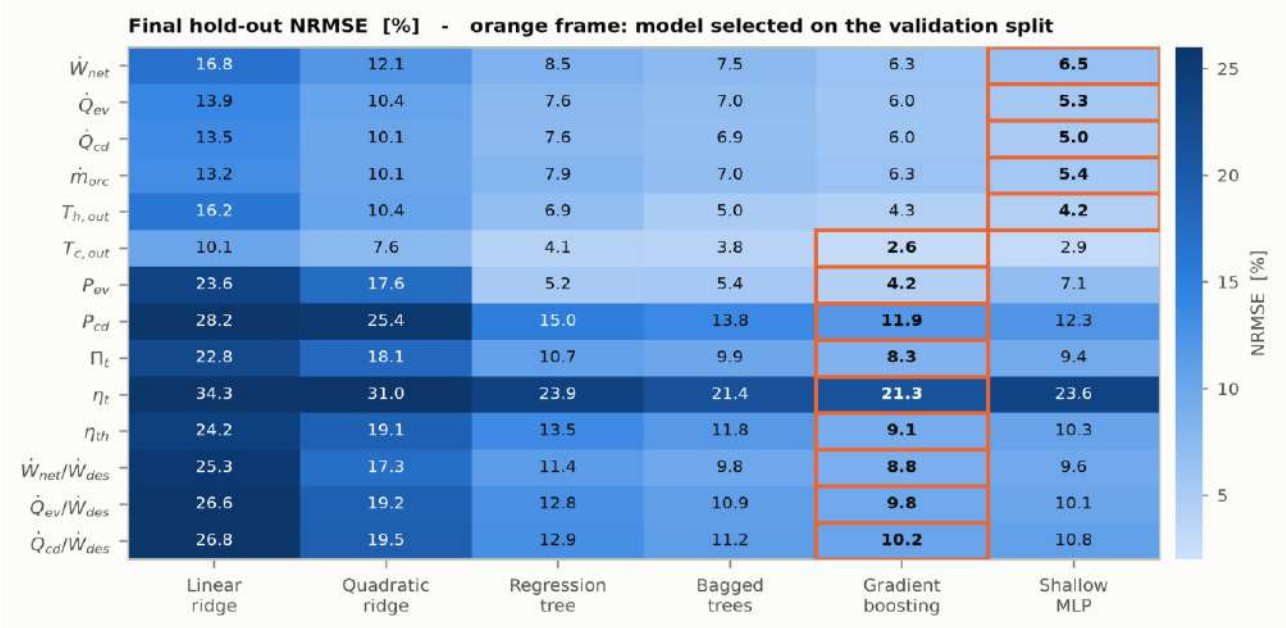


Fig. 11. Final hold-out NRMSE for all candidate regression families and targets. Orange frames identify the models selected on the validation subset. The hold-out is used for assessment rather than selection.

For net power, gradient boosting obtains 6.30% hold-out NRMSE compared with 6.55% for the selected MLP. The MLP remains the reported model because it was selected on validation performance before the hold-out was assessed. This small ranking reversal is retained in the comparison. Linear and quadratic ridge models have larger errors across the principal targets, indicating that the mapped behavior is not adequately described

by those baseline response surfaces.

3.7 Computational cost and reuse

The accumulated logged time for the 8224 reference evaluations is 2.979 h, with a mean cost of 1.304 s per point. At that mean rate, 8760 evaluations would correspond to approximately 3.17 h of accumulated reference-model calculation. Repeated annual or design-optimization evaluations motivate replacing these operating-point searches with classifier and regressor predictions.

The packaged surrogate accepts either design-referenced stream ratios or physical stream flows converted by a system wrapper. After the model objects are loaded, prediction consists of evaluating the operability gate and the selected regressors without repeating nominal sizing or heat-exchanger rating. The present results establish the reference-data cost and prediction accuracy; no numerical acceleration factor is claimed here. A practical implementation should load and retain the trained models for repeated use. The same trained model set can then be queried over the specified capacity family.

3.8 Scope of applicability

The validation covers nominal capacities of 50–1000 kW and the temperature and flow-ratio envelope in Table 3. It applies to the specified R1233zd(E)/Syltherm 800/water system, subcritical cycle, sizing rules and dispatch procedure. Changing the working fluid, cycle configuration or equipment-design rules would require a corresponding development dataset. The classifier deliberately favors conservative acceptance, and the pressure/turbine-efficiency outputs are less accurate than the primary thermal outputs. The study assesses agreement with the numerical reference model; experimental plant validation and full integrated-system annual assessment are outside the present scope.

4 Conclusion

A capacity-aware machine learning surrogate was developed for a family of subcritical R1233zd(E) ORCs between 50 and 1000 kW. Nominal capacity, the two stream inlet temperatures and the two design-referenced stream flow ratios provide a common five-input representation for separately sized designs. A campaign of 8224 reference evaluations supports the two-stage architecture, consisting of a cost-sensitive operability gate and fourteen target-specific regressors.

On the independent hold-out, the classifier achieves 0.41% false-feasible rate, 87.97% feasible recall and 93.78% balanced accuracy. Separately, regression on the 1588 reference-feasible hold-out points gives R^2 values of 0.96–0.99 and NRMSE of 2.60–6.55% for the principal power, heat-duty, flow, evaporating-pressure and outlet-temperature targets. Condensing pressure and turbine efficiency are more difficult because they reflect the operating decisions and turbine corrections of the reference model. The different preferred regression families support selecting models separately for each target.

At the five intermediate capacities excluded from development, the classifier gives no false-feasible predictions and 93.84% balanced accuracy. Median absolute relative error in net power increases from 8.62% at trained capacities to 12.42% at the intermediate capacities. The study thus quantifies both the capability and the penalty of interpolation across the specified ORC design family. The resulting framework provides a basis for repeated capacity-dependent performance evaluation and subsequent integration with a larger thermal-system model.

Declaration of generative AI

During the preparation of this work, the author used ChatGPT (OpenAI) to improve the English language, readability, and clarity of the manuscript, including assistance with linguistic revision and rephrasing. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

References

[1] Manente, G., Toffolo, A., Lazzaretto, A., and Paci, M. (2013). An Organic Rankine Cycle off-design model for the search of the optimal control strategy. Energy, 58, 97–106. https://doi.org/10.1016/j.energy.2012.12.035

[2] Walraven, D., Laenen, B., and D'haeseleer, W. (2014). Optimum configuration of shell-and-tube heat exchangers for the use in low-temperature organic Rankine cycles. Energy Conversion and Management, 83, 177–187. https://doi.org/10.1016/j.enconman.2014.03.066

[3] Walraven, D., Laenen, B., and D'haeseleer, W. (2014). Comparison of shell-and-tube with plate heat exchangers for the use in low-temperature organic Rankine cycles. Energy Conversion and Management, 87, 227–237. https://doi.org/10.1016/j.enconman.2014.07.019

[4] Hosoz, M., Ertunc, H. M., and Bulgurcu, H. (2007). Performance prediction of a cooling tower using artificial neural network. Energy Conversion and Management, 48(4), 1349–1359. https://doi.org/10.1016/j.enconman.2006.06.024

[5] Katinas, C., d'Entremont, B., Ray, W., Willis, M., and Reichardt, T. (2023). Assessing parallel path cooling tower performance via artificial neural networks. Annals of Nuclear Energy, 192, 109993. https://doi.org/10.1016/j.anucene.2023.109993

[6] Qin, C., Seo, J., Yoon, S., Lee, B. J., and Zhu, Q. (2025). Performance analysis and design optimization of a direct-absorption parabolic-trough solar collector with concentric nanofluid partitions. Solar Energy Materials and Solar Cells, 282, 113327. https://doi.org/10.1016/j.solmat.2024.113327

[7] Wang, W., Deng, S., Zhao, D., Zhao, L., Lin, S., and Chen, M. (2020). Application of machine learning into organic Rankine cycle for prediction and optimization of thermal and exergy efficiency. Energy Conversion and Management, 210, 112700. https://doi.org/10.1016/j.enconman.2020.112700

[8] Feng, Y.-Q., Zhang, Q., Xu, K.-J., Wang, C.-M., He, Z.-X., and Hung, T.-C. (2023). Operation characteristics and performance prediction of a 3 kW organic Rankine cycle (ORC) with automatic control system based on machine learning methodology. Energy, 263, 125857. https://doi.org/10.1016/j.energy.2022.125857

[9] Du, Q., Chen, X., Zhang, C., Liao, H., Liu, M., Shi, S., Yuan, D., Xie, T., and Yan, X. (2026). Performance prediction and power regulation of organic Rankine cycle turbine with deep learning. Energy, 355, 141143. https://doi.org/10.1016/j.energy.2026.141143

[10] Oh, J., Park, Y., and Lee, H. (2022). Development of a fully deterministic simulation model for organic Rankine cycle operating under off-design conditions. Applied Energy, 307, 118149. https://doi.org/10.1016/j.apenergy.2021.118149

[11] Serafino, A., Obert, B., Vergé, L., and Cinnella, P. (2020). Robust optimization of an organic Rankine cycle for geothermal application. Renewable Energy, 161, 1120–1129. https://doi.org/10.1016/j.renene.2020.07.052

[12] Bell, I. H., Wronski, J., Quoilin, S., and Lemort, V. (2014). Pure and pseudo-pure fluid thermophysical property evaluation and the open-source thermophysical property library CoolProp. Industrial & Engineering Chemistry Research, 53(6), 2498–2508. https://doi.org/10.1021/ie4033999

[13] Perkins, R. A., Huber, M. L., and Assael, M. J. (2017). Measurement and correlation of the thermal conductivity of trans-1-chloro-3,3,3-trifluoropropene (R1233zd(E)). Journal of Chemical & Engineering Data, 62(9), 2659–2665. https://doi.org/10.1021/acs.jced.7b00106

[14] Calise, F., Macaluso, A., Pelella, P., and Vanoli, L. (2018). A comparison of heat transfer correlations applied to an Organic Rankine Cycle. Engineering Science and Technology, an International Journal, 21(6), 1164–1180. https://doi.org/10.1016/j.jestch.2018.09.009

[15] Kern, D. Q. (1958). Mathematical development of tube loading in horizontal condensers. AIChE Journal, 4(2), 157–160. https://doi.org/10.1002/aic.690040208

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ACADEMIC WOMEN IN TURKISH HIGHER EDUCATION MANAGEMENT: AN INTERNATIONAL PERSPECTIVE

Özlem ATAY
Prof. Dr., Ankara University, Faculty of Political Sciences, Department of Business Administration, Ankara, Türkiye, ORCID ID: 0000-0002-2563-825X

Abstract

The aim of this research is to highlight the past and present of academic women in Turkish higher education management. Earlier than many other countries around the world, Turkish women obtained equal social and political rights with men. Türkiye is one of the countries in the world in which the right to elect and to be elected is given to women in 1934. During the Turkish Republic, women gained their rights to access higher education, pursue academic advancement and be appointed to administrative positions at universities. The average proportion of women professors across the EU-28 countries is 24%, Türkiye exceeds this average with a rate of 34%. An international perspective is analyzed. Despite women's high representation at the professorial level, their representation in senior university management — particularly at the levels of Rector and Dean — is low. Currently women constitute 8% of the Rectors and 17% of the Deans in Türkiye. The literature indicates that disciplinary background, career mobility, caregiving responsibilities, experience outside academia, appointment processes for senior management, and gender bias may influence women's likelihood of attaining senior leadership positions in universities. As a conclusion, the situation of Turkish academic women is discussed in this paper. In addition, insights for future, guidelines for improvement and solution suggestions for barriers are developed.

Keywords: Academic Women, Turkish Higher Education Management, Women Rights, Gender Equality.

Introduction

The development of women's participation in Turkish higher education is closely connected with the broader modernization process and the transformation of women's legal, political and educational status. Following the foundation of the Turkish Republic in 1923, the Turkish great leader, Türkiye's first president Gazi Mustafa Kemal Atatürk placed women's education and participation in public life among the central objectives. His approach emphasized that social progress could not be achieved while women remained outside education, science and professional life. Atatürk envisioned a modern Turkish state. Those words of Atatürk at his speech in 1923 show his determination (Atatürk, 1969, p. 700):

"One must believe that, everything we see in the world is the work of the woman…If a society satisfies the fulfilment of one of its components' contemporaneous needs, and then it is more likely that it weakens. Thus, a society must consider this as a starting point if it wants to develop and modernize… Our women will be scientists and pass through all education steps as well as men. Then, walking together with men in social life, they will help and support each other."

Atatürk, speaking on August 30, 1925 in Kastamonu, said (Güler, 1997):

"A nation consists of women and men: we do not divide and select. Do not doubt that women and men should work together for revolution. However, if men and women are divided, then the aims of our revolution will not be realized."

Atatürk aimed giving women equal status with men. The reforms of the early Republican period established the institutional basis for this transformation. The abolition of the Sultanate, the adoption of secular principles, the Law on the Unification of Education, constitutional equality, clothing reform and the adoption of the Civil Code in 1926 were among the major steps highlighted in the keynote presentation. Women were included in

the first National Census in 1927, and the adoption of the Latin alphabet in 1928 was accompanied by a broad educational campaign that expanded opportunities for literacy and education. Political participation also developed rapidly: women participated in municipal elections in 1930 and were granted the right to vote and to be elected to the Grand National Assembly of Türkiye in 1934. In the general elections at 8th of February, 1935, 18 women entered Parliament. The secular ideology and reforms enabled the rise in women's education and representation in senior management. Turkish women entered education, employment and other public domains of life increasing numbers since 1923 (Atay & Çetin, 2017). There is a positive correlation between women's education and their employment (Özkanlı, 2001: 131).

The international dimension of these reforms was visible in the International Women's Congress convened at Beylerbeyi Palace in Istanbul on 22 April 1935. In his message to the Congress, Atatürk emphasized the importance of women's political and social rights for human dignity and well-being. These developments established a historical context in which women's access to education, academic careers and public leadership became increasingly legitimate and institutionally possible. The president of the Congress Nur Hüda Muhammed Sultan eş-Şaravi replied Atatürk's message at her speech, she made the following statement regarding Atatürk: "The Turks gave you the name "Atatürk"—meaning "Father of the Turkish people" I, however, wish to call you "Ataşark"—meaning "Father of the Orient people" (Cumhuriyet Newspaper, 23 April 1935, 1).

Women's participation in higher education had begun before the establishment of the Republic. Female students were admitted to the Darülfünun by 5th of February, 1914. The University Reform of 1933 and the establishment of Istanbul University marked another important stage. Academic women were admitted to the Higher School of Economics and Commerce for the first time in the 1932–1933 academic year. Over subsequent decades, women became increasingly visible as students, researchers, lecturers and professors, and they also gained formal access to administrative positions in universities. Since 1993, there has been a significant increase in the number and share of women teaching staff (Özkanlı, 2007). Historical, social and cultural factors explain the relatively high representation of Turkish women in professional positions, and the support to advance to senior academia (Özkanlı & White, 2008).

This paper focuses on the historical development and contemporary position of academic women in Turkish higher education management. It examines changes in women's overall representation in academia, differences across academic disciplines and titles, international comparisons, and the continuing gap between women's participation in academic employment and their participation in senior university leadership. The paper also highlights the Turkish scientific contribution within the previous international projects of the Women in Higher Education Management (WHEM) Network and its current REACHING project.

Materials and Methods

The paper uses a descriptive, interpretive and historical approach on academic women in Turkish higher education management after a comprehensive literature review. The research is based primarily on the statistical and documentary evidence. Statistics are reported as presented in the source materials, together with their stated reference years and access dates. The research examines the Turkish Council of Higher Education statistics to analyze the changing proportion of academic women, their distribution across disciplinary fields and academic titles, and their representation in senior management. Historical milestones concerning women's political, educational and academic rights are used to establish the institutional context.

The analysis is organized around four dimensions. First, the historical development of women's access to higher education and academic employment is reviewed. Second, women's contemporary representation is examined by academic field and academic title. Third, Türkiye is analyzed within an international perspective. Fourth, the paper considers women's representation among Rectors/ Deans and discusses the factors that may affect progression to senior leadership positions.

The study also incorporates the international research context provided by the WHEM Network. Since 2006, Prof. Dr. Özlem Atay has been representing Türkiye in this network. WHEM research has examined gender,

academic careers and higher education management across multiple national contexts and has resulted in a series of international publications. The current REACHING network project extends this comparative agenda by examining academic leadership from intersectional and gender perspectives.

Findings and Discussion

Historical Growth of Women's Participation in Turkish Academia

The long-term pattern is one of substantial growth. Turkish women constituted 13.9% of academic staff in 1946, and this proportion had risen to 30% by 1984. The current proportion is approximately 47%. The historical trajectory therefore indicates a major transformation in the gender composition of Turkish academia. The trend line presented in Figure 1 suggests that, if the observed pattern continues, the proportion of academic women may exceed 50% by 2030. This increase is important because it demonstrates that women are effective group within Turkish academia. Nevertheless, aggregate representation alone does not reveal whether women and men are distributed similarly across disciplines, academic ranks or leadership positions. Figure 1 shows the overall changes.

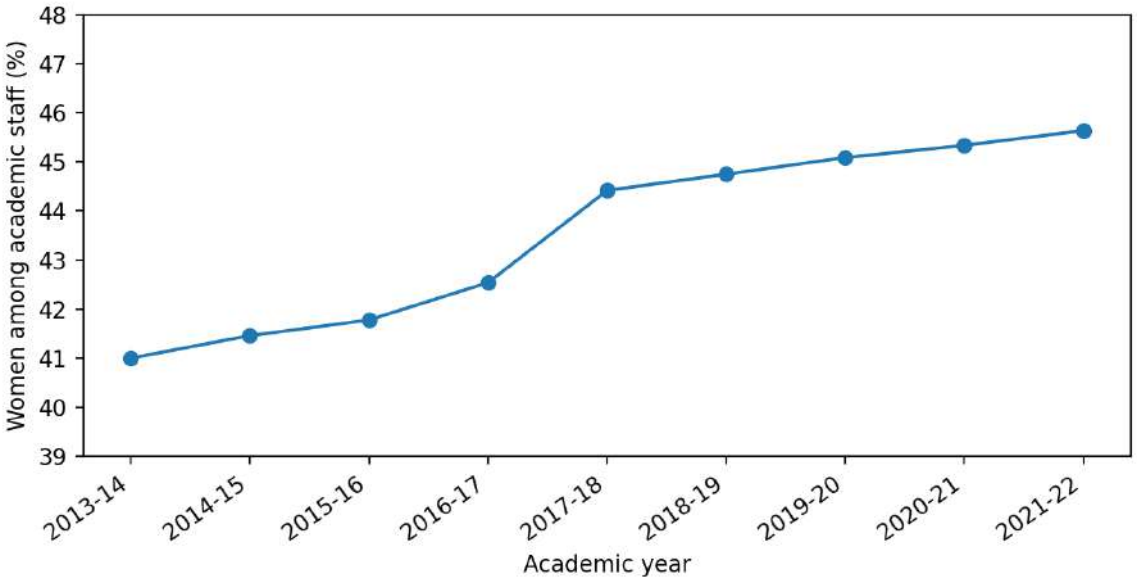


Figure 1. Changes in the Proportion of Turkish Academic Women (Council of Higher Education Statistics, Retrieved: September 15, 2026)

Representation by Academic Field

Turkish women constitute 53.0% of academic staff in Health Sciences, In Natural Sciences, Mathematics and Statistics, women account for 48.2%, indicating near parity. In contrast, women represent 35.2% of academic staff in Engineering, Manufacturing and Construction and 31.3% in Information and Communication Technologies. These differences show that a national figure close to gender balance can coexist with considerable disciplinary segregation. Fields associated with health and the natural sciences display comparatively high female representation, whereas engineering-related, information and communication technology fields remain more male dominated. Consequently, policies concerned with gender equality in academia need to consider not only the overall number of academic women but also the distribution of women across disciplinary areas. There are disciplinary differences, with a higher representation of women in language-based studies at almost every level and a lower representation in engineering and technology (Özkanlı & Machado-Taylor, 2013). All around the world, at areas like natural sciences, medicine and

engineering women are generally underrepresented academically (White and Özkanlı, 2009). However, Figure 2 shows impressive percentages of Turkish academic women.

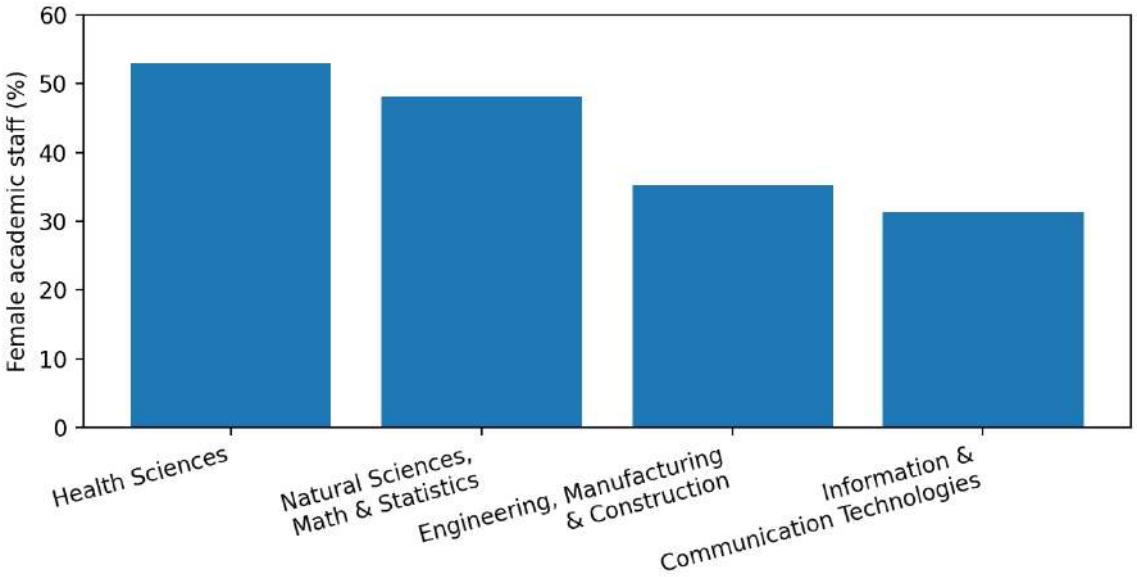


Figure 2. Percentage of Female Academic Staff by Field in Türkiye (Council of Higher Education Statistics, Access Date: 15.09.2026)

Representation by Academic Title

The distribution of academic staff by title provides a second indication of vertical differentiation. The 2025 data show that women constitute 55.7% of research assistants and 50.8% of lecturers. Their representation is 47.9% among assistant professors and 43.7% among associate professors, but decreased to 35.1% among professors. In total, women account for 87,770 of the 186,942 academics corresponding to 46.9% (Table 1).

Table 1. Percentage of Turkish Academic Staff by Academic Title and Gender (Council of Higher Education Statistics, Access Date: 02.12.2025)

Academic Title	Women	Men	Total	Women (%)
Professor	14,204	26,230	40,434	35.1
Associate Professor	11,479	14,757	26,236	43.7
Assistant Professor	22,339	24,205	46,544	47.9
Lecturer	18,439	16,662	36,229	50.8
Research Assistant	21,354	17,282	38,636	55.7
Total	87,770	99,172	186,942	46.9

The reason for the high representation of women in the professoriate in Türkiye may relate to the status of academic jobs. Zeytinoglu (1999) and Kandiyoti (1997) noted that academic careers were historically and socially constructed and sex-typed as “safe” and “proper” choices for graduate women in Turkey. Women were socially encouraged to take up professional employment, as opposed to entrepreneurial or commercial careers, since these were considered harmonious with the potent image of “a respectful Turkish woman”. This ideology was effective in demarcating women’s careers in “safe”, “secure” and “esteemed” forms of professional employment (Healy et al. 2005, 253).

Reskin and Roos (1990) argue that men, owing to change market conditions, may leave the competition for certain jobs and women take their place in the queue, leading to the gendering of those previously contested jobs (Özbilgin and Healy, 2004:361).

International Perspective

The paper examines the situation of Turkish academic women in an international perspective. The average proportion of women professors across the EU-28 countries is 24% and 34% in Türkiye. This comparison indicates that Türkiye's reported share of women professors is above the EU-28 average. Table 2 shows substantial variation among countries, emphasizing that women's academic participation is shaped by national institutional and historical contexts. Table 2 examines changes in women's share of academic staff at some countries.

Table 2. Distribution of Women Professors in Selected Countries and the EU-28, (Council of Higher Education Statistics, Access Date: 02.12.2025)

Country	Women Professors (%)	Country	Women Professors (%)
North Macedonia	67	Switzerland	23
Romania	54	Austria	23
Latvia	41	Italy	22
Croatia	41	France	22
Lithuania	39	Greece	22
Bulgaria	37	Spain	21
Türkiye	34	Denmark	21
Finland	29	Malta	21
Slovenia	29	Ireland	21
Norway	28	Hungary	20
United Kingdom	26	Germany	19
Portugal	26	Netherlands	19
Iceland	26	Belgium	18
Sweden	25	Luxembourg	17
Slovakia	25	Czech Republic	15
Estonia	24	Israel	14
Poland	24	Cyprus	14
European Union (EU-28)	24		

The Women in Higher Education Management (WHEM) Network and International Research Collaboration

The Women in Higher Education Management (WHEM) Network brings together internationally-recognized gender in higher education researchers in 14 countries; Australia, Austria, Ireland, New Zealand, Portugal, Sweden, South Africa, Turkey, India, Czech Republic, the United Arab Emirates, Germany, USA and the UK. The vision of the WHEM Network is to analyze the challenges for women in university management and to develop strategies that can empower them to apply for and succeed in senior management roles.

Prof. Dr. Özlem Atay has been representing Türkiye at the international gender research consortium, the WHEM Network since 2006. WHEM member professors have published numerous comparative books, book chapters, journal articles and conference papers on women's academic careers, gendered organizational processes and leadership in higher education institutions.

WHEM Network published its first book with Palgrave - Gender, Power and Management - in April 2011. It is the first multi-country study to examine the dynamics of men and women working together in higher

education senior management teams within a broader organizational context. It is based on interviews with women and men in university senior management in the participating countries. It explores pathways into senior management, perceptions of how women and men regard each other's performance in top management jobs, and their influence on universities. It questions where women fit in university senior management, whether or not women can and do make a distinctive contribution to university decision-making, and the impact of organizational cultures on their effectiveness as managers and leaders. Finally, it explores why interventions need to be developed for women who wish to apply for higher education senior management positions

The Network's second book with Palgrave, Generation and Gender in Academia is published in June 2013. This book provided the first cross-cultural analysis of the differences in career trajectories and experiences between a senior and younger group of women academics. It used individual autobiographies of women academics in Australia, Ireland, New Zealand, Portugal, South Africa, Sweden, Türkiye and the United Kingdom, who are members of the WHEM Network. Four major themes in their stories are national context; organizational context; family, class and location; and agency. While the younger generation believe they are entitled to careers on the same terms as their male colleagues, major challenges remain. These include countering the argument that the battles have been won for younger academics; lack of support and mentoring at the outset of careers; the continuing difficulty of aspiring to a traditional academic career; capacity for playing the 'game' in managerial universities; and recognizing mobility as crucial to career success.

The third multi-country research book with Palgrave- Gendered Success in Higher Education: Global Perspectives- is published in February 2017. Much has been written about the barriers to women's promotion in these contexts; about their masculinist culture and male oriented structures and career paths; and about the underlying gender schemas which legitimate such arrangements and which depict women as 'the problem'. Little attention has been paid to an analysis of atypical cases; that is, those organizations which in their gender profile at senior level; in their organizational culture; positional and informal leadership create alternative contexts which are more 'gender friendly'. This is the focus of the case studies in this book. In their various national and organizational contexts, they identify key factors in bringing about the successful implementation of gendered change in higher education organizations at various levels. The final chapter draws together the key factors into an overall change model. It includes a focus on external facilitating factors such as legislative framework, policy or advocate interventions; internal facilitating factors, including leadership (both top down and 'bottom up'); as well as context specific intervention points. This model will provide important knowledge for HE institutions about how sustainable gendered change can be created in organizations as well as providing insights into the creation of a new gender agenda.

The fourth multi-country research book with Palgrave- Gender, Power and Higher Education in a Globalised World – is published in 2021. The authors examine persistent gender inequalities in higher education and ask why change is so slow. The discussion refers to feminist institutionalism as the underlying theoretical perspective and focuses on institutional resistance, and the legitimating discourses of excellence, choice, displacement, biological essentialism and gender neutrality. In highlighting the importance of gender-competent leadership and empowering equality structures as ways of creating change, it explores the situation in 14 countries—Australia, Austria, Germany, India, Ireland, New Zealand, Portugal, South Africa, Sweden, the Czech Republic, the United Arab Emirates, the United Kingdom, the United States and Türkiye. The analysis stresses the importance of institutional transformation, the vital contribution of feminist activists and the importance of women's deceptively 'small victories' in the academy.

The Network's fifth book with Palgrave, Gender and Higher Education Management in Times of Crisis is published in October 2025. Higher education institutions (HEIs) all over the world are facing difficult times that are often labelled a crisis but could also—due to the complexity of the phenomena under discussion—be characterized as a polycrisis. The chapters in this edited volume approach crisis in the context of higher education (HE) from a social constructivist perspective and from three angles: First, they focus on HEIs in crisis as the consequence of external factors, which impact the way how HEIs are able to perform and to fulfil their tasks. Second, they explore the concept of crisis as an endemic element within the HE environment. This

perspective suggests that the underlying causes of the crisis are interwoven with the very logic of HE and research, exemplified by the prevailing notion of excellence. Third, they discuss the expectations towards HEIs in times of crises to provide solutions for current or upcoming crises. The individual contributions adopt multidimensional, multilevel and intersectional approaches to gender inequalities to better understand power relations as expressed through institutional and cultural change processes. The chapters explore the ways in which crises play out and the extent to which they undermine, ratify or reconfigure gender relations in higher education. Contributing authors from different geographical locations also reflect on how higher education management conceives of gender when responding to crisis, as well as the consequences of a binary approach and related essentialism. Prof. Dr. Özlem Atay wrote her chapter with her co-author titled "Exploring academic women's perception of the Glass Ceiling in times of Crisis: Gender and Turkish Higher Education Management" for the fifth WHEM Network book. This chapter examines Turkish academic women's perceptions of barriers to career progression and the effect of the COVID-19 context on those perceptions. Her chapters in these five books shed light on the situation of women in Turkish academia (Atay & Gürgen, 2025).

The sixth WHEM Network Project titled REACHING (Reframing Educational and Academic Leadership to Respond to Challenges in Neoliberal Higher Education – Intersectional and Gender Perspectives) is funded by the Swedish Research Council (SRC) for the period 2025–2029. REACHING Project funding is for three years is for six network meetings during 2025, 2026, 2027. The meetings will last two to three days and be arranged in the higher education institutions of the WHEM members. The first project meeting was held in Vienna between 29 September and 1 October 2025 at the Institute for Advanced Studies. The second project meeting was held in Berlin between 7-8 May 2026 at the Freie University. The third project meeting is online between 8-9 October 2026.

The REACHING Project aims to generate new research on the organization and management of higher education from a gender perspective and to advance knowledge development in this field. The project also provides a platform for collaboration and exchange among researchers, practitioners, and academic leaders. Academic leadership is generally an underdeveloped field in many countries and there is a particular lack of research that has used a comparative method to examine challenges and opportunities across national borders with a focus on gender equality and equal conditions. The work within the WHEM Network will result in a joint book based on empirical case studies from Türkiye and other 13 participating countries with contributions to theory development in the field. Currently Prof Dr Özlem Atay is working on the sixth multi-country research project and writing a chapter titled "Gendered Ruling Relations in Turkish & Portuguese Higher Education Institutions: Linking Academic Work, Job Crafting & Career Self-Efficacy" for the sixth research book.

You can find detailed information on WHEM International Cooperation Program at the link below:

https://www.ihs.ac.at/events/research-platforms/gd/women-in-higher-education-management/

You can find detailed information on sixth WHEM Network Project titled REACHING at the link below:

https://www.oru.se/forskning/forskningsprojekt/fp/?rdb=p2803

You can find detailed information on publications about Turkish women in higher education management at the link below:

https://ozlemataysbf.blogspot.com/

Turkish Academic Women in Senior Management

Türkiye has 208 higher education institutions-129 public universities, 75 foundation universities and 4 foundation Vocational Schools currently. There is a high representation of women in professoriate in Türkiye. On the other hand, women are under-represented in senior management, especially at Rector and Dean levels (Neale and Özkanlı, 2010).

According to Table 3, only 5 of the 129 rectors of public universities are women, while 11 of the 75 rectors of foundation universities are women. Across all institutions, 16 of 204 rectors are women, corresponding to 8%. Women Deans constitute 15% at public universities and 20% at foundation universities (total 17%).

Table 3. Percentage of Women Rectors and Deans in Public and Foundation Universities (Council of Higher Education Statistics, Access Date: 02.12.2025)

University Type	Women Rectors	Men Rectors	Total	Women Rectors (%)	Women Deans (%)
Public Universities	5	124	129	4	15
Foundation Universities	11	64	75	14.6	20
Total	16	188	204	8	17

The literature indicates that disciplinary background, career mobility, caregiving responsibilities, experience outside academia, appointment processes for senior management, and gender bias may influence women's likelihood of attaining senior leadership positions in universities. These factors operate at different levels. Some relate to individual career trajectories and mobility opportunities, while others concern organizational structures, expectations, selection procedures and the distribution of care responsibilities. The persistence of a leadership gap despite high overall participation therefore points toward the importance of examining institutional processes rather than relying solely on workforce participation rates.

Özkanlı & Korkmaz (2000) stated that being a woman is far from being an advantage in academic and administrative promotion. As discussed by Özkanlı & Korkmaz (2000, 321) one of the important problems faced by academic women in Turkish universities is role conflict. Academic women experience a big role conflict especially during their assistant professorship stage where their desire of promotion is intensive. Succeeding their promotion and rising up to professorship, they tend to think that men and women have to work equally hard to promote, leaving aside the idea that they have to work harder than men do. Taking care of the changes in the roles of academic women in their non-work life (wife, homemaker, mother...), changing opinions according to titles is thought to be in close relation with role conflict. Academic women are found to be responsible for managing the household although men 'help' rather than sharing domestic tasks. For that reason, academic women should work more than men in order to achieve career success (Özkanlı & Korkmaz, 2000a).

Research in Türkiye (Özkanlı & Korkmaz 2000, Acar 1983; Köker 1988) indicated that academic women usually do not want administrative positions because of role conflict rather than institutional discrimination. These women usually point only to the presence of an overload of demands placed on them by ever-increasing obligations of their family roles as the reason for their withdrawal from competition.

Generally, most of the Turkish academic women think that there is no gender discrimination both in academic promotion and management, but they report that their careers are seriously affected by role conflict (Acar, 1983; Cindoğdu & Muradoğlu 1996; Köker 1988; Erkut 1982; Özkanlı & Korkmaz 2000b). According to such findings, most academic women face role conflict in family responsibilities especially motherhood which is found to be an important obstacle in academic career. In a study, personal barriers to academic women's career development were stated as lack of support from family and friends, undergoing a divorce, having a child with disability and administrative obstructions (Ozbilgin & Healy, 2004, 367).

Recent research by Atay and Gürgen (2025) similarly describes the continuing under-representation of women in senior higher education management and examines academic women's perceptions of the glass ceiling before and after the COVID-19 pandemic. Their study reports that overall perceptions of the glass ceiling remained relatively stable, while perceptions of authoritarian behavior among superiors increased during the pandemic.

Limitations and Directions for Future Research

The descriptive evidence in this paper is drawn from the statistical and documentary material. Accordingly, the figures/tables refer to the reference years and classifications used in those materials, and some international comparisons combine data reported for different years. They are therefore most appropriate for describing broad patterns rather than for making strict year-by-year causal comparisons across countries.

A second limitation is that aggregate statistics cannot by themselves explain the mechanisms that produce the leadership gap. The contrast between women's overall share of academic employment and their smaller share of professorial and senior management positions identifies an important organizational pattern, but it does not establish the relative contribution of appointment practices, mobility, caregiving, disciplinary location, organizational culture or gender bias.

Future research can address these limitations through longitudinal analyses of academic careers, comparative studies of public and foundation universities, and qualitative research with academic women. The REACHING project is particularly relevant in this respect because its intersectional and comparative orientation can connect institutional structures with the experiences of academic leaders across different higher education systems.

Conclusion and Recommendations

The historical evidence reviewed in this paper demonstrates that women's participation in Turkish higher education has expanded substantially. The legal and educational reforms associated with the early Republican period created an important foundation for women's access to education and public life, and women have subsequently become a major component of the academic workforce. The current overall representation is approximately 47%. However, the findings also show why aggregate participation should not be treated as equivalent to equality throughout the academic system. Women's representation varies across disciplinary fields and declines across the higher academic ranks. Most importantly, women remain markedly under-represented among Rectors and Deans. The 8% representation rate of women Rectors and 17% representation rate of women Deans are in contrast with women's 46.9% share of academic staff.

These patterns support continued attention to the organizational processes that shape access to senior leadership. Transparent and inclusive appointment procedures, equal access to career-development and leadership opportunities, institutional recognition of caregiving constraints, and systematic monitoring of gender patterns across disciplines, ranks and management positions are relevant areas for universities to consider. Increased support from the university management such as mentoring for leadership roles, improved childcare/ elderly care facilities, positive segregation and quotas may increase the number of female managers in Turkish universities.

International comparative research is also important because it enables institutions to distinguish nationally specific patterns from challenges that recur across higher education systems. The WHEM Network and the REACHING project provide an important platform for this continuing work. The comparative orientation the WHEM Network can contribute to a deeper understanding of gendered leadership structures and to the development of evidence-based strategies for institutional change. The long-term objective is not simply to increase the number of women in academia, but to ensure that women can participate at every level of academic leadership.

References

Acar, F. (1983). Turkish Women in Academia: Roles and Careers. *METU Studies in Development*, 10(4), 409-446.

Atatürk, M. K. (1969). *Atatürk'ün söylev ve demeçleri (Atatürk's Speeches and Declarations)* (Vol. 2). Türk İnkılâp Tarihi Enstitüsü Publishing House.

Atay, Ö., & Gürgen, N. E. (2025). "Perceptions of Turkish academic women on the glass ceiling in times of crisis", in S. Barnard & A. Wroblewski (Eds.), *Gender and higher education management in times of crisis*. Palgrave Macmillan, p.p. 249–268 https://doi.org/10.1007/978-3-031-98941-4_11

Atay, Ö. (2017). "Gendered Success and Strategies for Change in a Turkish University", in *Gendered Success in Higher Education Global Perspectives*, Kate White, Pat O'Connor (Eds.), Palgrave Macmillan Publishers Ltd., London, UK, p.p. 215-232. https://doi.org/10.1057/978-1-137-56659-1

Atay, Ö. & Çetin, F. (2017). Perceptions of Turkish Working Women on Success, Empowerment and Information Technologies, *7th International Interdisciplinary Business- Economics Advancement Conference (IIBA) Proceedings Book*, Miami, Florida, USA, 9-14 April, 2017, p.p. 18-29.

Cindoğdu, D & Muradoğlu G. (1996). *Türkiye'de Muhasebe ve Finans Dalındaki Bilim Kadınlarının İş ve Aile Rolleri ile Başetme Stratejileri (Coping Strategies of Women Academics in the Fields of Accounting and Finance in Turkey Regarding Work and Family Roles)*. in H Coşkun (Ed.), *Akademik Yaşamda Kadın (Women in Academia),* Ankara: Türk-Alman Kültür İşleri Publication, p.p. 244- 260.

Council of Higher Education (YÖK). (2025). Higher education statistics. Retrieved: December 2, 2025, from https://www.yok.gov.tr/en

Cumhuriyet Newspaper, 23 April 1935, p.1.

Erkut, S. (1982). Dualism in Values Towards Education of Turkish Women, in Ç. Kağıtçıbaşı (ed.). *Sex Roles, Family and Community in Turkey*. Bloomington, Ind.: Indiana University Turkish Studies, p.p. 121-132.

Güler, A. (1997). *Eğitimin Tarihi ve Sosyal Temelleri (Historical and Social Foundations of Education)*. Bolu: Abant İzzet Baysal University Publication.

Healy, G., Ozbilgin, M. & Aliefendioglu, H. (2005). Academic Employment and Gender: A Turkish Challenge to Vertical Sex Segregation, *European Journal of Industrial Relations*, 11(2), 247-264.

Kandiyoti, D. (1997), *Cariyeler, Bacılar, Yurttaşlar: Kimlikler ve Toplumsal Dönüşümler (Concubines, Sisters, Citizens: Identities and Social Transformations)*, İstanbul: Metis Publication.

Köker, E. (1988). *Türkiye'de Kadın, Eğitim ve Siyaset: Yükseköğrenim Kurumlarında Kadının Durumu Üzerine Bir İnceleme (Women, Education, and Politics in Turkey: A Study on the Status of Women in Higher Education Institutions),* Unpublished Ph.D Thesis, Ankara University, Ankara.

Linkova, M., Atay, Ö. & Zulu, C. (2021). Making the Right Choice: Discourses of Individualised Responsibility in Higher Education, in *Gender, Power and Higher Education in a Globalised World*, Pat O'Connor, Kate White (Eds.), Palgrave Macmillan Publishers Ltd., London, UK, p.p.71-93. https://doi.org/10.1007/978-3-030-69687-0

Machado-Taylor, Maria de Lourdes & Özkanlı, Ö. (2013). Gender and Academic Careers in Portuguese and Turkish Higher Education Institutions, *TED Education and Science Journal*, 38(169), p.p. 346-356.

Neale, J. & Özkanlı, Ö. (2010). Organizational Barriers for Women in Senior Management: a comparison of Turkish and New Zealand Universities, *Gender and Education Journal*, Routledge, Taylor and Francis Publishing Company, 22(5), England, p.p.547-563.

Özbilgin, M. & Healy, G. (2004). The Gendered Nature of Career Development of University Professors: The Case of Turkey. *Journal of Vocational Behaviour*, 64, 358-371.

Özkanlı, Ö. & Korkmaz, A. (2000). *Kadın Akademisyenler (Academic Women)*. Ankara University Publication. Publication No:586, Ankara.

Özkanlı, Ö. & Korkmaz, A. (2000a). Academic Women in Turkey: The Structure of Attitudes Towards Role Conflict. *The Global Awareness Society International Ninth Annual International Conference Proceedings Book*. Bloomsburg University Publication. New York, USA, 26-28 May, p.p. 314-322.

Özkanlı, Ö. & Korkmaz, A. (2000b). Turkish Women in Academic Life: Attitude Measurement towards Gender Discrimination in Academic Promotion and Administration. *Emerging Economies, Academy of Business Administrative Sciences 2000 International Conference Proceedings Book*. St. Bonaventure University, Prague, Czech Republic, 10-12 July, p. 56.

Özkanlı, Ö. (2001). Women's employment in Turkey- trends and prospects. *Hacettepe University İ.İ.B.F. Journal*, 19(2), p.p. 123-141.

Özkanlı, Ö. (2007). The situation of academic women in Turkey. *TED Education and Science Journal*, 144(3), p.p.59-73.

Özkanlı, Ö., Carvalho, T., Prozesky, H., Peterson, H. (2013). Chapter 7- Careers of Early and Mid-career Academics, in *Generation and Gender in Academia*, Kate White, Barbara Bagilhole (Eds), Palgrave Macmillan Publishers Ltd., London, UK, p.p.127-169. https://doi.org/10.1057/9781137269171

Özkanlı, Ö. & J. Neale (2011). Chapter 4-Research Design in *Gender, Power and Management: A Cross Cultural Analysis of Higher Education*, Kate White, Barbara Bagilhole (Eds.), Palgrave Macmillan Publishers Ltd., London, UK, p.p. 78-90.

Özkanlı, Ö. & K. White (2009). "Gender and Leadership in Turkish and Australian Universities", *Equal Opportunities International Journal*, Vol. 28, Issue:4, p.p.324-335. https://doi.org/10.1108/02610150910954782

Reskin, B.F. & Roos, P.A. (1990). *Job queues, gender queues: Explaining women's inroads into male occupations*. Temple University Press.

Zeytinoglu, I.U. (1999), Constructed Images as Employment Restrictions: Determinants of Female Labour in Turkey. In: Z.F. Arat (Ed.) *Deconstructing Images of "The Turkish Women*, New York, USA: Palgrave, p.p. 183-97.

https://www.ihs.ac.at/events/research-platforms/gd/women-in-higher-education-management/

https://www.oru.se/forskning/forskningsprojekt/fp/?rdb=p2803

https://ozlemataysbf.blogspot.com/

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE EFFECT OF VISUAL TRAINING MATERIALS IN DIFFERENT FORMATS ON AWARENESS IN DIVERSIFIED PHISHING SCENARIOS

Ercan Emre YÜREK
Çelebi ULUYOL
https://orcid.org/0009-0002-4057-5354
Gazi University, Graduate School of Informatics, Ankara, TÜRKİYE
Prof. Dr., https://orcid.org/0000-0001-9774-0547
Gazi University, Faculty of Education, Computer Education and Instructional Technologies, Ankara, TÜRKİYE

Abstract

Technical advancements in cybersecurity technologies rapidly improving but when we consider about social engineering, the human still remains the weakest link. Attackers especially exploit the human weakness to have access to information systems. This creates a significant workload for cyber incident response teams. Cyber security awareness programs often rely on static, text-based, and theoretical methods, frequently fail to achieve expected lasting behavioral change. Previous studies in the issue suggest that video-based training may be more effective than text-based and static education materials but comparisons between different visual formats are limited. Researchs usually has been implemented in small groups or student-focused groups or laboratory settings, validation within large-scale corporate environments is limited. Prior researchs rely on single-shot experiments, this leaves an unaddressed gap regarding whether training format rotation can establish behavioral change in repeat clickers. To address these gaps at literature, this study will be conducted at 2,000 personnel who using corporate e-mail account a steps of: Pre-test – Visual Training – Intermediate Test – Visual Training (Format Rotation) – Post-Test. Phishing emails will be sent to users via a commercial platform will involve a variaty of scenarios: administrative fines, banking campaigns, travel agency discounts, and charming credit card offers. Personnel who fail at the pre-test will be randomly divided into four groups, each group will receive one training format: banners, newsletters, infografic posters, or scenario-based videos. Individuals who continue clicking after implemented visual education methods in tests will be rotated to an alternative visual education material. After the post-test, semi-structured surveys will be condected to personnel who lacks the expected level of cyber security awareness level to analyze workplace stressors and time pressure, while analysing the effects of demographic elements like age, gender, and department. We expect that video-based training will be statistically superior in increasing cyber security awareness level in social engineering methods especially phishing, while format rotation is anticipated to break resistance in clicking behaviour. Finally, we aim with this research to turn personnel into human sensors in cybersecurity, to hinder most of the incidents at the source and to reduce cyber incident response teams workloads.

Keywords: Phishing Simulation, Cybersecurity Awareness, Visual Training Materials, Digital Forensic Readiness, Root Cause Analysis.

ÇEŞİTLENDİRİLMİŞ OLTALAMA SENARYOLARINDA FARKLI BİÇİMLERDE GÖRSEL MATERYALLERİN FARKINDALIK ÜZERİNDEKİ ETKİSİ

Özet

Siber güvenlik alanında kullanılan tespit ve engelleme teknolojilerindeki hızlı gelişmelere rağmen, sosyal mühendislik saldırıları söz konusu olduğunda zafiyetleri nedeniyle insan hala en zayıf halka olmayı sürdürmektedir. Bu durum, siber olay müdahale ekipleri üzerinde ağır bir iş yükü oluşturmaktadır. Kurumsal farkındalık programları genellikle statik, metin tabanlı teorik yöntemlere dayanmakta ve kalıcı davranışsal değişimi sağlamada yetersiz kalmaktadır. Literatürdeki mevcut çalışmalar video tabanlı eğitimlerin metin tabanlı materyallerle kıyaslandığında daha üstün olabileceğini öne sürmektedir ancak görsel formatları kıyaslama konusunda yapılan çalışmalar sınırlıdır. Mevcut araştırmalar incelendiğinde deneylerin küçük,

öğrenci odaklı çalışmalar veya laboratuvar ortamında sınırlı kaldığı, gerçek ve büyük ölçekli kurumsal alanlarda test edilmediği görülmektedir. Yapılan çalışmalar tek seferlik simülasyonlara dayanmakta ve görsel eğitim format rotasyonunun ısrarla zafiyet gösteren personelde kalıcı bir davranış değişikliği sağlayıp sağlayamayacağı konusunda önemli bir boşluk olduğu tespit edilmiştir. Bu eksiklikleri gidermek maksadıyla yapılacak bu çalışma, Ön test – Görsel Eğitim – Ara Test – Görsel Eğitim Formatı Rotasyonu – Son Test dizilimi kullanılarak aktif olarak kurumsal e-posta hesabı kullandığı log incelemeri neticesinde tespit edilen 2.000 personel üzerinde gerçekleştirilecektir. Ticari bir platform vasıtasıyla personele gönderilecek oltalama e-postaları idari para cezaları, bankacılık kampanyaları, seyahat acente indirimleri ve kredi teklifleri gibi çeşitli senaryoları kapsayacaktır. Ön testte başarısız olan personel rastgele dört gruba ayrılacak ve her gruba bir eğitim formatı uygulanacaktır (afişler, bültenler, infograik posterler, video tabanlı eğitimler) ve Ara Test icra edilecektir. Ara testte başarısız olmaya devam eden personel alternatif bir eğitim türüne yönlendirilecektir. Son testin ardından, beklenen farkındalık düzeyine ulaşamayan personele yarı yapılandırılmış anketler uygulanarak iş yeri ve zaman baskısı incelenecek; yaş, cinsiyet ve departman gibi demografik değişkenlerin farkındalık seviyesi üzerindeki etkisi analiz edilecektir. Video tabanlı eğitimlerin farkındalık seviyesini artırmada daha üstün olması, format rotasyonunun ise alışkanlığa bağlı direnci kırması beklenmektedir. Sonuç olarak bu çalışma, personeli siber güvenlik alanında zafiyetli bireylerden olayları olmadan bildiren birer "insan sensörlerine" dönüştürmeyi, güvenlik ihlallerini daha gerçekleşmeden durdurmayı ve siber olay müdahale ekiplerinin iş yükünü azaltmayı hedeflemektedir.

Anahtar Kelimeler: Oltalama Simülasyonu, Siber Güvenlik Farkındalığı, Görsel Eğitim Materyalleri, Dijital Adli Bilişim Hazırlığı, Kök Neden Analizi.

PROBLEM DURUMU

Kurumlar tarafından sahip olunan ağların yönetimi ve güvenliği için kullanılan sistemler, güvenlik duvarları, e-posta sunucuları ve tehdit tespit/önleme sistemleri her ne kadar yaygınlaşmış ve gelişmiş olsa da, siber saldırgan olarak tabir edilen kötü niyetli kullanıcılar sistemlerdeki zafiyetler yerine insan zafiyetlerini hedef almaktadır. (Baki & Verma, 2022; Desolda et al., 2021). İnsan zafiyetlerini hedef alan ve sosyal mühendislik saldırıları olarak adlandırılan saldırılar, özellikle en yaygın bilinenlerinden ve karşılaşılanlarından biri olan oltalama, kurum personelinin zafiyetlerini kullanarak kurumların güvenlik sistemlerini atlatmayı hedeflemektedir. Bundan ötürü kurum personeli, kurumun bilgi sistem varlıklarının güvenliğinin alınmasında aslında düşündüklerinin aksine çok önemli bir rol oynamaktadır ve insan zafiyetlerinden kaynaklanan hatalar, kötü niyetli kişilerin sömürebileceği bir zayıf nokta oluşturmaktadır (Aburrous et al., 2010; Aldawood & Skinner, 2019). Bu zafiyetler ise, özellikle e-posta yoluyla gerçekleştirilen sosyal mühendislik saldırılarında, kurum personelinin zafiyeti sebebiyle kurum bilgi sistem varlıklarında çok büyük bir güvenlik ihlalinin başlayabileceğini göstermektedir (Berrou, 2026). Bu durum, personele yönelik zafiyet giderici yaklaşımların sadece yılda bir icra edilen teorik farkındalık seviyesini artırmaya yönelik eğitimlerle sınırlı kalmaması, bunların yanı sıra gerçek durumlara benzer simülasyonlar ve davranış analizleriyle desteklenerek farkındalık seviyesinin en üst seviyeye çıkarılması gerektiğini açıkça göstermektedir (Alsaqer et al., 2025).

Adli Bilişim ve Olaya Müdahale Ekipleri Üzerindeki İş Yükü

Oltalama saldırılarının sağlayacağı başarı kötü niyetli kişilerin sistemlere girmesine, kullanıcı oturum bilgilerini çalmasına, bilgi sistem varlıklarına yetkisiz girişler yapmasına veya fidye yazılımı gibi zararlı yazılımlar vasıtasıyla kurumların sahip olduğu bilgi ve saygınlığı yitirmesine neden olabilir. Bu kötü senaryoların gerçekleşmesi durumunda ise Siber Olaylara Müdahale Ekiplerinin (SOME) iş yükü ciddi oranda artar (A et al., 2025; Halim et al., 2025). SOME Uzmanlarının olay sonrasında sistem kayıtlarını (log kayıtları) incelemesi, bulaş durumunda kalan bilgi sistem malzemesinin kontrolünü gerçekleştirmesi, zararlı yazılım analizi yapması ve çalınan verileri tespit etmesi saatler, hatta günler bile sürebilir. Kurum personeli şüpheli e-postayı daha kendisine gelir gelmez hiçbir işlem yapmadan fark edip SOME personeline bildirirse siber saldırı büyümeden ve hatta başlamadan sonlandırılabilir. Bu da adli bilişim ekipleri tarafından siber olayın durdurulması için harcanacak zamanı azaltmış olur. Personelin şüpheli olarak algıladığı e-postayı rapor etmesi, sürecin ilk anlarında önemli olan bilginin doğru yere iletilmesini sağlayarak saldırının türünün ve kapsamının süratle belirlenmesine olanak tanımaktadır. Siber Güvenlik Farkındalığını artırıcı eğitimlerin etkisinin

yeterince kalıcı etki bırakmadığı ve çalışanların zamanla farkındalık seviyesinin düştüğü ve bu sebeple oltalama saldırılarına karşı yeniden hassas hale geldiği bilinmektedir (Thomopoulos et al., 2024). Buradan yola çıkarak, hâlihazırda uygulanan farkındalık seviyesini artırmayı hedefleyen faaliyetlerin yalnızca teorik bilgi aktarımı yerine, personelin davranışlarını kalıcı olarak değiştirecek yinelenen ve farklı formatların sürekli geliştirerek uygulandığı simülasyona dayalı farkındalık artırıcı müdahalelere ihtiyaç duyulduğu söylenebilir (Arslan, 2021). Mevcut literatürde oltalama saldırıları karşısında personelin farkındalığının kalıcı davranış değişikliğine dönüşmesi için, söz konusu farkındalık artırıcı eğitimlerin yılda bir kez değil, tekrarlı ve farklı formatlarda uygulanacak simülasyon tatbikatları ile desteklenmesine bağlı olduğunun altı çizilmektedir (Vivas et al., 2024).

Geleneksel Farkındalık Eğitimlerinin Yetersizliği ve Alışkanlık Doğurması

Birçok kurum, çalışanların farkındalığını artırmak için yılda bir kez metin ağırlıklı sunumlar yapıyor veya PDF kılavuzlar paylaşıyor. Ancak Bilişsel Yük Kuramı'na göre, çok fazla metin içeren materyaller çalışanların çalışma belleğini zorlayabilir ve öğrenilen bilgilerin uzun süre akılda kalmasını güçleştirebilir (Sweller, 1988). Benzer şekilde, aynı tür metinlerin veya e-posta uyarılarının sık sık tekrarlanması, çalışanların bu uyarılara alışmasına ve zamanla dikkatlerini daha az vermesine yol açabilir. Bunun sonucunda kullanıcılar güvenlik uyarılarını okumadan kapatabilir (Anderson et al., 2015). Ayrıca, yalnızca bir kez uygulanan eğitimlerin davranışları kalıcı biçimde değiştirmesi genellikle zordur (Kumaraguru et al., 2007). Bu nedenle, farkındalık çalışmalarının etkisini sürdürülebilir kılmak için eğitimlerin tek seferlik bilgi aktarımı yerine, simülasyon temelli ve tekrarlı biçimde yapılandırılması gerektiği savunulmaktadır (Baadel et al., 2021). Bu yaklaşımın etkinliği, tekrarlı simülasyonların çalışanların oltalama girişimlerini tanıma ve bildirme davranışını sürdürülebilir biçimde geliştirebileceğini öne süren mevcut bulgularla da desteklenmektedir (Althobaiti & Alsufyani, 2024). Bununla birlikte, tekrarlı simülasyon temelli eğitimlerin etkisinin zamanla azalabildiği ve bu nedenle hatırlatmaların belirli aralıklarla yenilenmesi gerektiği de ifade edilmektedir (Zheng & Becker, 2023).

Araştırmalarda Hâlâ Yanıtlanmamış Temel Sorular

Mevcut literatür incelendiğinde, araştırmalarda öne çıkan üç temel boşluk belirlenmiştir:

Farklı Görsel Eğitim Yöntemlerinin Karşılaştırılmaması: Araştırmalarda videolu eğitimlerin metin tabanlı eğitimlerden daha etkili olup olmadığı tartışılsa da dijital afiş, haber bülteni, infografik poster ve senaryo videosu gibi farklı yöntemleri aynı koşullarda karşılaştıran saha çalışmaları çok azdır.

Gerçek Kurumlarda Yapılan Çalışmaların ve Örneklem Büyüklüğünün Sınırlı Olması: Birçok araştırma laboratuvarlarda ya da az sayıda öğrenciyle yapılmıştır. Gerçek bir kurumun e-posta sisteminde, farklı görevlerde çalışan 2.000 kişiyi kapsayan bir araştırma ise henüz yeterince yapılmamıştır.

Sürekli Tıklayan Çalışanlarda Eğitim Biçiminin Değiştirilmemesi: Önceki araştırmalarda genellikle tek bir eğitim yöntemi kullanılmıştır. Oltalama e-postalarına tekrar tekrar tıklayan çalışanlara farklı türde eğitimler sunmanın, bu alışkanlığı kırıp kıramayacağı yeterince incelenmemiştir. Bu nedenle, tekrarlı simülasyonların ve farklı eğitim formatlarının birlikte uygulandığı uzun vadeli saha çalışmalarına duyulan ihtiyaç, bu çalışmanın temel motivasyonunu oluşturmaktadır.

AMAÇ VE HEDEFLER

Yapacağımız araştırmanın temel amacı, bir kamu kurumunda kurumsal e-posta sahibi ve aktif olarak e-postasının kullandığı sistem log kayıtları ile tespit edilen 2.000 personelin farklı görsel eğitim yöntemlerinin (dijital afiş, haber bülteni, infografik poster ve senaryo videosu) oltalama e-postalarına karşı farkındalık seviyelerini nasıl etkilediğini incelemektir. Araştırmada, oltalama e-postaları karşısında farkındalık seviyesinde iyileşme sağlanamayan ve düzenli olarak oltalama e-postaları karşısında başarısız olan personele farklı eğitim yöntemleri uygulamanın faydalı olup olmadığı değerlendirilecek ve hangi eğitim yönteminin daha başarılı olduğu kıyaslanacaktır. Bu doğrultuda araştırma sonucunda, elde edilecek bulgular kurumsal güvenlik

politikalarının belirlenmesine ve insan zafiyetlerinden kaynaklanan bilgi güvenliği risklerinin minimize edilmesine yönelik kurumlar tarafından uygulanabilir çözümler sunmak hedeflenmektedir.

Araştırma Hipotezleri

H1: Senaryo bazlı video eğitimi alan grup, durağan görsel materyalleri (afiş, bülten, poster) alan gruplara kıyasla oltalama simülasyonlarındaki tıklama oranlarında istatistiksel olarak anlamlı düzeyde daha yüksek bir düşüş sergileyecektir.

H2: Ön ve ara testlerde oltalama e-postalarına tıklamaya devam eden çalışanlara (repeat clickers) farklı bir formatta eğitim materyali sunulması (format rotasyonu), aynı formatın tekrarlanmasına kıyasla kanıksama direncini kırarak tıklama oranlarını anlamlı derecede azaltacaktır.

H3: H3: Çalışanların yaşı, cinsiyeti ve görev yaptığı departman (Teknik/BT, İdari, Saha vb.), verilen görsel eğitimin ne kadar etkili bulunduğunu ve oltalama e-postalarına tıklama davranışını etkileyebilir (Morić et al., 2025).

H4: Farkındalığı yeterince gelişmeyen çalışanların oltalama e-postalarına tıklamasında iş yerindeki stres, zihinsel yükün fazla olması ve zaman darlığı etkili olabilir (Vishwanath et al., 2011).

Hedeflenen Kurumsal ve Operasyonel Çıktılar

Araştırmanın uygulamaya dönük amacı, kurumsal e-posta kullanan çalışanların oltalama e-postalarını fark edip hemen bildirmelerini sağlamaktır. Böylece olası siber saldırılara erken müdahale edilebilir; olayları incelemek için harcanan emek ve kurumun karşı karşıya olduğu risk azaltılabilir.

KAVRAMSAL ÇERÇEVE VE LİTERATÜR

Araştırma, insanların bilgiyi nasıl öğrendiğini ve işlediğini, görsel unsurlara nasıl dikkat ettiğini ve alışkanlıklarını nasıl değiştirebildiğini açıklayan kuramlara dayanmaktadır.

Öğrenirken Zihni Yormamak ve Görsel-İşitsel İçeriklerden Yararlanmak

Sweller'in (1988) Bilişsel Yük Kuramı'na göre, insan zihni aynı anda sınırlı miktarda bilgiyi işleyebilir. Bu nedenle, siber güvenlik eğitimlerinde uzun ve karmaşık metinler ile teknik terimler kullanmak, çalışanların konuyu anlamasını ve öğrendiklerini hatırlamasını zorlaştırabilir. Mayer'in (2002) çoklu ortam öğrenme yaklaşımına göre, bilgi hem görsellerle hem de sözcüklerle anlatıldığında daha kolay öğrenilebilir. Bu yüzden görsel ve videolu eğitimler; şüpheli bağlantılar, sahte logolar ve aciliyet yaratan ifadeler gibi oltalama işaretlerinin daha kolay fark edilmesine yardımcı olabilir.

Bilgiyi İşleme, İki Farklı Düşünme Biçimi ve Alışkanlıkları Kırma

Kahneman'ın (2011) yaklaşımına ve Evans ile Stanovich'in İkili Süreç Kuramı'na göre insanlar karar verirken iki farklı düşünme biçimini kullanır. Sistem 1 hızlı ve otomatik çalışır; Sistem 2 ise daha yavaş, dikkatli ve düşünerek karar vermeyi sağlar. Oltalama saldırıları, korku ve merak gibi duygulardan ya da otorite izleniminden yararlanarak kişilerin hızlı ve düşünmeden tepki vermesini hedefler (Vishwanath et al., 2011). Çalışanlar e-postalarını aceleyle kontrol ederken hızlı düşünme biçimi öne çıkabilir ve bu da şüpheli bağlantılara düşünmeden tıklama ihtimalini artırabilir. Aynı tür uyarılar sık sık tekrarlandığında ise insanlar bunlara alışıp daha az dikkat edebilir; böylece durup düşünmek ve dikkatli değerlendirme yapmak zorlaşabilir (Anderson et al., 2015). Bu çalışmada önerilen "Format Rotasyonu" stratejisi, eğitim materyallerinin biçimini değiştirerek çalışanların alışkanlıklarını bozmayı amaçlar. Böylece çalışanların otomatik tepkiler yerine daha dikkatli düşünüp karar vermeleri teşvik edilir.

E-postalardaki Görsel İpuçlarına Dikkat ve Düzenli Oltalama Simülasyonları Üzerine Araştırmalar

Göz izleme araştırmaları, insanların e-postaları okurken güvenlik bilgilerine (adres çubuğu, SSL sertifikası ve gönderenin tam adresi gibi) çok kısa süre baktığını gösteriyor. Dikkatlerini daha çok e-postanın içeriğine ve kurumsal logolara veriyorlar (Alsharnouby et al., 2015; Baki & Verma, 2022; Baltuttis & Teubner, 2024). Bu nedenle, şüpheli e-postalardaki görsel işaretleri tanımayı öğretmek önemlidir. Araştırmalar ayrıca, tek seferlik

teorik eğitimler yerine gerçek e-posta ortamında düzenli oltalama denemeleri yapmanın ve kullanıcı hata yaptığında hemen geri bildirim vermenin farkındalığı artırabildiğini gösteriyor (Kumaraguru et al., 2007; Morić et al., 2025).

YÖNTEM

Bu bölümde araştırmanın nasıl yürütüleceği; kimlerin çalışmaya katılacağı, oltalama senaryolarının nasıl hazırlanacağı, eğitimlerin ve veri toplama sürecinin nasıl uygulanacağı ve sonuçların nasıl değerlendirileceği açıklanmaktadır.

Araştırma Modeli

Çalışmada hem sayısal veriler toplanacak hem de katılımcıların deneyimleri incelenecektir. Önce katılımcılara bir test uygulanacak, ardından görsel eğitim verilecek ve ara test yapılacaktır. Daha sonra bazı katılımcılara farklı bir biçimde eğitim sunulacak ve son test uygulanacaktır. Son testte farkındalık düzeyi yeterince artmamış katılımcılarla, deneyimlerini ve oltalama e-postalarına tıklama nedenlerini anlamak amacıyla yarı yapılandırılmış anketler yapılacaktır. Bu görüşmelerde elde edilecek nitel veriler, sayısal bulguların yorumlanmasında ve katılımcıların tıklama davranışının arkasındaki motivasyonların anlaşılmasında tamamlayıcı bir rol üstlenecektir.

Örneklem ve Çalışma Grubu

Araştırmamızın örneklem grubunu, bir kamu kurumunda kurumsal e-posta adresini aktif olarak kullanan 2.000 çalışan oluşturacaktır. Katılımcı olarak belirlenecek personel yaş, cinsiyet ve görev yaptığı birim (Teknik, İdari vb.) yönünden değerlendirildiğinde farklı özelliklere sahip olacaktır.

Simülasyon Platformu ve Oltalama Senaryoları

Oltalama simülasyonları, kurum içinde mevcutta kullanılan ticari bir yazılım olan siber farkındalık platformu kullanılarak, örneklem grubunu oluşturan kurum personeline önceden haber vermeden gönderilecektir. E-postalar dört farklı konuyu içerecektir:

Bankacılık ve Finans: Uygun faizle kredi kullanımı kampanyası, Taksitli nakit avans kampanyası.

e-Devlet / İdari Bildirimler: Tescil plakasına yazılan trafik cezası tebligatı, Hızlı Geçiş Sistemi İhlal Bildirimi.

E-Ticaret / Kargo ve Seyahat: Alışveriş indirim kampanyaları, dönemsel olarak kampanyalı uçak bileti.

İK ve Kurumsal İletişim: Kuruma özel Telekom vb. kampanyalar, maaş zam beklentisi anketi.

Deneysel İşlem Adımları ve Format Rotasyonu

Deney aşaması aşağıdaki 4 başlıkta uygulanacaktır:

1. Aşama (Ön Test): Ön test aşamanda örneklem grubunda yer alan 2.000 personele, habersiz olarak ilk tur oltalama e-postaları gönderilir. E-posta karşısında beklenmeyen davranışı sergileyen ve farkındalık seviyesi yetersiz olan personel tespit edilecek.

2. Aşama (1. Eğitim Müdahalesi ve Ara Test): Ön testte başarısız olan personel, rastgele dört deney grubuna homojen olarak atanacak:

Grup 1: Dijital Afiş (e-posta/intranet afişi)

Grup 2: Haber Bülteni (interaktif metin-görsel bülten)

Grup 3: İnfografik Poster (dijital/basılı infografik)

Grup 4: Senaryo Videosu (kısa animasyon/gerçek senaryo videosu)

3. Aşama (2. Eğitim Müdahalesi / Format Rotasyonu ve Son Test): Ara testte oltalama e-postası karşısında tekrar başarısız olan personele, ilk eğitimden farklı bir türde eğitim materyali sunulacak ve böylece eğitim türü değiştirilerek format rotasyonu uygulanacaktır.

4. Aşama (Kök Neden Analizi- Yarı Yapılandırılmış Anketler): Son testte de oltalama e-postalarına karşı başarısız olan personele, başarısızlık nedenlerini tespit etmek için yarı yapılandırılmış anketler uygulanacaktır. Yapılacak olan anketlerde zaman baskısı, iş yükü, duygu durumu ve yaş ve cinsiyet gibi demografik değişkenlerin etkileri araştırılacaktır.

Aşama	Uygulama (Simülasyon / Müdahale)	Hedef Kitle & İşlem
Faz 1: Ön Test	1. Oltalama Simülasyonu	Temel zafiyet tespiti
Faz 2: Format Karşılaştırması	4 Gruba Ayrı Eğitim → 2. Simülasyon (Ara Test)	Afiş, Bülten, İnfografik Poster, Video kıyası
Faz 3: Format Rotasyonu	Zafiyeti Sürenlere Farklı Format → 3. Simülasyon (Son Test)	Direnç kırma ve format değiştirme etkisi
Faz 4: Kök Neden Analizi	Yarı Yapılandırılmış Anketler	Kronik tıklayanlarla derinlemesine analiz

Tablo-1: Yöntem Aşamaları

BEKLENEN ÇIKTILAR VE KATKILAR

Araştırmamızın, siber güvenlik ve kurumsal güvenlik yönetimine ve adli bilişim süreçlerine dikkate değer katkılar sağlaması beklenmektedir. Kurumların oltalama farkındalık seviyesini artırmaya yönelik olarak icra edilen eğitim programlarını, geniş bir örneklem gruptan elde edilen veriye dayanarak tasarlamalarına yön vereceği ve eğitim biçimlerinin etkinliğine anlamlı sonuçlar ortaya koyması hedeflenmektedir.

Akademik ve Teorik Katkılar

Görsel Eğitim Türlerinin Kıyaslanması: Literatürde tespit edilen önemli bir boşluğu doldurarak afiş, bülten, infografik ve video eğitim metotlarının oltalama e-postalarının tespiti konusunda farkındalık seviyesinin artırılması üzerindeki etkilerini büyük bir örneklem grubundan elde edilecek veriler vasıtasıyla kanıtlayacaktır.

Format Rotasyonu Modeli: Yapacağımız çalışmada, oltalama e-postalarına devamlı olarak maruz kalan personelde oluşabilecek alışkanlığı azaltmak maksadıyla farklı eğitim türlerini sırayla kullanmanın yaratacağı etki değerlendirilecektir.

Kurumsal Güvenliğin Güçlendirilmesinde Personelin Rolü

İcra edilecek eğitimlerden sonra kurum personelinin oltalama saldırıları karşısındaki farkındalık seviyesinin belirgin oranda artması, şüpheli e-postaları bildirme oranlarının önemli ölçüde artması beklenmektedir. Bu sayede personelin siber saldırganlar için hedef olmaktan ziyade, tehditleri fark edip ve SOME Personeline raporlayan aktif insan tespit sistemlerine dönüşmesi hedeflenmektedir.

Dijital Adli Bilişim ve Olay Müdahale İş Yükünün Azaltılması

Oltalama e-postalarının kurumlar için ciddi bir güvenlik problemine dönüşmeden engellenmesi, kurumun SOME personelinin iş yükünün artmasını engelleyecektir. (Halim et al., 2025). Böylece bu ekipler zamanlarını daha ciddi ve öncelikli tehditlere ayırabilecektir.

Pratik Politika Önerileri

Kurumların siber güvenlik yöneticilerine ve eğitim ekiplerine, tüm personele aynı tekdüze metin eğitimini uygulamak yerine çalışanların departmanları, demografik yapıları ve geçmiş davranışlarını dikkate alan; farklı türde görsel eğitim materyallerinin dönüşümlü kullanıldığı kişiselleştirilmiş eğitim programları hazırlamaya yönelik öneriler sunulacaktır.

KAYNAKÇA

A, J. S., Venkatesh, K., Prabhu, N. M., & Mohideen, A. B. (2025). Cybercrime Investigation: Forensic Approaches to Social Phish Attacks. International Conference on Computational Robotics, Testing and Engineering Evaluation (ICCRTEE), 1–6. https://doi.org/10.1109/iccrtee64519.2025.11052898

Aburrous, M. R., Hossain, M. A., Dahal, K. P., & Thabtah, F. (2010). Experimental Case Studies for Investigating E-Banking Phishing Techniques and Attack Strategies. Cognitive Computation, 2(3), 242–253. https://doi.org/10.1007/s12559-010-9042-7

Aldawood, H., & Skinner, G. (2019). Reviewing Cyber Security Social Engineering Training and Awareness Programs—Pitfalls and Ongoing Issues. Future Internet, 11(3), 73. https://doi.org/10.3390/fi11030073

Alsaqer, A., Almajed, H., Alarfaj, K. A., & Frikha, M. (2025). Phishing Simulation as a Proactive Defense: A Customizable Platform for Training and Behavioral Analysis. International Journal of Advanced Computer Science and Applications, 16(6). https://doi.org/10.14569/ijacsa.2025.01606104

Alsharnouby, M., Alaca, F., & Chiasson, S. (2015). Why phishing still works: User strategies for combating phishing attacks. International Journal of Human-Computer Studies, 82, 69–82. https://doi.org/10.1016/j.ijhcs.2015.05.005

Althobaiti, K., & Alsufyani, N. (2024). A review of organization-oriented phishing research. PeerJ Computer Science, 10. https://doi.org/10.7717/peerj-cs.2487

Anderson, B. B., Kirwan, C. B., Jenkins, J. L., Eargle, D., Howard, S., & Vance, A. (2015). How Polymorphic Warnings Reduce Habituation in the Brain—Insights from an fMRI Study. ScholarsArchive (Brigham Young University). https://scholarsarchive.byu.edu/facpub/9306

Arslan, Y. (2021). Oltalama Saldırıları Farkındalık Tatbikatı Örneği. Düzce Üniversitesi Bilim ve Teknoloji Dergisi, 9(3), 348–358. https://doi.org/10.29130/dubited.832862

Baadel, S., Thabtah, F., & Lu, J. (2021). Cybersecurity Awareness: A Critical Analysis of Education and Law Enforcement Methods. Informatica, 45(3). https://doi.org/10.31449/inf.v45i3.3328

Baki, S., & Verma, R. M. (2022). Sixteen Years of Phishing User Studies: What Have We Learned? IEEE Transactions on Dependable and Secure Computing, 20(2), 1200–1212. https://doi.org/10.1109/tdsc.2022.3151103

Baltuttis, D., & Teubner, T. (2024). Effects of visual risk indicators on phishing detection behavior: An eye-tracking experiment. Computers & Security, 144, 103940. https://doi.org/10.1016/j.cose.2024.103940

Berrou, D. (2026). Reducing Phishing Susceptibility among University Students: A Pre–Post Cybersecurity Awareness Intervention. International Journal of Scientific Research in Computer Science Engineering and Information Technology, 12(2), 38–48. https://doi.org/10.32628/cseit26121325

Desolda, G., Ferro, L. S., Marrella, A., Catarci, T., & Costabile, M. F. (2021). Human Factors in Phishing Attacks: A Systematic Literature Review. ACM Computing Surveys, 54(8), 1–35. https://doi.org/10.1145/3469886

Halim, M. Y., Raharjo, T., Syahputra, R. R., & Ramadhani, E. (2025). Simulated Phishing Attack and Forensic Analysis Using the D4I Framework: A Case Study on Kredivo. Journal of Technology and Informatics (JoTI), 7(2), 121–133. https://doi.org/10.37802/joti.v7i2.1086

Kumaraguru, P., Rhee, Y. W., Acquisti, A., Cranor, L. F., Hong, J., & Nunge, E. (2007). Protecting people from phishing. CHI Conference on Human Factors in Computing Systems, 905–914. https://doi.org/10.1145/1240624.1240760

Morić, Z., Dakić, V., Plećaš, M., & Biškupić, I. O. (2025). Evaluating End-User Defensive Approaches Against Phishing Using Education and Simulated Attacks in a Croatian University. Journal of Cybersecurity and Privacy, 5(3), 38. https://doi.org/10.3390/jcp5030038

Sweller, J. (1988). Cognitive Load During Problem Solving: Effects on Learning. Cognitive Science, 12(2), 257–285. https://doi.org/10.1016/0364-0213(88)90023-7

Thomopoulos, G. A., Lyras, D. P., & Fidas, C. (2024). A systematic review and research challenges on phishing cyberattacks from an electroencephalography and gaze-based perspective. Personal and Ubiquitous Computing, 28, 449–470. https://doi.org/10.1007/s00779-024-01794-9

Vishwanath, A., Herath, T. C., Chen, R., Wang, J., & Rao, H. R. (2011). Why do people get phished? Testing individual differences in phishing vulnerability within an integrated, information processing model. Decision Support Systems, 51(3), 576–586. https://doi.org/10.1016/j.dss.2011.03.002

Vivas, D. E. D., Pena, W. Y. G., Botero, S. P. C., & Rojas, A. E. (2024). A Controlled Phishing Attack in a University Community: A Case Study. Journal of Internet Services and Information Security, 14(3), 98–110. https://doi.org/10.58346/jisis.2024.i2.007

Zheng, S. Y., & Becker, I. (2023). Phishing to improve detection. European Symposium on Usable Security (EuroUSEC), 334–343. https://doi.org/10.1145/3617072.3617121

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

TOURISM GUIDANCE STUDENTS' EXPERIENCES USING NOTEBOOKLM: ADVANTAGES, LIMITATIONS, AND INTENTIONS FOR FUTURE USE

Emre YAŞAR
Bilal Nadir ALKAN
Res. Asst. Ph.D., 0000-0003-1573-0930, Isparta University of Applied Sciences, Faculty of Tourism, Department of Tourism Guidance, Isparta, Türkiye.
Ph.D., 0000-0002-4330-3613, Hatay, Türkiye.

Abstract

The aim of this study is to examine the experiences of tourism guidance students regarding the use of NotebookLM in the assignment preparation process, their perceptions of its advantages and disadvantages, and their intentions for future use. The research was conducted using a qualitative approach, involving interviews with 29 students. Participants were asked four open-ended questions concerning their experience using NotebookLM, the advantages provided by the tool, the disadvantages encountered, and their intentions to use it in future tourism courses. The data obtained were analyzed using a thematic analysis approach. The findings indicate that the students' experiences with NotebookLM were generally positive. Key advantages identified included the tool's ability to facilitate the assignment and presentation preparation process, save time, enable rapid access to information and resources, and provide support for text, outlines, and visuals during presentation creation. Conversely, primary disadvantages included daily usage limits, long processing times, technical errors, the generation of incorrect or incomplete information, and the inability to sufficiently customize the generated presentations. While all participants expressed a positive attitude toward using NotebookLM in future tourism courses, some conditioned this intention on the resolution of technical issues and further development of the application. The results demonstrate that NotebookLM is embraced as a tool that enhances efficiency and accessibility in academic tasks, though its technical limitations must also be taken into account. Overall, the findings clearly indicate that NotebookLM can be used as a supportive learning tool in tourism education, but that its use requires awareness and supervision.

Keywords: Artificial intelligence, NotebookLM, Tourism guiding, Digitalization.

Introduction

Developments in the field of artificial intelligence (AI) affect many aspects of social life. These impacts vary according to the needs of individuals and businesses; for instance, the way a student utilizes AI differs from the purpose for which an academic might use it (Garzón et al., 2025). Similarly, the effects on businesses can vary depending on sectoral characteristics. The growing number of AI tools and the diversification of their functions have made this variation more apparent. One area significantly impacted by AI is education (Singh et al., 2025).

In the realm of education, the use of AI tools particularly by students has become a subject of debate. Some studies suggest that the use of AI may weaken students' cognitive evaluation processes (Kamalov et al., 2023; Zhu et al., 2025). Other potential risks include becoming passive during the research process, a diminished mastery of the subject matter, and the acquisition of incorrect information (Ivanov, 2023; Pareskeva, 2026). Conversely, it is also noted that AI tools accelerate access to information and diversify the learning process (El Gourari et al., 2024; Săseanu et al., 2024). Consequently, there are varying assessments in the literature regarding the impact of AI on students.

In recent years, the effects of AI on tourism guidance students and tourism guidance education have also begun to be explored (Aktaş, 2024; Alan, 2026; Taşkın & Karaş, 2026). Furthermore, the potential impacts of AI on the profession of tourist guiding have been addressed in various studies (Ceylan, 2025; Şahin, 2025). A significant portion of existing research discusses the effects of AI on education and the profession in terms of

possibilities. In contrast, there appears to be limited evaluation based on the direct, hands-on experiences of students.

The primary objective of this study is to examine the impact of using NotebookLM an AI tool on students of tourist guiding. In this context, the study evaluates students' experiences with NotebookLM, their perceptions of its advantages and disadvantages, and their intentions regarding its future use. Thus, the aim is to reveal how tourist guiding students evaluate an AI-powered academic tool based on their own direct usage experiences.

The Impacts of Artificial Intelligence in Education

AI enables personalized learning by tailoring educational content to the individual needs of students (Plooy et al., 2024). Adaptive learning technologies can identify students' strengths and weaknesses, while also analyzing their learning paces and preferences. Based on the data obtained, lesson plans and resources specific to each student can be created, allowing them to access content that aligns with their unique learning characteristics (Gedik, 2025).

A key feature that distinguishes AI from other educational technologies is its ability to shape pedagogical processes according to individual requirements. These systems facilitate interactive communication and provide real-time feedback (Aydın, 2021). Furthermore, they can model students' cognitive development and learning processes. By analyzing past performance data, a student's current level of knowledge can be assessed, and subsequent learning steps can be determined. These capabilities contribute to the creation of a data-driven learning environment through AI (Vatansever et al., 2025).

The contributions of AIto the field of education are evident in student-centered practices such as individualized instruction, dialogue-based learning systems, discovery-based learning, and educational data mining (Holmes et al., 2019). Other applications that can be integrated into learning processes include the analysis of academic texts, AI-powered chatbots, and child-robot interaction (Akgun & Greenhow, 2022). The scope of artificial intelligence's application is not limited solely to learning processes. This technology is also utilized in the administrative processes of educational institutions. Areas of application include the preparation of course schedules, the organization of examination processes, the development of cybersecurity infrastructure, the management of campus facilities, and the implementation of security measures (Gürbüz et al., 2026).

Although AI offers significant advantages in educational processes, it also brings forth various ethical concerns. Foremost among these are data privacy and the protection of personal information (Uğurlu & Usta, 2025). For AI systems to function effectively, they require comprehensive data regarding students' academic backgrounds, development, and individual tendencies. The collection and processing of such sensitive data can pose substantial risks to privacy (Nguyen et al., 2023).

AI is driving a major transformation in educational systems by providing personalized learning paths, automated assessment and evaluation practices, and data-driven analyses (Huang, 2023). At the same time, the collection and processing of student data can increase the risk of privacy violations. The use of data for purposes other than those originally intended is also considered a significant ethical issue. Furthermore, there is a possibility that AI systems used in education may reproduce biases present in the datasets upon which they are trained. This can lead to discriminatory or unfair outcomes for certain groups of students (Gedik, 2025).

The uncontrolled use of AI in education carries the risk that the learning process could shift toward a structure focused primarily on the transmission of information and rote memorization. One of the fundamental goals of education is to cultivate individuals who are conscious, responsible, and embrace universal values (Popenici & Kerr, 2017). Therefore, it is important to utilize AI as a supportive tool rather than placing it at the center of the educational process. Maintaining communication between teachers and students is also considered an essential requirement in this process. AI applications integrated into the educational system should not diminish human interaction; instead, they should support the learning process in a complementary manner.

Just as AI transforms daily life and the professional world, it also brings about significant changes in educational processes. Its data- and information-driven structure allows for the continuous evolution of this technology a characteristic that distinguishes AI from traditional educational tools. Rather than offering the same learning path to all students, AI-powered systems can create learning processes tailored to individual

needs. This enables the development of more flexible educational environments that align with students' own paces and specific learning requirements (Alanoğlu & Karabatak, 2020).

The use of AI in education offers various advantages for students, including the ability to track learning processes, support for distance education, and continuous access to educational content. Conversely, potential disadvantages include students experiencing difficulties in maintaining motivation and a reduction in teacher-student interaction. For teachers, the use of AI provides significant benefits, such as facilitating student management, monitoring performance, and analyzing learning processes. On the other hand, the increased professional competencies expected of teachers, combined with concerns regarding the future of the teaching profession due to artificial intelligence, can lead to negative outcomes in terms of motivation (Güleryüz & Özcan, 2023).

Materials and Methods

The primary objective of this study is to examine the effects of using NotebookLM an AI tool on tourism guidance students. Given the study's purpose, a qualitative research approach was adopted, specifically employing semi-structured interviews. Since interview techniques allow for the exploration of participants' feelings and thoughts regarding a particular subject, this method was deemed appropriate for the study.

The study population consists of students enrolled in tourism guidance programs; however, due to constraints related to time and accessibility, a specific sample was selected. The sample comprises students from the Tourism Guidance Department at Isparta University of Applied Sciences. Prior to the study, students were assigned topics for presentations and asked to prepare them using NotebookLM. Subsequently, interviews were conducted with 29 students. These interviews took place in person between May and June 2026. Ethical approval for the study was granted by the Scientific Research and Publication Ethics Committee of Isparta University of Applied Sciences (decision no. 10, dated May 12, 2026).

The demographic characteristics of the participants are presented in Table 1. Of the participants, 19 are female and 10 are male; they range in age from 18 to 23, and all are currently pursuing an undergraduate degree.

Table 1. Demographic characteristics of the participants

Participant	Gender	Age
P1	Male	23
P2	Female	22
P3	Female	20
P4	Female	20
P5	Female	22
P6	Female	20
P7	Female	18
P8	Male	20
P9	Female	21
P10	Female	21
P11	Male	20
P12	Female	21
P13	Male	21
P14	Female	21
P15	Male	19
P16	Female	21
P17	Female	20
P18	Male	21
P19	Female	21
P20	Male	22
P21	Female	21
P22	Male	21
P23	Male	22
P24	Female	19
P25	Female	22

P26	Female	23
P27	Female	20
P28	Male	19
P29	Female	22

Prior to the interviews, students prepared presentations using NotebookLM, after which the interviews were conducted. The interview form included four questions designed to assess the students' experiences. Additionally, questions regarding age, gender, and educational background were included to capture demographic information. The interview questions were as follows:

1. What was your experience like using NotebookLM during the process of preparing your assignment?
2. What are the advantages that NotebookLM provides you when preparing assignments?
3. What are the disadvantages of using NotebookLM when preparing assignments?
4. Would you like to use NotebookLM in future courses related to the field of tourism?

The interviews lasted an average of 13 minutes. They were recorded, and the recordings were subsequently transcribed. The interview notes were analyzed using the thematic analysis.

Findings and Discussion

Participants were first asked, *"What was your experience like using NotebookLM during the process of preparing your assignments?"* Their experiences were categorized into two main themes: positive and negative user experiences. Within the scope of positive experiences, factors such as ease of use, practicality, time savings, access to information and resources, support for academic work, and general satisfaction were highlighted. A large proportion of participants noted that NotebookLM simplified the process of preparing assignments and presentations, reduced the time spent on their work, and facilitated access to resources. Conversely, negative experiences were associated with usage limitations, technical issues, the inability to generate desired outputs, complexity, and the need for repeated operations. Some participants indicated that these limitations extended the time required for their tasks or made it difficult to achieve the expected results. Overall, while NotebookLM appears to offer a largely positive user experience for students, technical and functional limitations have, for some participants, detracted from this experience.

Table 2. User experience

Main theme	Subthemes	Participant views
Positive user experience	Ease and practicality; time savings and speed; access to information and resources; support for academic production; satisfaction; inclination toward reuse; positive perception of artificial intelligence	K3: "It was a good experience; it made my work much easier—I liked it." K8: "It was a good experience; it saved me time." K9: "By simplifying my work, it enabled me to prepare a more efficient presentation in less time." K21: "It was very useful for creating a bibliography and easily accessing reliable sources." K23: "It helped with finding sources and preparing an outline; I was satisfied with the experience."
Negative user experience	Usage limitations; technical issues; inability to produce output; complexity; need for repetition; requirement for further development; mixed experience	K16: "Since I only had 3 attempts, I waited for my usage allowance to reset, then completed it over the course of a few days." K25: "It cancelled every time I tried. It wasn't a very good experience for me." K26: "It was a bit complicated. To get the result I wanted, I had to start over and set up the note 9 separate times." K29: "I struggled a bit at first... plus,

	there's a limit for the slide presentation, which makes it difficult."

Secondly, participants were asked, *"What are the advantages that NotebookLM provides you when preparing assignments?"* The participants' perspectives on the benefits of NotebookLM during the assignment preparation process were categorized into four themes: time savings and speed, easier access to information and resources, simplified creation of presentations and assignments, and the facilitation of the learning and study process. Among the points raised by the participants, time savings emerged as the most prominent advantage. By shortening the time spent researching sources, consolidating information from various materials, and enabling rapid access to data, NotebookLM has streamlined students' research processes. Furthermore, the tool's functions such as assisting with the preparation of presentations, drafting content, generating headings and text, and providing visuals have contributed to a more practical approach to completing academic tasks. Some participants also noted that the tool helped them identify details they had previously overlooked, acquire new information, and manage their study process more comfortably.

Table 3. Advantages of using NotebookLM

Main theme	**Subthemes**	**Participant views**
Time savings and speed	Shorter preparation time; accelerated research; reduced loss of time; obtaining results in a short period	K3: "It has significantly shortened my preparation time and made creating slides much simpler." K5: "I've saved time; I no longer need to search through various different websites." K19: "The biggest advantage is the time saved." K26: "The fact that it handles resource research—which would take me hours, or perhaps even days, to do on my own—in just a few minutes."
Easier access to information and resources	Finding resources; accessing various sources; quick retrieval of information; consolidating information in one place; support for bibliographies	K7: "Faster and more practical access to information." K11: "It provided sources quickly and answered my questions in a way that was relevant to the topic." K14: "Having everything in one place, rather than having to gather information from various different websites, is an advantage." K17: "It allowed me to find all the information in one place without needing to conduct extensive research." K21:"Accurate literature/source searching..."
Simplified creation of presentations and assignments	Preparing slides; creating outlines; developing presentation text and titles; providing visual support; offering ideas	K9: "Being able to prepare more effective presentations in less time." K16: "It created a well-crafted set of slides in the language I requested, in response to my prompt, and in a very short amount of time." K21: "The advantage of easily generating presentation text and headings, along with the ability to create presentations quickly using more engaging visuals."

		K23: "A highly advantageous tool for tasks such as finding resources, drafting outlines, and generating ideas."
Facilitation of the learning and working process	Facilitating research; practicality; convenience; accessibility; noticing new details; supporting learning	K8: "It facilitated my research and made finding information easier." K12: "It enabled me to make good use of my time and notice details I hadn't seen before." K15: "Ease and convenience." K24: "Accessibility, ease of learning." K29: "Learning valuable information and being able to prepare the presentation with ease."

Thirdly, participants were asked, *"What are the disadvantages of using NotebookLM when preparing assignments?"* The disadvantages perceived by participants were categorized into several themes: usage limitations and loss of time; issues regarding the accuracy and adequacy of content; constraints on control and customization; technical and interactive difficulties; and over-reliance on artificial intelligence, leading to a diminished mastery of the subject matter. Some participants, however, stated that they did not encounter any significant disadvantages while using NotebookLM. It was observed that daily usage limits and long loading times could delay the workflow; the tool could occasionally generate inaccurate, incomplete, or unnecessary content; and users lacked sufficient control over the outputs produced. Furthermore, one participant noted that relying solely on information provided by the AI reduced their grasp of the subject matter a limitation that warrants consideration regarding the learning process in AI-assisted assignment preparation.

Table 4. Disadvantages of using NotebookLM

Main theme	**Subthemes**	**Participant views**
Usage limitations and loss of time	Daily usage limits; restricted usage rights; long loading times; time-consuming presentation creation	K4: "Daily usage limit." K7: "It takes a long time to prepare slides." K16: "Since the usage allowance is limited to once every 24 hours, what could have been done in a single day ended up taking me several days." K17: "Preparing the presentation took a very long time." K27: "Loading time is very long."
Issues regarding the accuracy and adequacy of content	Generating incorrect information; providing unnecessary information; presenting incomplete information; failing to convey the requested information accurately; inability to answer certain questions	K2: "Sometimes making mistakes in the slides." K5: "Sometimes providing unnecessary information on completely different topics." K10: "Leaving out parts of certain topics." K18: "Not conveying all the information I'm looking for, though it wasn't too bad." K24: "Sometimes I can't find the answers to everything I'm looking for."
Constraints on control and customization	Difficulty in modifying slides; limited customization options; failure to generate the desired number of slides; inability to specify presentation details	K3: "It is difficult to make changes when there is something I don't like in a slide." K20: "I couldn't modify the slides much; I was forced to include slides I didn't

		want." K22: "The only drawback was that it didn't generate as many slides as I had hoped for." K26: "It doesn't allow me to decide on the specific details of the presentation or to present them in the way I consider important."
Technical and interactive difficulties	Failure to understand commands; encountering errors; system malfunctions; the need to restart; overall complexity	K12: "Sometimes it fails to fully grasp the commands I give." K21: "Sometimes it throws an error while working, forcing me to start over." K25: "It doesn't work." K29: "It imposes limitations on presentation slides and is somewhat complex."
Over-reliance on artificial intelligence and a decline in subject mastery	Using AI-generated information without verification; a lack of sufficient subject-matter expertise	K28: "I couldn't fully grasp the subject because I relied solely on the information provided by the artificial intelligence."
Lack of awareness regarding potential disadvantages	Perceiving no disadvantages; experiencing no issues	K1: "Virtually none." K6: "I didn't see any disadvantages." K8: "There weren't any." K14: "I don't think there were any." K15: "There are no disadvantages." K23: "I don't believe it has any disadvantages."

Finally, participants were asked, *"Would you like to use NotebookLM in future courses related to the field of tourism?"* Their intentions regarding the future use of NotebookLM in such courses were categorized into two main themes: a direct willingness to use it and a conditional willingness to use it. A large majority of the participants expressed a desire to use NotebookLM in the future. This interest is primarily driven by factors such as time savings, ease of use, rapid access to information and resources, support in preparing presentations, and the ability to incorporate visuals. Some participants also noted that the tool helps them acquire new knowledge and gain a better grasp of the subject matter. Meanwhile, two participants conditioned their intention to use the tool on further development of the application and the resolution of existing technical issues. Overall, it was determined that students have a strong intention to use NotebookLM in the future, although technical problems may influence the decision to use it for some participants.

Table 5. Intention to use NotebookLM in the future

Main theme	**Subthemes**	**Participant views**
Request for use	Utility; time-saving; ease of use; quick access to information; access to resources; support for preparing presentations; visual support; acquiring new knowledge; mastery of a subject; practicality	P1: "Yes, it's useful and serves my needs." P4: "I would. It made things easier when I was giving a presentation, and I was able to quickly find information that would have otherwise taken me hours to track down." P6: "It provides convenience in every respect and saves a great deal of time." P14: "I can gather all the information I need from a single application." P27: "Yes, because it does a good job with slide design."

Conditional request for use	Resolving technical issues; improving the application; reducing existing limitations	P19: "Definitely—provided that this version is developed further." P25: "If the error I encountered is fixed, I would certainly use it."

Conclusion and Recommendations

The research findings indicate that the experiences of tourism guidance students with NotebookLM are generally positive. Participants particularly highlighted time savings, ease of use, and the ability to complete academic tasks more quickly. This result aligns with studies suggesting that AI-powered systems can support the learning process by catering to individual needs. Plooy et al. (2024) note that AI contributes to personalized learning, while Gedik (2025) points out that such systems can provide content and resources tailored to students' specific learning characteristics. The practicality and time efficiency observed in the use of NotebookLM can be understood within this context. The fact that the majority of students found the tool useful suggests that AI is perceived not merely as a technology for providing information, but as a learning aid that facilitates the completion of academic tasks. This finding reinforces the perspective that AI can play a supportive role in education.

Another significant finding of the study is the enhanced accessibility to information and resources. Participants stated that being able to access various sources through a single platform streamlined the research process. Functions such as generating bibliographies, preparing drafts, and creating presentations were also identified as key advantages. Holmes et al. (2019) state that AI applications can provide support to students in areas such as individualized instruction and educational data mining. Similarly, Akgun and Greenhow (2022) highlight the role of AI-powered conversational systems and academic text analysis within the learning process. The findings of this study support these perspectives. The ability of students to access information more rapidly, identify new details, and receive support during the preparation of presentations demonstrates that AI-based tools can diversify learning activities. However, it is crucial that this convenience does not relegate the student to a passive role, where they merely consume pre-existing content. In this context, the perspective of Popenici and Kerr (2017) who argue that AI should be viewed as a complementary tool rather than a fundamental component of education becomes particularly significant.

The findings also indicate that the use of NotebookLM entails certain technical and content-related limitations. Participants reported issues such as daily usage caps, long processing times, technical errors, and an inability to sufficiently customize presentations. The generation of inaccurate, incomplete, or superfluous information was also cited as a disadvantage. These results suggest that the convenience offered by AI tools should not be regarded as an unequivocal advantage. The potential for the generation of incorrect or incomplete content, in particular, necessitates that students verify the information they obtain. In this regard, it is significant that one participant in the study noted a decline in their mastery of the subject matter, attributing this to their reliance solely on information provided by the AI. Popenici and Kerr (2017) caution that the unchecked use of artificial intelligence could transform the learning process into one based merely on the transmission of information. Similarly, Güleryüz and Özcan (2023) point out that the use of AI in education may give rise to certain challenges related to learning and interaction. Therefore, the use of AI must not absolve students of their responsibility to conduct research, evaluate information, and interpret content.

The high level of interest among participants in using NotebookLM for future tourism-related courses indicates that the tool has been well-received by students. This intention to use the tool is driven by factors such as time savings, access to information, ease of preparing presentations, and the availability of visual support. Some students also noted that NotebookLM helped them acquire new knowledge and gain a better grasp of the subject matter. This finding aligns with the perspective that, unlike traditional educational tools, AI can create a personalized learning environment tailored to the individual student (Alanoğlu & Karabatak, 2020; Vatansever et al., 2025). Notably, two participants conditioned their future use of the tool on the resolution of existing technical issues; this suggests that the acceptance of technology is not solely dependent on the perception of its benefits factors such as system reliability and user control also play a role in the decision to adopt it. Therefore, the potential of NotebookLM in tourism guidance education should not be evaluated solely based on its capacity for rapid content generation. Instead, one must also consider the extent to which the tool

supports the student's learning process, the accuracy of the content it produces, and its ability to sustain the student's active engagement.

Based on the research findings, it can be suggested that NotebookLM be used as a supportive tool in tourism guidance courses. Students should be guided on how to verify information generated by AI, evaluate sources, and critically examine content. Instructors can position NotebookLM not as a tool for directly generating assignments, but as a technology that supports research, literature searching, and the development of drafts. It is also important to ensure that students are aware of the application's technical limitations and potential content errors. Furthermore, data privacy and ethical usage principles must not be overlooked (Nguyen et al., 2023; Uğurlu & Usta, 2025).

This study has certain limitations. The fact that the research was conducted with 29 students restricts the generalizability of the findings. The data are based on the students' subjective evaluations, and the study focuses exclusively on the experience of using NotebookLM. Future research could compare different artificial intelligence tools, utilize larger sample sizes, and include students from various tourism-related programs. By examining long-term usage experiences, the impact of AI on learning success and subject mastery could be assessed in greater detail.

References

Akgun, S. & Greenhow, C. (2022). Artificial intelligence in education: Addressing ethical challenges in K-12 settings. AI and Ethics, 2, 431-440. https://doi.org/10.1007/s43681-021-00096-7

Aktaş, A. C. (2024). Turist rehberliği mesleğine yapay zekâ programı ChatGPT'nin katkısı olabilir mi?. *Artuklu Tourism Studies*, (1), 13-25.

Alan, A. A., Aydınlı, F., & Başer, G. (2026). Dijital dönüşümün lisans düzeyinde turizm eğitimi müfredatlarına yansıması: Türkiye örneği. *Türk Turizm Araştırmaları Dergisi*, *10*(1), 23-44. https://doi.org/10.26677/TR1010.2026.1629

Alanoğlu, M. & Karabatak, S. (2020). Eğitimde Yapay Zeka. *Eğitim Araştırmaları,* Eyuder Yayınları.

Aydın, S. (2021). Eğitimde yapay zekâ kullanımı: Fırsatlar ve zorluklar. *Yükseköğretim ve Bilim Dergisi*, 11(2), 220-231.

Ceylan, U. (2025). Yapay zekâ bakış açısıyla Türkiye'de turist rehberliği mesleğinin geleceği. *Anatolia: Turizm Araştırmaları Dergisi*, *36*(1), 157-161. https://doi.org/10.17123/atad.1698989

El Gourari, A., Raoufi, M., Skouri, M., Braim, A. A. B., Ezzini, M., Ait Lahcen, Y., & Achki, S. (2024, April). The positive impact of artificial intelligence on education. In *2024 International Conference on Global Aeronautical Engineering and Satellite Technology (GAST)* (pp. 1-6). IEEE.

Garzón, J., Patiño, E., & Marulanda, C. (2025). Systematic review of artificial intelligence in education: Trends, benefits, and challenges. *Multimodal Technologies and Interaction*, *9*(8), 84. https://doi.org/10.3390/mti9080084

Gedik, Y. (2025). Eğitimde Yapay Zekâ: Avantajları, zorlukları ve stratejileri üzerine kavramsal bir değerlendirme. *Kastamonu insan ve Toplum Dergisi – KİTOD* 3(6), 187–212. https://doi.org/10.5281/zenodo.16917890.

Gürbüz, C., Köse, E., & Bekci, İ. (2026). Eğitimde yapay zekâ sistemlerinin kullanımı ve yapay zekâ etiği. Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 60, 1-17. https://doi.org/10.52642/susbed.1618517

Güleryüz, S., & Özcan, U. M. (2023). Yapay Zekâ Uygulamaları, Eğitime Yansımaları ve Geleceğe İlişkin Yönelimler. Kaygusuz (Ed.), 21. Yüzyılda Mühendislikte Çağdaş Araştırma Uygulamaları Üzerine Disiplinler Arası Çalışmalar, (271-286). Özgür Yayınları.

Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. Center for Curriculum Redesign.

Huang, L. (2023). Ethics of Artificial Intelligence in education: Student privacy and data protection. Science Insights Education Frontiers, 16(2), 2577-2587. https://doi.org/10.15354/sief.23.re202

Ivanov, S. (2023). The dark side of artificial intelligence in higher education. *The Service Industries Journal*, *43*(15-16), 1055-1082. https://doi.org/10.1080/02642069.2023.2258799

Kamalov, F., Santandreu Calonge, D., & Gurrib, I. (2023). New era of artificial intelligence in education: Towards a sustainable multifaceted revolution. *Sustainability*, *15*(16), 12451. https://doi.org/10.3390/su151612451

Nguyen, A., Ngo, H. N., Hong, Y., Dang, B. & Nguyen, B. P. T. (2023). Ethical principles for artificial intelligence in education. *Education and Information Technologies*, 28(4), 4221-4241. https://doi.org/10.1007/s10639-022-11316-w.

Paraskeva, M. (2026). The Negative Impacts of AI on Education: A Critical Approach and Contemporary Challenges. *Postmodernism Problems*, *16*(1), 128-143.

Plooy, D, E., Casteleijn, D., & Franzsen, D. (2024). Personalized adaptive learning in higher education: A scoping review of key characteristics and impact on academic performance and engagement. *Heliyon*, *10*(21), https://doi.org/10.1016/j.heliyon.2024.e39630

Popenici, S. A. D., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. Research and Practice in Technology Enhanced Learning, 12(22), 1–13.

Săseanu, A. S., Gogonea, R. M., & Ghiță, S. I. (2024). The social impact of using artificial intelligence in education. *Amfiteatru Economic*, *26*(65), 89-105.

Singh, A. K., Kiriti, M. K., Singh, H., & Shrivastava, A. (2025). Education AI: exploring the impact of artificial intelligence on education in the digital age. *International Journal of System Assurance Engineering and Management*, *16*(4), 1424-1437. https://doi.org/10.1007/s13198-025-02755-y

Şahin, İ. (2025). Turist rehberliği teknolojiye yenik düşer mi? Yapay zekâ ve artırılmış gerçeklik destekli Ayasofya dijital rehberlik yazılımına ilişkin görüşlerin analizi. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *34*(Uygarlığın Dönüşümü: Yapay Zekâ), 355-376. https://doi.org/10.35379/cusosbil.1678218

Taşkın, G. A., & Karaş, Y. K. (2026). Yapay zeka turizm araştırmalarına katkıda bulunabilir mi? ChatGPT'ye göre turist rehberliği mesleği. *Karamanoğlu Mehmetbey Üniversitesi Sosyal Ve Ekonomik Araştırmalar Dergisi*, *28*(52), 371-388. https://doi.org/10.18493/kmusekad.1657991

Uğurlu, C. T. ve Usta, H. G. (2025). Yapay zekânın (yz) eğitime yansımaları: Öğretmenlerin bakış açıları. *Batı Anadolu Eğitim Bilimleri Dergisi,* 16(1), 1350-1374. https://doi.org/10.51460/baebd.1578952

Vatansever, A. N., Çoban, S. Yalı Çoban, E, & Şen, K. (2025). Eğitimde yapay zekâ ve uygulamalarına ilişkin bir literatür incelemesi, *International Primary Educational Research Journal*, 9 (2): 216-229, https://doi.org/ 10.38089/iperj.2025.219.

Zhu, H., Sun, Y., & Yang, J. (2025). Towards responsible artificial intelligence in education: a systematic review on identifying and mitigating ethical risks. *Humanities and Social Sciences Communications*, *12*(1), 1111. https://doi.org/10.1057/s41599-025-05252-6

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

PERCEPTION OF SUCCESS AMONG 11–13-YEARS OLD CHILDREN ATTENDING RECREATIONAL SPORTS SCHOOLS

Mesut ÇOLAKOĞLU
Elif KARAGÜN
Orcid.org/0000-0002-8280-0372, Kocaeli Metropolitan Municipality, İzmit, Kocaeli,
Orcid.org/0000-0003-1974-4117, Kocaeli University, Faculty of Sports Sciences, İzmit, Kocaeli

Abstract

The purpose of this study is to determine the perceptions of success among children aged 11–13 who attend sports schools in the Gölcük district of Kocaeli during their leisure time, and to examine these perceptions in relation to various socio-demographic characteristics. To this end, children aged 11–13 attending sports schools that provide recreational sports training—along with their families—were informed about the study. For those who volunteered and received parental consent, data were collected using a 6-item demographic information form and the 12-item "Perception of Success Questionnaire," originally developed by Roberts et al. (1998) and adapted into Turkish by Kazak Çetinkalp (2006). Following the survey process, 87 forms were deemed valid, resulting in a final participant group of 87 children. Perceptions of success were examined using task and ego orientation subscale scores and an exploratory composite mean across all 12 items. The Mann–Whitney U and Kruskal–Wallis tests were used for group comparisons.

Mean scores were 4.31 ± 0.27 for task orientation, 3.96 ± 0.50 for ego orientation, and 4.13 ± 0.32 for the exploratory composite. None of the three scores differed significantly by age, gender, number of siblings, maternal education, or paternal education (all $p > .05$).

Keywords: Perception of success, ego orientation, task orientation, sports school, recreation, child.

REKREATİF AMAÇLI SPOR OKULLARINA DEVAM EDEN 11-13 YAŞ ARASI ÇOCUKLARDA BAŞARI ALGISI

Özet

Bu çalışmanın amacı, Kocaeli'nin Gölcük ilçesindeki spor okullarına serbest zamanlarında devam eden 11–13 yaş grubundaki çocukların başarı algılarını belirlemektir. Belirlenen başarı algılarını da çeşitli sosyo-demografik özellikler açısından incelemektir. Bu amaç doğrultusunda, rekreatif amaçlı spor eğitimi veren spor okullarında 11-13 yaş arasında olan çocuklar ile ailelerine çalışma hakkında bilgilendirme yapılmış. Araştırmaya gönüllü olan ve ailelerinin de onay verdiği 11-13 yaş arasındaki bireylere; veri toplama aracı olarak 6 maddelik bir demografik bilgi formu ile Roberts ve arkadaşları (1998) tarafından geliştirilen ve Kazak Çetinkalp (2006) tarafından Türkçeye uyarlanan 12 maddelik "Başarı Algısı Ölçeği" kullanılmıştır. Anket uygulaması sonrası geçerli olduğu görülen 87 adet form olması nedeniyle katılımcılar toplam 87 gönüllü çocuktan oluşturulmuştur. Başarı algısı, görev ve ego yönelimi alt boyutları ile 12 maddelik keşifsel bileşik ortalama üzerinden incelenmiştir. Grup karşılaştırmalarında Mann–Whitney U ve Kruskal–Wallis testleri kullanılmıştır.

Katılımcıların görev yönelimi ortalaması 4,31 ± 0,27, ego yönelimi ortalaması 3,96 ± 0,50 ve keşifsel başarı algısı bileşik ortalaması 4,13 ± 0,32 olarak bulunmuştur. Yaş, cinsiyet, kardeş sayısı, Anne ve Baba eğitim düzeyine göre yapılan karşılaştırmalarda üç puan için de istatistiksel olarak anlamlı farklılık saptanmamıştır (tüm $p > 0,05$).

Anahtar Kelimeler: Başarı algısı, ego yönelim, görev yönelim, spor okulu, rekreasyon, çocuk.

1.Giriş

Düzenli olarak özellikle serbest zamanlarında fiziksel aktivite ve egzersizlere katılmanın; fiziksel sosyal yönlerin yanı sıra duygusal ve bilişsel ve pek çok gelişim alanları açısından olumlu etkilerini ortaya koyan araştırmalar mevcuttur (Baltaş & Baltaş, 1993; Downward & Rasciute, 2011; Karagün, 2015, Karagün, 2018; Lök & Lök, 2016; Müftüoğlu, 2003). Bu araştırmalar, sporun sağlık üzerindeki olumlu etkilerini ortaya koymakla birlikte farklı yaş grubunda olan bireyler için önemli bir yaşam alışkanlığı olarak kabul edilmesi gerektiğini de göstermektedir. Pek çok alışkanlıklarda olduğu gibi spor ve egzersiz çalışmalarının çocukluk döneminde başlanması ileriye dönük alışkanlık kazanılmasında önemli bir destekleyici olarak karşımıza çıkmaktadır. Bu doğrultuda spor psikolojisi alanında çalışan araştırmacılar, çocuk ve gençlerin sportif faaliyetlere katılım süreçlerine, bu faaliyetlere yönelme nedenlerine ve spor deneyimlerini etkileyen psikolojik faktörlere yönelik çalışmalara ağırlık vermektedir.

Günümüzde sosyolojik, psikolojik ve özellikle hareketsizlikle birlikte artan bedensel sorunlar olumlu etkileri nedeniyle sporu temel ihtiyaç noktasına taşımakta ve bireylerin yaşam kalitesini artıran önemli sosyal aktivitelerden biri olarak değerlendirilmektedir. Sportif faaliyetlerine katılım, çocukların fiziksel ve duygusal gelişimlerine katkı sağlamanın yanı sıra sosyal çevrelerine uyum süreçlerini kolaylaştırmakta ve kişiler arası iletişim becerilerini geliştirmektedir. Bununla birlikte, spor faaliyetlerine katılım kadar bu faaliyetlerin sürdürülebilir olması da önem taşımaktadır. Bu noktada öz yeterlik, spora yeni başlayan çocuk ve yetişkinlerin sportif faaliyetlere devam etmesinde belirleyici faktörlerden biri olarak öne çıktığı belirtilmektedir (Bozkurt, 2014).

Bireylerin yaşamları boyunca ulaşmayı hedefledikleri temel unsurlardan biri de başarıdır. İnsanlar, varoluşlarından itibaren farklı arayışlar içerisinde olmuş ve bir şeyleri başarma arzusu, yaşamlarını şekillendiren önemli amaçlardan biri hâline gelmiştir. Özellikle kendini gerçekleştirme, saygınlık kazanma ve toplumsal statü elde etme gibi ihtiyaçlar, bireylerin hem özel hem de iş yaşamlarında başarılı olma isteğini güçlendirmektedir (Başoğlu, 2017). Kavramsal açıdan başarı, genel olarak birey için anlam taşıyan amaçların, oluşturulan günlük programlar doğrultusunda aşamalı olarak gerçekleştirilmesi şeklinde tanımlanmaktadır (Keskin & Yapıcı, 2008).

Başarı kavramı, bireylerin sportif faaliyetlere katılımını ve bu faaliyetlerdeki motivasyonlarını anlamlandırmak açısından da önemli bir yere sahiptir. Özellikle son yıllarda spor psikologları, sporcular arasındaki motivasyon farklılıklarını açıklayabilmek amacıyla başarı hedefleri üzerinde yoğunlaşmışlardır. Başarı hedefleri teorisine göre bireyin motivasyonunu belirleyen üç temel faktör bulunmaktadır. Bunlar başarı hedefleri, algılanan yetenek ve başarı davranışlarıdır. Bireyin motivasyon yapısını anlayabilmek için öncelikle başarı ve başarısızlığa yüklediği anlamın ortaya konulması gerekmektedir. Bu durum, bireyin başarı hedeflerinin ve kendi yeterliliğini algılama biçiminin birlikte değerlendirilmesini gerekli kılmaktadır.

Başarı hedef yönelim kuramına göre başarı hedefi, algılanan beceri ve başarı davranışı şeklinde üç faktör önemli olmaktadır (Duda & Hall, 2001; Weinberg & Gould, 1995). Bireyler, belirledikleri hedeflere ulaştıklarında başarı duygusu yaşamakta ve bu duygu, hedeflerin gerçekleştirilme düzeyine göre şekillenmektedir. Dolayısıyla başarı veya başarısızlık algısı, bireyin sahip olduğu hedef yönelimiyle yakından ilişkilidir. Spor ortamında bireyin performansını değerlendirme biçimi de bu yönelim doğrultusunda farklılaşabilmektedir. Başka bir ifadeyle birey, başarısını kimi zaman kendi gelişimi ve önceki performansıyla, kimi zaman ise diğer bireylerin performanslarıyla karşılaştırarak değerlendirmektedir. Bu açıdan hedef yönelimi, bireyin başarıyı nasıl tanımladığını, değerlendirdiğini ve sportif faaliyetler sırasında nasıl bir motivasyon geliştirdiğini açıklayan önemli bir unsur olarak karşımıza çıkmaktadır (Weinberg & Gould, 1995).

Başarı algısının oluşumunda bireylerin sahip oldukları hedef yönelimleri önemli bir rol oynamaktadır. Başarı hedefleri kuramı çerçevesinde bu yönelimler genel olarak görev yönelimi ve ego yönelimi olmak üzere iki temel boyutta ele alınmaktadır. Görev yönelimli bireyler başarıyı kendi performanslarını geliştirme, yeni beceriler kazanma, çaba gösterme ve belirlenen görevleri en iyi şekilde yerine getirme üzerinden değerlendirirken; ego yönelimli bireyler başarıyı daha çok diğer bireylerden üstün olma, rakiplerini geride bırakma ve yeteneklerini başkalarıyla kıyaslama üzerinden tanımlamaktadır (Nicholls, 1989; Duda et al., 1992). Bu iki yönelim, bireylerin sportif faaliyetlere yönelik motivasyonlarını, başarı ve başarısızlık algılarını ve sportif deneyimlerinden elde ettikleri doyumu farklı şekillerde etkileyebilmektedir. Özellikle çocukluk döneminde gelişen bu yönelimlerin, bireylerin spora yönelik tutumlarının ve sportif faaliyetlere katılım sürekliliklerinin anlaşılmasında önemli olduğu ifade edilmektedir (Duda, 1987; Duda et al., 1992). Tüm bu literatür değerlendirmelerle bakıldığında sporun sosyal, bedensel ve psikolojik etkilerini inceleyen ve spor yapma ile ilişkisini değerlendiren pek çok çalışma olduğu görülmekle birlikte özellikle rekreatif amaçlı spor yapan çocukların başarı algısı ne durumda olduğu merak edilmiştir. Bu açıdan 11-13 yaş arasında olup rekreatif amaçlı spor okullarına katılan çocukların başarı algısının incelenmesi amaçlanmıştır.

2. Materyal ve Metod

Bu çalışmanın amacı, Kocaeli'nin Gölcük ilçesindeki spor okullarına serbest zamanlarında devam eden 11–13 yaş grubundaki çocukların başarı algılarını belirlemektir. Belirlenen başarı algılarını da çeşitli sosyo-demografik özellikler açısından incelemektir. Bu amaç doğrultusunda, rekreatif amaçlı spor eğitimi veren spor okullarında 11-13 yaş arasında olan çocuklar ile ailelerine çalışma hakkında bilgilendirme yapılmış. Araştırmaya gönüllü olan ve ailelerinin de onay verdiği 11-13 yaş arasındaki bireylere; veri toplama aracı olarak 6 maddelik bir demografik bilgi formu ile Roberts ve arkadaşları (1998) tarafından geliştirilen ve Kazak Çetinkalp (2006) tarafından Türkçeye uyarlanan 12 maddelik "Başarı Algısı Ölçeği" kullanılmıştır. Anket uygulaması sonrası geçerli olduğu görülen 87 adet form olması nedeniyle katılımcılar toplam 87 gönüllü çocuktan oluşturulmuştur.

2.1. Veri Toplama Araçları

Araştırmada veri toplama aracı olarak araştırmacılar tarafından hazırlanan 6 soruluk Kişisel Bilgi Formu ile Roberts ve arkadaşları (1998) tarafından geliştirilen, Türkçe uyarlaması Kazak Çetinkalp (2006) tarafından gerçekleştirilen Başarı Algısı Envanteri'nin çocuk versiyonu kullanılmıştır.

Başarı Algısı Envanteri, 5'li Likert tipinde hazırlanmış olup toplam 12 maddeden oluşmaktadır. Ölçek, çocukların sportif faaliyetlerde başarıyı nasıl algıladıklarını ve başarıya yönelik hedef yönelimlerini belirlemek amacıyla kullanılmıştır.

2.2. Verilerin Analizi

Başarı Algısı Envanteri'nin çocuk versiyonunda görev yönelimi 4, 5, 7, 8, 9 ve 12. maddelerden, ego yönelimi ise 1, 2, 3, 6, 10 ve 11. maddelerden oluşmaktadır. Ham veri dosyasında 1 "kesinlikle katılıyorum", 5 "kesinlikle katılmıyorum" olarak kodlandığından, yüksek puanın daha güçlü yönelimi göstermesi için yanıtlar 6 − ham puan işlemiyle yeniden puanlanmıştır. Her alt boyut için ilgili altı maddenin aritmetik ortalaması alınmıştır.

Başarı algısı bileşik puanı, yeniden puanlanan 12 maddenin aritmetik ortalamasıdır. Ölçeğin geçerlik çalışmaları görev ve ego yönelimi olmak üzere iki alt boyutu desteklediğinden, bu bileşik ortalama keşifsel bir gösterge olarak değerlendirilmiştir (Roberts vd., 1998; Kazak Çetinkalp, 2006). Puanlar 1–5 aralığındadır. Analize 87 katılımcının eksiksiz madde yanıtları dâhil edilmiştir.

Tanımlayıcı istatistikler frekans, yüzde, aritmetik ortalama ve standart sapma olarak verilmiştir. Grup karşılaştırmalarında ortalama ± standart sapma ile asimptotik p değerleri raporlanmıştır. Cinsiyet için iki yönlü Mann–Whitney U, yaş, kardeş sayısı ve ebeveyn eğitim düzeyleri için Kruskal–Wallis testi uygulanmıştır. Anlamlılık düzeyi 0,05 olarak alınmıştır.

3. Bulgular

Tablo 1. Sosyo-Demografik Özelliklere Ait Bulgular

Değişkenler	Alt Kategoriler	N	%
Cinsiyet	Kız	44	50,6
	Erkek	43	49,4
Yaş	11	34	39,1
	12	33	37,9
	13	20	23,0
Anne Eğitim	İlköğretim	39	44,8
	Lise	31	35,6
	Lisans	17	19,5
Baba Eğitim	İlköğretim	12	13,8
	Lise	35	40,2
	Lisans	40	46,0
Kardeş Sayısı	0	15	17,2
	1	32	36,8
	2	24	27,6
	3+	16	18,4

Katılımcıların 34'ü 11, 33'ü 12 ve 20'si 13 yaşındadır. Anne eğitim düzeyi en fazla ilköğretim iken baba eğitiminde en fazla lisans mezunları olduğu görülmektedir. Kardeş sayısında en fazla oranın tek kardeş ardından iki kardeş olduğu görülmektedir.

Tablo 2. Başarı algısı puanlarına ilişkin tanımlayıcı istatistikler (n = 87)

Puan	Ortalama	Standart sapma
Başarı algısı*	4,13	0,32
Görev yönelimi	4,31	0,27
Ego yönelimi	3,96	0,50

Görev yönelimi ortalaması, ego yönelimi ortalamasından betimsel olarak daha yüksektir. *Başarı algısı, 12 maddelik keşifsel bileşik puandır.

Tablo 3. Katılımcıların sosyodemografik özellikler açısından Mann–Whitney U analizleri

Cinsiyet	Başarı algısı*	Görev yönelimi	Ego yönelimi
Kız	4,16 ± 0,29	4,30 ± 0,27	4,03 ± 0,46
Erkek	4,10 ± 0,35	4,32 ± 0,28	3,88 ± 0,52
p	0,464	0,643	0,217

Cinsiyete göre başarı algısı toplam puanı ile görev ve ego yönelimleri puanlarında anlamlı fark saptanmamıştır ($p > 0,05$).

Tablo 4. Katılımcıların sosyodemografik özellikler açısından Kruskal–Wallis test analizleri

Değişken	Grup	Başarı algısı*	Görev yönelimi	Ego yönelimi
Yaş	11	4,21 ± 0,29	4,37 ± 0,24	4,05 ± 0,45
	12	4,06 ± 0,34	4,26 ± 0,30	3,86 ± 0,50
	13	4,11 ± 0,32	4,27 ± 0,26	3,96 ± 0,55
	p	0,132	0,176	0,301
Anne eğitimi	İlköğretim	4,20 ± 0,27	4,34 ± 0,26	4,06 ± 0,40
	Lise	4,12 ± 0,37	4,32 ± 0,27	3,92 ± 0,59
	Lisans	4,00 ± 0,27	4,21 ± 0,29	3,78 ± 0,49
	p	0,080	0,368	0,142
Baba eğitimi	İlköğretim	4,14 ± 0,27	4,31 ± 0,20	3,97 ± 0,44
	Lise	4,22 ± 0,29	4,38 ± 0,24	4,07 ± 0,47
	Lisans	4,05 ± 0,33	4,24 ± 0,30	3,85 ± 0,52
	p	0,051	0,064	0,206
Kardeş sayısı	0	4,14 ± 0,32	4,27 ± 0,29	4,02 ± 0,54
	1	4,07 ± 0,36	4,29 ± 0,29	3,86 ± 0,55
	2	4,20 ± 0,31	4,36 ± 0,27	4,05 ± 0,45
	3+	4,12 ± 0,23	4,30 ± 0,21	3,95 ± 0,40
	p	0,538	0,648	0,569

11, 12 ve 13 yaş grupları arasında başarı algısı toplam puanı ile görev ve ego yönelimleri puanlarında anlamlı bir fark saptanmamıştır. Ebeveyn eğitimi ve kardeş sayısına göre de anlamlı fark bulunmamıştır ($p > 0,05$).

4. Tartışma ve Sonuç

Gölcük'teki spor okullarına rekreatif amaçlı devam eden 11–13 yaş grubundaki çocukların görev yönelimi ortalaması (4,31 ± 0,27), ego yönelimi ortalamasının (3,96 ± 0,50) üzerindedir. Bu betimsel fark, çocukların çaba, beceri gelişimi ve kendi hedeflerine ulaşma gibi başarı ölçütlerine ortalama olarak daha fazla katıldıklarını düşündürmektedir. Literatür incelendiğinde; çocuklarda görev yöneliminin çaba ve iş birliğine verilen önemle ilişkili olması, görev odaklı hedef ve inançların da spordan alınan keyifle pozitif ilişkili olduğu bildirilmiştir (Duda et al.,1992). Bir başka çalışmada ise 431 öğrenci-sporcuda görev yöneliminin öz yeterliği pozitif yönde yordadığı saptanmıştır (Canpolat & Kazak Çetinkalp, 2011). Bu sonuçlar gözlenen görev yönelimi örüntüsünün çocukların spordaki deneyimleriyle birlikte, gruba dâhil olma ve uyum sağlama süreçlerinin, kişilik gelişimdeki dinamiklerin etkisi ile olduğu yönünde yorumlamamızı desteklemektedir.

Mann–Whitney U analizinde cinsiyete göre görev ve ego yönelimi ile başarı algısı puanları anlamlı biçimde farklılaşmamıştır. Literatüre bakıldığında; aynı çocuk envanterini kullanan Canpolat ve Kazak Çetinkalp (2011) öğrenci-sporcularda, Kasımoğlu ve Aygün (2026) ise Ardahan'daki yaz spor okullarına katılan ortaokul öğrencilerinde her iki yönelim için benzer sonuçlar alındığını bildirmiştir. Ancak Koruç'un (2009) genç atletlerle yürüttüğü çalışmasında ise ego yöneliminde cinsiyete göre fark bulunmuştur. Çalışmaların spor ortamı, spor deneyimi ve katılımcı özellikleri gibi detayların daha kapsamlı çalışmalarla ele alınmasının önerilmesi uygun görülmüştür.

Yine yapılan analizlerde 11, 12 ve 13 yaş grupları arasında görev yönelimi, ego yönelimi ve başarı algısı puanları bakımından anlamlı bir farklılık bulunmamıştır. Tapşın ve Karagün (2025) de İzmit'te rekreatif basketbol kursuna katılan 86 kız öğrencide, 10–12 ve 13–14 yaş grupları arasında görev ve ego yönelimi açısından anlamlı bir fark saptamamışlardır. Aynı bildiride sınıf düzeyine göre bakıldığında ise 5–6. sınıflarda ego, 7–8. sınıflarda görev yönelimi anlamlı derecede daha yüksek bulunmuştur. Kasımoğlu ve Aygün (2026) ise 5. sınıf öğrencilerinin ego yöneliminin 6. sınıf öğrencilerinden daha yüksek olduğunu bildirmiştir. Sınıf

düzeyi okul deneyimini de yansıttığından, bu bulgular yaş gruplarına ilişkin sonuçlarla ayrı değerlendirilmesi gerektiği düşünülmüştür.

Anne ve baba eğitim düzeyine göre iki alt boyutta da anlamlı bir fark görülmemiştir. Ebeveyn eğitimi, Benar ve Loghmani'nin (2012) genç sporcularda hedef yönelimleri açısından ele aldığı değişkenlerden biri olarak görülmektedir. Tapşın ve Karagün (2025) de görev yönelimi için benzer sonuçlar bildirmiş, ego yöneliminde ise üniversite mezunu annelerin ve babaların çocuklarının, ilgili ebeveyni lise mezunu olan çocuklardan daha yüksek puan aldığını göstermiştir. Söz konusu araştırmada yalnızca kız basketbolcular incelenmiştir, 13 maddelik Ego ve Görev Yönelimi Ölçeği kullanılmış ve ebeveyn eğitimi iki grupta karşılaştırılmıştır. Bu çalışmada ise rekreatif amaçlı spor okuluna katılan kız ve erkek katılımcılar 12 maddelik Başarı Algısı Envanteri'nin çocuk versiyonuyla ve üç eğitim kategorisinde değerlendirilmiştir. Bu farklılıklar, özellikle ego yönelimine ilişkin sonuçların doğrudan karşılaştırılmasını sınırlandırmaktadır.

Bu araştırmada kardeş sayısına göre alt boyut puanlarında anlamlı bir farklılık saptanmamıştır. Tapşın ve Karagün'ün (2025) çalışmasında, kardeşi olan ve olmayan katılımcıları karşılaştırdığında her iki yönelimde de anlamlı bir farklılık bulamamışlardır. Başoğlu (2017) da yıldız erkek güreşçilerde kardeş sayısına göre başarı algısı puanlarının anlamlı biçimde farklılaşmadığını bildirmiştir.

Spor deneyimine ilişkin bulgular da örnekleme göre değişmektedir. Tapşın ve Karagün (2025) okul takımında oynama durumuna göre iki yönelimde de anlamlı fark saptamazken, Kasımoğlu ve Aygün (2026) okul takımında oynayan öğrencilerin her iki alt boyutta daha yüksek puan aldığını bildirmiştir. Gölcük örneklemiyle yapılan bu çalışmada ise; okul takımında oynama durumu değerlendirilmediği için, bu sonuçlar spor okuluna katılım bağlamını anlamaya yardımcı olan karşılaştırmalar olarak ele alınmıştır.

Sonuç olarak bu örneklemde görev yönelimi ortalaması betimsel olarak daha yüksektir. Yaş, cinsiyet, kardeş sayısı ve ebeveyn eğitim düzeyine göre görev yönelimi, ego yönelimi ve keşifsel bileşik başarı algısı puanları bakımından anlamlı fark saptanmamıştır. Bulgular, 87 katılımcıdan oluşan Gölcük örneklemi ve karşılaştırılan grupların büyüklükleri evren tam belirlenemediğinden araştırmanın sınırlılığı olarak değerlendirilmiş. Konuyla ilgili daha kesin sonuçlara ulaşmak için de evren sayısının belirlendikten sonra evreni temsil eden örneklem grubuyla çalışılmasının önerilmesi uygun görülmüştür.

5. Kaynaklar

Baltaş, A., & Baltaş, Z. (1993). *Stres ve başaçıkma yolları* (14. bs.). Remzi Kitabevi.

Başoğlu, B. (2017). Grekoromen yıldız erkek güreş milli takım oyuncularının başarı algısı ve özyeterlilik düzeylerinin incelenmesi. *Gaziantep Üniversitesi Spor Bilimleri Dergisi, 2*(1), 31–40.

Benar, N., & Loghmani, M. (2012). Comparison between sport participation motivation and goal-orientation of youth athletes: The role of parents' education level. *Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports, 12*, 168-173. https://doi.org/10.6084/m9.figshare.105478

Bozkurt, Ş. (2014). *Okul sporlarına katılan öğrencilerin katılım motivasyonu, başarı algısı ve öz yeterliliklerinin incelenmesi* [Yüksek lisans tezi, Akdeniz Üniversitesi].

Canpolat, A. M., & Kazak Çetinkalp, Z. (2011). İlköğretim II. kademe öğrenci-sporcuların başarı algısı ve öz-yeterlik düzeyleri arasındaki ilişki. *Selçuk Üniversitesi Beden Eğitimi ve Spor Bilim Dergisi, 13*(1), 14–19.

Downward, P., & Rasciute, S. (2011). Does sport make you happy? An analysis of the well-being derived from sports participation. *International Review of Applied Economics, 25*(3), 331–348. https://doi.org/10.1080/02692171.2010.511168

Duda, J. L. (1987). Toward a developmental theory of children's motivation in sport. *Journal of Sport Psychology, 9*(2), 130–145.

Duda, J. L., Fox, K. R., Biddle, S. J. H., & Armstrong, N. (1992). Children's achievement goals and beliefs about success in sport. *British Journal of Educational Psychology, 62*(3), 313–323. https://doi.org/10.1111/j.2044-8279.1992.tb01025.x

Duda, J. L., & Hall, H. K. (2001). Achievement goal theory in sport: Recent extensions and future directions. In R. N. Singer, H. A. Hausenblas, & C. M. Janelle (Eds.), *Handbook of sport psychology* (2nd ed., pp. 417–443). John Wiley & Sons.

Karagün, E. (2015). Violence tendencies of high school students: An examination in terms of exposure to violence, participation in sports and socio-demograpic attributes. *Educational Research and Reviews, 10*(1), 29–35. https://doi.org/10.5897/ERR2014.2002

Karagün, E. (2018). Perception-attention-memory reaction time of PE teacher and computer teacher candidates. *Journal of Education and Training Studies, 6*(11a), 98–104. https://doi.org/10.11114/jets.v6i11a.3805

Kasımoğlu, N., & Aygün, M. (2026). Yaz Spor Okullarına Katılan Ortaokul Öğrencilerinin Başarı Algılarının İncelenmesi. *İnönü Üniversitesi Beden Eğitimi ve Spor Bilimleri Dergisi, 13*, 1-20. https://izlik.org/JA86WW28PP

Kazak Çetinkalp, Z. (2006). Başarı Algısı Envanterinin çocuk versiyonu-BAE-Ç'nun Türk sporcuları için geçerlik ve güvenirlik çalışması. *9. Uluslararası Spor Bilimleri Kongresi Bildiri Kitabı* (ss. 1325-1327). https://sporbilimleri.org.tr/wp-content/uploads/2022/05/2006-9.-SBK-Mug%CC%86la-3.pdf#page=353

Keskin, H, K., & Yapıcı, Ş. (2008). Başarılı ve başarısız öğrencilerin kişilik özellikleri ile ilgili öğretmen ve veli görüşleri. *Kuramsal Eğitimbilim Dergisi, 1*(1), 20–32.

Koruç, P. B. (2009). Genç atletlerin yarışma öncesi durumluk kaygı düzeyleri ile motivasyon boyutları ve hedef yönelimleri arasındaki ilişki. *Spor Hekimliği Dergisi, 44*(2), 61–69.

Lök, S., & Lök, N. (2016). Kronik psikiyatri hastalarına uygulanan fiziksel egsersiz programlarının etkinliği: Sistematik derleme. *Psikiyatride Güncel Yaklaşımlar, 8*(4), 354–366. https://doi.org/10.18863/pgy.253440

Müftüoğlu, O. (2003). *Yaşasın hayat*. Doğan Kitap.

Nicholls, J. G. (1989). *The competitive ethos and democratic education*. Harvard University Press. https://books.google.kg/books?id=CmdUo6P9CL0C

Roberts, G. C., Treasure, D. C., & Balague, G. (1998). Achievement goals in sport: The development and validation of the Perception of Success Questionnaire. *Journal of Sports Sciences, 16*(4), 337–347. https://doi.org/10.1080/02640419808559362

Tapşın, F. O., & Karagün, E. (2025). Basketbol kurslarına katılan kız öğrencilerinin ego ve görev yönelimleri. İ. Erpay (Ed.), *VIII. BİLSEL Uluslararası Dünya Bilim ve Araştırma Kongresi kongre kitabı* (ss. 285–294) içinde. Bilsel Publishing. https://bilselkongreleri.com/wp-content/uploads/8.-BILSEL-INTERNATIONAL-WORLD-SCIENCE-AND-RESEARCH-CONGRESS-BOOK.pdf

Weinberg, R. S., & Gould, D. (1995). *Foundations of sport and exercise psychology*. Human Kinetics. https://books.google.com.tr/books?id=GHGLEAAAQBAJ

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FROM CONTACT TO EVIDENCE: ANALYSIS OF COSMETIC TRACES AND CURRENT ANALYTICAL APPROACHES IN FORENSIC COSMETOLOGY

Didem ÇİLENGİROĞLU
PhD Student, Ondokuz Mayıs Üniversitesi, Adli Bilimler Ana Bilim Dalı, Samsun-Türkiye
ORCID: 0000-0002-8497-0404
Yıldıray TOPCU
Prof. Dr., Ondokuz Mayıs Üniversitesi, Kimya Mühendisliği Ana Bilim Dalı, Samsun-Türkiye
ORCID: 0000-0002-2095-6603

Abstract

Cosmetic products are increasingly important alternative trace evidence in forensic science due to their widespread use, complex chemical compositions, and ease of transfer through physical contact. According to Locard's Exchange Principle, contact among individuals, objects, and the environment can lead to mutual material transfer. Accordingly, micro-traces originating from foundations, lipsticks, eyeliners, eyeshadows, face powders, and nail polishes contribute significantly to establishing and evaluating associations among suspects, victims, incident-related objects, and crime scenes. This review evaluates selected studies on the forensic examination of cosmetic products chronologically and analytically, covering forensic cosmetology, analytical advances, trace transfer, persistence, and chemometric data evaluation defined as a multidisciplinary science that extracts meaningful information from chemical and biochemical systems using multivariate statistics, mathematical models, and computer science. The literature indicates that early forensic studies relied mainly on colour analysis, thin-layer chromatography, high-performance liquid chromatography, and elemental analysis. In contrast, subsequent research increasingly employed Attenuated Total Reflectance–Fourier Transform Infrared Spectroscopy (ATR-FTIR), Raman Spectroscopy, Scanning Electron Microscopy coupled with Energy-Dispersive X-Ray Spectroscopy (SEM-EDS), X-Ray Diffraction (XRD), and Mass Spectrometry techniques for characterization and comparison of cosmetic samples. In recent years, integrating analytical data with chemometric and statistical approaches, including Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), and various spectral-matching algorithms, has supported more objective and reproducible discrimination and classification of visually similar products. Furthermore, sequential application of multiple analytical techniques increases overall discriminatory power by reducing the limitations of individual methods. Nevertheless, sample characteristics, environmental exposure, temporal changes, within-product heterogeneity, and batch-to-batch variations must be considered carefully in analytical evaluation and forensic interpretation. Cosmetic microtraces should not be regarded as individualizing evidence. However, when supported by appropriate sampling strategies, validated analytical methods, and statistical evaluations, they constitute crucial associative trace evidence that contributes effectively to source comparison, assessment of contact relationships, and retrospective crime scene reconstruction.

Keywords: Forensic Cosmetology, Cosmetic Trace Evidence, Source Identification, ATR-FTIR, SEM-EDS, Chemometrics.

TEMASTAN DELİLE: ADLİ KOZMETOLOJİDE KOZMETİK İZLERİN ANALİZİ VE GÜNCEL ANALİTİK YAKLAŞIMLAR

Özet

Kozmetik ürünler; yaygın kullanımları, karmaşık kimyasal bileşimleri ve fiziksel temas sonucunda kolaylıkla transfer edilebilmeleri nedeniyle adli bilimlerde giderek daha fazla önem kazanan alternatif iz delilleridir. Locard'ın değişim prensibine göre kişiler, nesneler ve çevre arasındaki her temas, karşılıklı materyal transferine yol açabilir. Bu bağlamda fondöten, ruj, göz kalemi, göz farı, yüz pudrası ve oje gibi kozmetik ürünlere ait mikroizler, şüpheli, mağdur, olayla ilişkili nesneler ve olay yeri arasındaki bağlantının ortaya konulmasına ve değerlendirilmesine katkı sağlayabilir. Bu derleme çalışmasında, kozmetik ürünlerin adli amaçlı incelenmesine ilişkin seçilmiş çalışmalar kronolojik gelişimleri ve kullanılan analitik yaklaşımlar açısından değerlendirilmiş; adli kozmetoloji kavramının kapsamı, analitik yöntemlerdeki gelişmeler, kozmetik izlerin transferi ve kalıcılığı ile çok değişkenli istatistik, matematiksel modeller ve bilgisayar bilimi kullanarak kimyasal ve biyokimyasal sistemlerden anlamlı bilgiler çıkaran multidisipliner bir bilim dalı olarak tanımlanan kemometrik veri değerlendirme yaklaşımları ele alınmıştır. Literatürün incelenmesi, erken dönem çalışmaların başlıca renk analizi, ince tabaka kromatografisi, yüksek performanslı sıvı kromatografisi ve elementel analizlere dayandığını; izleyen dönemlerde ise Zayıflatılmış Toplam Yansıma-Fourier Dönüşümlü Kızılötesi Spektroskopisi (ATR-FTIR), Raman Spektroskopisi, Taramalı Elektron Mikroskobu- Enerji Dağılımlı X-Işını Spektroskopisi (SEM-EDS), X-Işını Kırınımı (XRD) ve Kütle Spektrometrik tekniklerin kozmetik örneklerin karakterizasyonu ve karşılaştırılmasında yaygınlaştığını göstermektedir. Son yıllarda Temel Bileşen Analizi (PCA), Doğrusal Diskriminant Analizi (LDA) ve çeşitli spektral eşleştirme algoritmaları gibi kemometrik ve istatistiksel yaklaşımların analitik verilerle birlikte kullanılması, benzer görünümlü ürünlerin daha objektif ve tekrarlanabilir biçimde ayırt edilmesine ve sınıflandırılmasına katkı sağlamaktadır. Çoklu analitik tekniklerin ardışık kullanıldığı çalışmalar ise tek bir yöntemin sınırlılıklarını azaltarak ayrım gücünü artırmaktadır. Bununla birlikte analiz edilen numunenin özellikleri, çevresel koşullara maruziyet, zamanla meydana gelen değişimler, ürün içi heterojenlik ve üretim partileri arasındaki varyasyonlar, kozmetik izlerin analitik olarak değerlendirilmesi ve adli yorumlanmasında dikkate alınması gereken başlıca faktörlerdir. Sonuç olarak, kozmetik mikroizler tek başına bireyselleştirici nitelikte deliller olarak değerlendirilmemelidir. Bu deliller; uygun örnekleme stratejileri, doğrulanmış analitik yöntemler ve istatistiksel değerlendirmelerle desteklendiğinde kaynak karşılaştırmasına, temas ilişkilerinin değerlendirilmesine, olay yerinin ve suçun işleniş mekanizmasının geriye dönük olarak canlandırılmasında katkı sağlayabilecek önemli bir ilişkilendirici iz delili grubu olarak ele alınmalıdır.

Anahtar Kelimeler: Adli Kozmetoloji, Kozmetik İz Delilleri, Kaynak Tanımlama, ATR-FTIR, SEM-EDS, Kemometri.

Giriş

Adli bilimler, olay yerindeki fiziksel, kimyasal ve biyolojik delillerin tespitini, karakterizasyonunu ve olayla ilişkilendirilmesini kapsayan çok disiplinli bir alandır (Houck ve Siegel, 2016). Locard'ın Değişim Prensibi'ne göre temas eden kişi, nesne ve yüzeyler arasında materyal transferi gerçekleşir; bu nedenle mikroizler soruşturmalar açısından önem taşır (Locard, 2010).

Kozmetik ürünler; temizleme, görünümü iyileştirme, koku verme veya vücudu koruma amacıyla uygulanan formülasyonlardır (Çomoğlu, 2012). Kullanımları tarih boyunca bakımın yanı sıra din, tıp, avcılık ve savaş gibi farklı alanlarla ilişkilendirilmiştir. Modern kozmetik pazarının hızla büyümesiyle birlikte formülasyonlar, inorganik pigmentler, polimerik bağlayıcılar, uçucu çözücüler ve koruyucu ajanlar içeren son derece karmaşık kimyasal matrislere dönüşmüştür.

Şekil 1. Temel kozmetik ürün türlerinin örnek ürünlerle şematik gösterimi (Bruce vd., 2024).

Kozmetik kullanımı farklı yaş, cinsiyet ve toplumsal gruplara yayılmıştır. Fondöten, ruj, göz kalemi, far, pudra ve oje gibi ürünler temasla giysi, kâğıt, tekstil, kap ve diğer yüzeylere aktarılabilir. Bu kalıntılar, özellikle fiziksel şiddet ve cinsel saldırı gibi yakın temas içeren vakalarda şüpheli, mağdur, nesne ve olay yeri arasındaki olası ilişkinin değerlendirilmesine katkı sağlayan alternatif mikroizlerdir (Chisvert ve Salvador, 2018; Chophi vd., 2019, 2021; Gładysz vd., 2021). Olay yerinde eser miktarda bulunabildiklerinden hassas ve tahribatsız analitik yöntemlerle incelenmelidir.

Kozmetik kalıntılar farklı yüzeylere aktarılabilir ve uygun koşullarda uzun süre saptanabilirliğini koruyabilir (AlSaeed vd., 2022; Turkay, 2023). Referans numunelerle karşılaştırılmaları olası kaynakların belirlenmesine veya dışlanmasına katkı sağlar (Shimamoto vd., 2013). Bununla birlikte kalıntının varlığı tek başına olayla doğrudan bağlantı kurmaya yetmez; ikincil transfer, yüzey türü, kalıcılık ve çevresel koşullar birlikte değerlendirilmelidir. Formülasyon ve aynı ürünün partileri arasındaki değişkenlik de yorumlamada dikkate alınmalıdır (Bruce vd., 2024). Ruj, dudak parlatıcısı, oje, pudra ve göz kozmetiklerinin yüksek transfer potansiyeli, adli karşılaştırmalarını anlamlı kılmaktadır (AlSaeed vd., 2022).

Adli kozmetik incelemelerinde yöntemlerin yüksek ayırt etme gücü sunması, az miktardaki örneği koruması, mümkün olduğunca tahribatsız ve tekrarlanabilir olması, laboratuvara uyarlanabilmesi beklenir. ATR-FTIR ve Raman Spektroskopisi, sınırlı örnek hazırlığıyla moleküler özellikleri inceleyen tamamlayıcı yöntemlerdir. Spektrumların istatistiksel değerlendirilmesi, görsel olarak benzer örneklerin ayrımını destekler (Bruce vd., 2024).

Kemometri analitik verilerin nesnel değerlendirilmesini destekler; ancak doğru örnekleme ve yöntem validasyonunun yerini alamaz. Az numune, çevresel maruziyet, yaşlanma ve partiler arası değişkenlik başlıca kısıtlardır. Laboratuvar bulgularının gerçek vakalara aktarılabilmesi için temsili örnekleme ve doğrulanmış yöntemler gereklidir. Bu nedenle kozmetik kalıntılar bireyselleştirici kanıtlar değil, kaynak karşılaştırmasını ve olayın yeniden kurgulanmasını destekleyen ilişkilendirici deliller olarak ele alınmalıdır.

Kozmetiklerin adli karşılaştırılabilirliği marka, ürün türü, ton ve üretim partisine bağlı formülasyon farklılıklarına dayanır. Yağ, mum, polimer, pigment ve mineral dolgu maddeleri çeşitli analitik yöntemlerle karakterize edilebilir. Ancak analitik benzerlik, örneklerin kesinlikle aynı kaynaktan geldiğini göstermez; bulgular olay bağlamı ve diğer delillerle birlikte yorumlanmalıdır.

Kozmetoloji, kişisel bakım ve kozmetik ürünlerin kullanımını inceleyerek adli bilimlerle kesişir. Adli kozmetoloji; kozmetik maddeler ile bunlardan kaynaklanan mikroizlerin tespiti, toplanması, karakterizasyonu, karşılaştırılması ve delil değerinin yorumlanmasını kapsar. Analitik kimya, malzeme bilimi, spektroskopi,

mikroskopi ve kemometriyi birleştiren bu disiplin, klasik tahribatlı analizlerden düşük örnek tüketimli veya tahribatsız yöntemlere ve çok değişkenli veri değerlendirmesine doğru gelişmiştir (Gül vd., 2018).

Gordon ve Coulson (2004), 53 fondöten örneğini FTIR, SEM-EDS ve GC-FID ile analiz ederek sırasıyla %98,3, %93,8 ve %82,0 ayrım oranları elde etmiştir. Yaklaşık 5 mm²'lik lekelerin incelenebildiği çalışmada üç tekniğin birlikte kullanılması ayrım gücünü %99,7'ye yükseltmiştir. Bulgular, FTIR'ın etkili bir tarama aracı olduğunu ve çoklu analiz yaklaşımının adli karşılaştırmaları güçlendirdiğini göstermektedir.

Sharma vd. (2020), 23 markaya ait 31 fondöteni ATR-FTIR ile incelemiş, spektrumları PCA ve LDA ile değerlendirmiştir. Ayırt etme başarısı görsel karşılaştırmada %98, PCA'da %99,3, LDA'da %100 olarak bildirilmiş; üç bilinmeyen örnek kör testte doğru eşleştirilmiştir. Kâğıt mendil ve pamuklu kumaşa aktarılan izlerin belirlenmesi, yöntemin transfer örneklerine uygulanabilirliğini desteklemiştir.

AlSaeed vd. (2022), beş topikal kozmetik ürününün plastik, cam ve paslanmaz çelik yüzeylerdeki geri kazanım ve yaşlanma profilini SALDI-MS ile incelemiştir. Doğrudan sürüntü alma, çözücüyle özütlemeye göre daha yüksek sinyal kalitesi sağlamış; bazı karakteristik bileşenler 38 gün sonra da saptanmıştır. McEwan vd. (2025), 35 sıvı ten kozmetiğini ATR-FTIR, Raman ve XRD ile analiz etmiştir. ATR-FTIR kemometrik modeli eğitimde %98, kör doğrulama setinde %72 doğruluk sağlamış; Raman ve XRD mineral içeriğine ilişkin tamamlayıcı veriler sunmuştur. Uçucu bileşenlerin ilk 96 saatte değişmesi ve yakın tonların ayrımındaki güçlük, kuruma süresi ile ölçüm koşullarının standartlaştırılması gerektiğini göstermektedir.

Najjar ve Bridge (2020), sim ve ışıltı içeren 76 kozmetik formülasyonunu mikroskopi ve SEM-EDS ile incelemiştir. Elementel bileşime göre simler yedi, ışıltı örnekleri dört gruba ayrılmış; çapraz doğrulama doğruluğu %94–100 bulunmuştur. Parçacıklar yakın temaslı olaylarda tamamlayıcı mikroiz olabilir. Bununla birlikte çalışma ürün örnekleriyle sınırlıdır ve SEM-EDS'nin parçacıklara zarar verme olasılığı nedeniyle sonuçlar diğer incelemelerle birlikte yorumlanmalıdır.

Kalender (2025), 260 toz ve likit far örneğini ATR-FTIR ile incelemiş ve PCA modelinde %79 ayırt edilebilirlik bildirmiş; yöntemin kesin kimliklendirmeden çok tamamlayıcı kanıt niteliğinde olduğunu vurgulamıştır. Güneysu vd. (2025), göz kalemi izlerinin farklı kâğıt ve tekstil yüzeylerde su, deniz suyu ve toprak koşullarındaki kararlılığını araştırmıştır. Numune bileşimlerinde belirgin çevresel değişim görülmemiş; ancak polyester kumaştan karakteristik pik alınamaması, taşıyıcı yüzeyin analiz başarısında önemli olduğunu göstermiştir.

Bu derleme, kozmetik kalıntıların adli incelemesine ilişkin temel ve güncel çalışmaları kronolojik ve yöntemsel açıdan değerlendirmektedir. Analitik teknikler ürün grubu, örnek özellikleri, ayırt etme kapasitesi ve çevresel değişimler bakımından karşılaştırılarak sınırlılıklar ve araştırma gereksinimleri tartışılmıştır.

Materyal ve Metot

Çalışmanın materyalini, kozmetik delillerin adli karakterizasyonu ve yöntemsel gelişmelerine odaklanan güncel araştırma literatürü oluşturmuştur. Ulusal ve uluslararası veri tabanlarındaki hakemli makaleler ve lisansüstü tezler; fondöten, ruj, göz kalemi, far, yüz pudrası ve oje kalıntıları bakımından taranmıştır. Seçilen çalışmalar yayın yılı, ürün grubu, örneklem büyüklüğü, spektroskopik, kromatografik ve mikroskobik yöntemler, kemometrik yaklaşımlar ve raporlanan adli çıktılar üzerinden karşılaştırılmıştır. Ayrıca transfer mekanizmaları ile zaman içindeki bozunma ve yaşlanma profilleri incelenmiştir.

Tablo 1. Kozmetik ürünlerin adli incelemesine ilişkin seçilmiş çalışmaların kronolojik gelişimi

Yıl	Yazar(lar)	Çalışmanın adı
1981	Andrasko	Forensic analysis of lipsticks
2004	Gordon ve Coulson	The evidential value of cosmetic foundation smears in forensic casework
2013	Shimamoto vd.	Use of portable X-ray fluorescence to discriminate brands of nail polishes: a potential forensic tool
2016	Gherghel vd.	Analysis of transferred fragrance and its forensic implications
2017	Boll vd.	Differentiation of hair using ATR FT-IR spectroscopy: A statistical classification of dyed and non-dyed hairs
2019	Gherghel vd.	Fragrance transfer between fabrics for forensic reconstruction applications

Yıl	Yazar(lar)	Çalışmanın adı
2020	Najjar ve Bridge	SEM-EDS analysis and characterization of glitter and shimmer cosmetic particles
2020	Sharma vd.	Differentiation of Cosmetic Foundation Creams Using ATR-FTIR: A Rapid and NonDestructive Approach in Trace Evidence Analysis
2020	Terlier vd.	Chemical recognition based on high-accuracy matching factors as per time-of-flight–secondary-ion mass spectrometry: Application to trace cosmetic residues in human forensics
2021	Chophi vd.	Rapid and non-destructive analysis of eye-cosmetics using ATR-FTIR spectroscopy and chemometrics
2022	AlSaeed vd.	Forensic analysis of cosmetic smudges using SALDI-MS: recovery and ageing study
2022	Paşaoğlu	Tırnak cilalarının Fourier dönüşümlü kızılötesi spektrometresi kullanılarak incelenmesi (Yüksek lisans tezi)
2022	Gładysz vd.	A multitechnique approach for discrimination and identification of lipsticks for forensic purposes
2023	Kendüz	Katı mat rujların adli amaçlı incelenmesi (Yüksek lisans tezi)
2023	Onursoy	Likit göz kalemlerinin adli amaçlı Fourier Transform Infrared Spektrofotometresi (FTIR) ile incelenmesi (Yüksek lisans tezi)
2023	Turkay	Adli bilimlerde dudak kozmetik ürünlerinin farklı ortamlardaki stabilitesine zamanın etkisinin incelenmesi (Yüksek lisans tezi)
2023	Soluk	Fondötenlerin FTIR (Fourier Dönüşümlü Kızılötesi Spektroskopisi) kullanılarak adli amaçlı incelenmesi (Yüksek lisans tezi)
2024	Liechti ve Lory	Hair fixative traces on footwear–Establishing a link between footwear and the victim's hair after kicks to the head
2025	Güneysu vd.	Göz kozmetiği ürünlerinin spektroskopik yöntemlerle adli kanıt olarak incelenmesi
2025	Kalender	Göz farlarının fourier dönüşümlü kızılötesi spektrometresi kullanılarak adli amaçlı incelenmesi
2025	McEwan vd.	A multi-modal spectroscopic approach to forensic discrimination of liquid cosmetic complexion products

Tablo 1, adli kozmetik incelemelerindeki tarihsel ve yöntemsel dönüşümü göstermektedir. İlk çalışmalar ruj gibi kolay transfer olan ürünlere odaklanmış; renk karşılaştırması, TLC, GC ve elementel analizden yararlanmıştır (Andrasko, 1981). 2000'li yıllarda fondöten, krem ve kapatıcı gibi çok bileşenli ten ürünlerinin karakterizasyonu öne çıkmış; FTIR ve SEM-EDS kullanılmıştır (Gordon ve Coulson, 2004; Sharma vd., 2020). 2019 sonrasında araştırmalar düşük örnek tüketimi, hız ve istatistiksel güvenilirliğe yönelmiştir. ATR-FTIR ve Raman'ın kemometriyle kullanımı yaygınlaşırken ToF-SIMS ve SALDI-MS gibi kütle spektrometrisi yöntemleri ile çoklu analitik iş akışları gelişmiştir (Bruce vd., 2024; Chophi vd., 2019, 2021; McEwan vd., 2025; Terlier vd., 2020).

Tablo 2. Seçilmiş çalışmaların analiz yöntemi, kısa özet ve temel sonuçlar açısından karşılaştırılması

Çalışmanın adı	Yazar (Yıl)	Analiz yöntemi	Kısa özet	Sonuç
Forensic analysis of lipsticks	Andrasko (1981)	TLC, GC	Ruj izlerinin ve bileşenlerinin adli amaçlı ilk sistemli kromatografik incelemelerinden biridir.	Rujların renk ve kimyasal bileşenlerine göre sınıflandırılabileceğini ve eşleştirilebileceğini göstermiştir.
The evidential value of cosmetic foundation smears in forensic casework	Gordon ve Coulson (2004)	FTIR, GC-FID, SEM-EDS	Giysilere ve yüzeylere bulaşan fondöten lekelerinin adli vakalardaki ayırt edici gücü araştırılmıştır.	Tekniklerin kombinasyonu %99,7 ayırt edicilik sağlamış; küçük ölçekli bir lekenin bile ayırt edilebildiği gösterilmiştir.

Çalışmanın adı	Yazar (Yıl)	Analiz yöntemi	Kısa özet	Sonuç
Use of portable X-ray fluorescence to discriminate brands of nail polishes: a potential forensic tool	Shimamoto vd. (2013)	EDXRF	Adli vakalarda delil niteliği taşıyabilen oje markalarının sınıflandırılmasını ve birbirinden ayırt edilmesini değerlendirmektedir.	EDXRF tekniğinin suç mahallerindeki oje örneklerini markalarına göre ayırt etmek için hızlı, düşük maliyetli ve çevre dostu bir alternatif olduğu gösterilmiştir.
Analysis of transferred fragrance and its forensic implications	Gherghel vd. (2016)	GC-MS	Kıyafetler üzerindeki parfüm izlerinin adli analizi amacıyla bir GC-MS yöntemi geliştirilmiş; yaşlanma ve temas süresinin transfer dinamiklerine etkileri incelenmiştir.	Bulgular, bir dakikalık kısa temasın dahi önemli ölçüde bileşen aktarımı sağladığını; dolayısıyla parfüm izlerinin yakın temaslı adli vakalarda dışlayıcı delil olarak değerlendirilebileceğini ortaya koymaktadır.
Differentiation of hair using ATR FT-IR spectroscopy: A statistical classification of dyed and non-dyed hairs	Boll vd. (2017)	ATR-FTIR Spektroskopisi ve Çok Değişkenli İstatistiksel Analiz	Doğal ve boyalı insan saçlarından alınan ATR-FTIR spektrumları istatistiksel olarak değerlendirilmiştir	Kontrol numunesi gerektirmeyen bu istatistiksel yaklaşım, saç delillerinin kimliklendirilmesinde mikroskobik analizleri destekleyen güvenilir bir yöntemdir.
Fragrance transfer between fabrics for forensic reconstruction applications	Gherghel vd. (2019)	SPME-GC-MS	Parfümün bir kumaştan diğerine transferinde yaşlanma ve temas süresi etkisi araştırılmıştır.	48 saate kadar yaşlanma sonrasında koku bileşenleri geri kazanılmış; transfer pamuk ve polyesterde farklılaşmıştır.
SEM-EDS analysis and characterization of glitter and shimmer cosmetic particles	Najjar ve Bridge (2020)	SEM-EDS	Kozmetik ürünlerdeki sim ve parıltı parçacıklarının elementel ve morfolojik karakterizasyonu yapılmıştır.	Boyut, şekil ve elementel bileşimlerin güçlü bir ilişkilendirme sağlayabileceğini göstermiştir.
Differentiation of Cosmetic Foundation Creams Using ATR-FTIR: A Rapid and NonDestructive Approach in Trace Evidence Analysis	Sharma vd. (2020)	ATR-FTIR Spektroskopisi	Krem fondötenlerin hızlı ve numuneye zarar vermeden ayırt edilebilmesi için kullanılmıştır.	Kimyasal fonksiyonel gruplara göre yüksek doğrulukla ayırt edilebildiğini göstermiştir.
Chemical recognition based on high-accuracy matching factors as per time-of-flight–secondary-ion mass spectrometry: Application to trace	Terlier vd. (2020)	ToF-SIMS	İnsan derisi veya yüzeylerdeki mikroskopik kalıntıların kütle spektrometrisi ile haritalaması yapılmıştır.	Az miktardaki kalıntıların bile kütle spektrometrisiyle karakterize edilebileceğini göstermiştir.

Çalışmanın adı	Yazar (Yıl)	Analiz yöntemi	Kısa özet	Sonuç
cosmetic residues in human forensics				
Rapid and non-destructive analysis of eye-cosmetics using ATR-FTIR spectroscopy and chemometrics	Chophi et al. (2021)	ATR-FTIR ve Kemometri	Göz kozmetiklerinin tahribatsız analizi yapılmış ve spektrumlar kemometrik modellerle işlenmiştir.	İstatistiksel modellerin birlikte kullanılmasının yüksek doğrulukla sınıflandırma sağlayabildiği görülmüştür.
Forensic analysis of cosmetic smudges using SALDI-MS: recovery and ageing study	AlSaeed vd. (2022)	SALDI-MS	Kozmetik lekelerin yüzeylerden geri kazanımı ve zamanla uğradıkları bozulma süreçleri incelenmiştir.	Lekelerin yaşlanma süreçlerinin izlenebileceği ve kimyasal profillerin korunabildiği saptanmıştır.
Tırnak cilalarının Fourier dönüşümlü kızılötesi spektrometresi kullanılarak incelenmesi (Yüksek lisans tezi)	Paşaoğlu (2022)	FTIR Spektroskopisi	Tırnak cilalarının adli amaçlı kimyasal karakterizasyonu yapılmıştır.	Polimer, çözücü ve pigment bileşenlerinin spektrumları sayesinde marka temelinde ayırt edilebildiğini göstermiştir.
A multitechnique approach for discrimination and identification of lipsticks for forensic purposes	Gładysz vd. (2022)	ATR-FTIR Spektroskopisi CRM (Konfokal Raman Mikroskobu) MEKC (Misel Elektrokinetik Kromatografi / Kapiler Elektroforez) GC-MS	Rujların ayırt edilebilmesi için morfolojik, elementel ve kimyasal teknikler bir arada kullanılmıştır.	En yüksek ayırt etme gücünün verilerin kombinasyonuyla sağlandığı sonucuna varılmıştır.
Katı mat rujların adli amaçlı incelenmesi (Yüksek lisans tezi)	Kendüz (2023)	ATR-FTIR Spektroskopisi TLC Kemometri	Transfer kanıtı olarak sıkça karşılaşılan katı mat rujların kimyasal yapıları çalışılmıştır.	Spesifik dolgu ve balmumu bileşenlerinin markalar ve seriler arasında ayırt edicilik sağlayabildiği bulunmuştur.
Likit göz kalemlerinin adli amaçlı FTIR ile incelenmesi	Onursoy (2023)	FTIR Spektroskopisi	Likit göz kalemlerinin kuruduktan sonra bıraktığı izlerin adli analizi simüle edilmiştir.	İzlerin tahribatsız incelenebileceğini ve farklılıkların spektral olarak belirlenebildiğini göstermiştir.
Fondötenlerin FTIR kullanılarak adli amaçlı incelenmesi	Soluk (2023)	FTIR Spektroskopisi	Fondötenlerin kızılötesi spektroskopisiyle veri tabanı oluşturulması ve adli incelemesi hedeflenmiştir.	İnorganik bileşenlerin belirgin tepe noktaları oluşturarak ayırt ediciliği artırdığını kanıtlamıştır.
Dudak kozmetik ürünlerinin stabilitesine zamanın etkisi	Turkay (2023)	ATR-FTIR Spektroskopisi TLC VSC	Dudak ürünlerinin farklı ortamlarda zamanla uğradığı değişimler incelenmiştir.	Belirli temel piklerin zamana karşı dirençli kalarak adli eşleştirmeye izin verdiğini saptamıştır.

Çalışmanın adı	Yazar (Yıl)	Analiz yöntemi	Kısa özet	Sonuç
Hair fixative traces on footwear– Establishing a link between footwear and the victim's hair after kicks to the head	Liechti & Lory (2024)	FTIR, Raman Spektroskopisi	Saç şekillendirici ürünlerin ayakkabı yüzeyine transferi deneysel olarak değerlendirilmiştir.	Kalıntıların saptanıp ayırt edilebildiği ve ilişkilendirici mikroiz olarak değerlendirilebileceği bildirilmiştir.
Göz kozmetiği ürünlerinin spektroskopik yöntemlerle adli kanıt olarak incelenmesi	Güneysu vd. (2025)	ATR-FTIR Spektroskopisi VSC Kemometri	Göz kozmetiklerinin adli delil olarak değeri değerlendirilmiştir.	Mikroskopik miktarlarda bile fiziksel teması doğrulamada yüksek delil değerine sahip olduğunu göstermiştir.
Göz farlarının fourier dönüşümlü kızılötesi spektrometresi kullanılarak adli amaçlı incelenmesi	Kalender (2025)	ATR-FTIR Spektroskopisi Kemometri	Adli vakalarda eser delil olan göz farlarının kimyasal analizle marka, renk ve yapılarına göre sınıflandırılmasını değerlendirmektedir.	ATR-FTIR ve PCA kullanılarak incelenen 260 göz farının yüksek oranda ayırt edilebildiği hesaplanmıştır.
A multi-modal spectroscopic approach to forensic discrimination of liquid cosmetic complexion products	McEwan vd. (2025)	ATR-FTIR Spektroskopisi Raman Spektroskopisi XRD Kemometri	Sıvı ten ürünlerinin ayrımı için birden fazla tekniğin kullanımı test edilmiştir.	Çok teknikli yaklaşımın, tek bir yönteme kıyasla çapraz doğrulama sağladığı sonucuna varılmıştır.

Tablo 3. Seçilmiş çalışmalarda kullanılan analitik yöntemlerin ürün gruplarına göre sınıflandırılması

Analiz yöntemi	Ürün grubu	Yazar(lar) (Yıl)
Kızılötesi Spektroskopisi (FTIR / ATR-FTIR)	Fondöten / Ten ürünleri	Gordon ve Coulson (2004), Sharma vd. (2020), Soluk (2023), McEwan vd. (2025)
	Göz kozmetiği	Chophi vd. (2021), Onursoy (2023), Güneysu vd. (2025), Kalender (2025)
	Tırnak cilası	Paşaoğlu (2022)
	Saç (Boyalı / Boyasız)	Boll vd. (2017)
	Saç şekillendirici ürün kalıntıları	Liechti ve Lory (2024)
	Dudak ürünleri (Ruj/Parlatıcı)	Turkay (2023), Gładysz vd. (2022), Kendüz (2023)
Kütle Spektrometrisi (ToF-SIMS, SALDI-MS, SPME-GC-MS, GC-MS)	Kozmetik lekeler	Terlier vd. (2020), AlSaeed vd. (2022)
	Parfüm	Gherghel vd. (2016); Gherghel vd. (2019)
	Ruj	Gładysz vd. (2022)
SEM-EDS	Sim ve parıltı parçacıkları, fondöten	Gordon ve Coulson (2004), Najjar ve Bridge (2020)
Kromatografik Yöntemler (TLC, GC, GC-FID, MEKC)	Fondöten	Gordon ve Coulson (2004)
	Ruj	Andrasko (1981), Kendüz (2023), Gładysz vd. (2022)
Raman Spektroskopisi	Saç şekillendirici ürün kalıntıları	Liechti ve Lory (2024)
	Ten ürünleri	McEwan vd. (2025)
X-Işını Kırınımı	Ten ürünleri	McEwan vd. (2025)

Analiz yöntemi	Ürün grubu	Yazar(lar) (Yıl)
Video Spektral Karşılaştırıcı	Dudak ürünleri (Ruj/Parlatıcı)	Turkay (2023)
	Göz kozmetiği	Güneysu vd. (2025)
EDXRF (Enerji Dağıtımlı X-Işını Floresan Spektrometresi)	Tırnak cilası	Shimamoto vd. (2013)

Bulgular ve Tartışma

Literatür, klasik yöntemlerden ATR-FTIR, Raman, SEM-EDS ve kütle spektrometrisine geçişi; bu analizlerin PCA ve LDA gibi kemometrik modellerle desteklendiğini göstermektedir. Hızlı ve tahribatsız ATR-FTIR öne çıkarken SEM-EDS ve kütle spektrometrisi elementel, morfolojik ve moleküler düzeyde tamamlayıcı bilgi sunar. Güncel çalışmalar transfer, yaşlanma ve çevresel koşulların etkisini de ele almaktadır. Lisansüstü tezler ise tırnak cilası, katı mat ruj, likit göz kalemi, dudak ürünleri, fondöten ve farlara ilişkin ulusal veri birikimini ortaya koymaktadır.

Ten ve Dudak Kozmetiklerine Ait İzler

Fondöten, likit ten ürünleri ve rujlar geniş yüzeylere uygulanmaları ve kolay transfer edilmeleri nedeniyle sık incelenmektedir. ATR-FTIR ve kemometri birçok örneği ayırt edebilmekte; gerektiğinde Raman, XRD, GC-MS veya MEKC gibi tamamlayıcı teknikler değerlendirmeyi güçlendirmektedir (Gładysz vd., 2022; Gordon ve Coulson, 2004; McEwan vd., 2025). Dudak ürünlerinde çevresel stabilite ve yaşlanma spektral sonuçları etkileyebilir (Turkay, 2023).

Göz, Tırnak ve Partiküler Kozmetik İzleri

Göz kozmetikleri ATR-FTIR ve kemometrik sınıflandırmayla, tırnak cilaları FTIR ve X-ışını floresansıyla karakterize edilebilir (Chophi vd., 2021; Paşaoğlu, 2022; Shimamoto vd., 2013). Sim ve ışıltı parçacıkları SEM-EDS ile morfolojik ve elementel açıdan sınıflandırılabilir (Najjar ve Bridge, 2020). Yüz pudralarına odaklanan bağımsız çalışmalar ise sınırlıdır. Tablolar, VSC'nin dudak (Turkay, 2023) ve göz kozmetiklerinde (Güneysu vd., 2025) kullanıldığını göstermektedir. VSC, karşılaştırmalı analizlerde tamamlayıcı görsel-spektral veri sağlayabilir.

Saç Ürünleri, Parfümler ve Kişisel Bakım Kaynaklı İzler

ToF-SIMS ve SALDI-MS, kozmetik kalıntıların kimyasal haritalanması, geri kazanımı ve yaşlanmasının incelenmesini sağlar (AlSaeed vd., 2022; Terlier vd., 2020). Saç boyası ve sabitleyici kalıntıları (Boll vd., 2017; Liechti ve Lory, 2024) ile kumaşlar arasındaki parfüm transferi (Gherghel vd., 2016, 2019), dekoratif kozmetik dışındaki kişisel bakım izlerinin de olay yeri rekonstrüksiyonuna katkı sunabileceğini göstermektedir.

Şekil 1'de temel kozmetik ürün sınıfları ve örnekleri verilmiştir; ancak derlemede bu ürünlerin tümüne yönelik adli analiz çalışmasına rastlanmamıştır. Vücut spreyi, kokulu yağlar, nemlendirici, temizleyici, tonik, cilt maskesi, güneş kremi, sabun, duş jeli, vücut losyonu, deodorant, ağız ve saç bakım ürünleri ile tırnak ürünleri için doğrudan adli karşılaştırma verisi bulunmamaktadır. Bu durum ürünlerin adli değer taşımadığı anlamına gelmez; transfer, kalıcılık, yüzey etkileşimi ve çevresel yaşlanma bakımından araştırma boşluğuna işaret eder.

Adli kozmetoloji, temasla transfer olan günlük ürünler üzerinden kişi, nesne ve olay yeri arasındaki ilişkilerin aydınlatılmasına katkı sağlar. Ruj, fondöten, göz kozmetikleri ve partiküler kalıntılara ilişkin bulguların güvenilirliği; transfer mekanizmaları, yüzey özellikleri, çevresel faktörler ve olay bağlamının birlikte değerlendirilmesine bağlıdır. Spektroskopik ve çoklu teknikler örnek bütünlüğünü daha iyi korurken istatistiksel modeller ürün ayrımını nesnelleştirebilir. Bununla birlikte örneklem büyüklüğü, ürün çeşitliliği ve analiz koşulları genellenebilirliği sınırlar. Temel eksiklik, laboratuvardaki yüksek sınıflandırma başarısının farklı marka, parti, ton ve yüzeylerde gerçek adli koşullarda korunup korunmadığıdır. İki örneğin ayırt edilememesi aynı kaynağı kanıtlamaz; analitik benzerlik, kaynak ilişkilendirmesi ve bireyselleştirme ayrılmalı, yöntemler duyarlılık, seçicilik, tekrarlanabilirlik ve genellenebilirlik bakımından sınanmalıdır.

Sonuç ve Öneriler

Gelecek çalışmalarda daha geniş pazar örneklemleriyle aynı ürünlerin farklı tonları ve partileri arasındaki varyasyonlar incelenmelidir. Karışık izler, farklı yüzeylere transfer, kalıcılık, çevresel yaşlanma ve depolama koşulları sistematik olarak değerlendirilmelidir. Kontrollü temas simülasyonları ve etik koşullarda toplanan gerçek vaka örnekleri, laboratuvar yöntemlerinin sahaya aktarılmasını destekleyecektir. VSC'nin dudak ve göz kozmetiklerinde farklı yüzey ve çevresel koşullardaki performansının ATR-FTIR ve kemometriyle karşılaştırılması, yöntemin kullanım alanı ve sınırlılıklarını belirlemeye yardımcı olacaktır.

Analitik iş akışlarında önce tahribatsız spektroskopik taramalar yapılmalı; gerektiğinde SEM-EDS gibi tamamlayıcı mikroanalizlere, son aşamada ise tahribatlı yöntemlere başvurulmalıdır. Tek bir protokol yerine numune miktarı ve laboratuvar olanaklarına uyarlanabilen yaklaşımlar benimsenmelidir. Referans spektrum kütüphaneleri ve ortak raporlama standartları karşılaştırılabilirliği artıracaktır. Kemometrik ve makine öğrenmesi modelleri bağımsız veri setleri, kör numuneler ve laboratuvarlar arası çalışmalarla doğrulanmalı; hata oranları ve belirsizlikler raporlanmalıdır.

Kozmetik mikroizler tek başına kesin kimliklendirme veya bireyselleştirme sağlamaz. Uygun örnekleme ve muhafaza, analitik kalite güvencesi, çoklu yöntem ve istatistiksel değerlendirmelerle şüpheli, mağdur, nesne ve olay yeri arasındaki olası ilişkilerin kurulmasına katkı sunabilir. Amaç yalnızca yüksek doğruluk değil, sonuçların güvenilir olduğu koşulları ve desteklediği adli çıkarımları da belirlemektir. Adli kozmetoloji; analitik kimya, kozmetik bilimi, malzeme bilimi, istatistik ve adli bilimleri birleştiren gelişime açık disiplinlerarası bir alandır.

Bilgilendirme Notu

Bu çalışma, herhangi bir ticari ürün veya markanın tanıtımını amaçlamamaktadır. Derleme kapsamında sunulan tüm bulgu ve bilgiler, konuyla ilgili yayımlanmış hakemli bilimsel makaleler ile lisansüstü tez çalışmalarından bağımsız bir şekilde derlenerek oluşturulmuştur. Yazarlar, bu araştırma ile ilgili herhangi bir çıkar çatışması bulunmadığını beyan eder.

Kaynakça

AlSaeed, H., Amin, M. O., & Al-Hetlani, E. (2022). Forensic analysis of cosmetic smudges using surface-assisted laser desorption/ionization mass spectrometry: Recovery and ageing study. *Microchemical Journal, 180*, 107609. https://doi.org/10.1016/j.microc.2022.107609

Andrasko, J. (1981). Forensic analysis of lipsticks. *Forensic Science International, 17*(3), 235–251. https://doi.org/10.1016/0379-0738(81)90173-0

Boll, M. S., Doty, K. C., Wickenheiser, R., & Lednev, I. K. (2017). Differentiation of hair using ATR FT-IR spectroscopy: A statistical classification of dyed and non-dyed hairs. *Forensic Chemistry, 6*, 1–9.

Bruce, K. A., Arnold, D. C., Sauzier, G., & Lewis, S. W. (2024). Considerations and future perspectives for the vibrational spectroscopic analysis of forensic cosmetic evidence. *Wiley Interdisciplinary Reviews: Forensic Science, 6*(6), e1533. https://doi.org/10.1002/wfs2.1533

Chisvert, A., & Salvador, A. (2018). Ultraviolet filters in cosmetics: Regulatory aspects and analytical methods. In A. Salvador & A. Chisvert (Eds.), *Analysis of cosmetic products* (2nd ed., pp. 85–106). Elsevier. https://doi.org/10.1016/B978-0-444-63508-2.00005-9

Chophi, R., Sharma, S., Jossan, J. K., & Singh, R. (2021). Rapid and non-destructive analysis of eye-cosmetics using ATR-FTIR spectroscopy and chemometrics. *Forensic Science International, 329*, 111062. https://doi.org/10.1016/j.forsciint.2021.111062

Chophi, R., Sharma, S., Sharma, S., & Singh, R. (2019). Trends in the forensic analysis of cosmetic evidence. *Forensic Chemistry, 14*, 100165. https://doi.org/10.1016/j.forc.2019.100165

Çomoğlu, T. (2012). Kozmetikler. *Marmara Pharmaceutical Journal, 16*(1), 1–8. https://doi.org/10.12991/201216414

Gherghel, S., Morgan, R. M., Arrebola-Liébanas, J. F., Blackman, C. S., & Parkin, I. P. (2019). Fragrance transfer between fabrics for forensic reconstruction applications. *Science & Justice, 59*(3), 256–267.

Gherghel, S., Morgan, R. M., Blackman, C. S., Karu, K., & Parkin, I. P. (2016). Analysis of transferred fragrance and its forensic implications. *Science & Justice, 56*(6), 413–420.

Gładysz, M., Król, M., Karoly, A., Szalai, R., & Kościelniak, P. (2022). A multitechnique approach for discrimination and identification of lipsticks for forensic purposes. *Journal of Forensic Sciences, 67*(2), 494–504. https://doi.org/10.1111/1556-4029.14945

Gładysz, M., Król, M., & Kościelniak, P. (2021). Current analytical methodologies used for examination of lipsticks and its traces for forensic purposes. *Microchemical Journal, 164*, 106002. https://doi.org/10.1016/j.microc.2021.106002

Gordon, A., & Coulson, S. (2004). The evidential value of cosmetic foundation smears in forensic casework. *Journal of Forensic Sciences, 49*(6), 1244–1252. https://doi.org/10.1520/JFS2004176

Gül, Ü., Kozacı, L. D., & Hancı, İ. H. (2018). *Adli kozmetoloji*. Seçkin Yayıncılık.

Güneysu, G. G., Kendüz, U., Kızıl, S., & Atasoy, S. (2025). Göz kozmetiği ürünlerinin spektroskopik yöntemlerle adli kanıt olarak incelenmesi. *Gümüşhane Üniversitesi Fen Bilimleri Dergisi, 15*(1), 184–196. https://doi.org/10.17714/gumusfenbil.1601077

Houck, M. M., & Siegel, J. A. (2016). *Adli bilimlerin temeli*. Nobel Akademik Yayıncılık.

Kalender, F. Ö. (2025). *Göz farlarının Fourier dönüşümlü kızılötesi spektrometresi kullanılarak adli amaçlı incelenmesi* [Yüksek lisans tezi, Üsküdar Üniversitesi].

Kendüz, U. (2023). *Katı mat rujların adli amaçlı incelenmesi* [Yüksek lisans tezi, Üsküdar Üniversitesi].

Liechti, J. M., & Lory, M. (2024). Hair fixative traces on footwear–Establishing a link between footwear and the victim's hair after kicks to the head. *Forensic Science International, 355*, 111918.

Locard, E. (2010). *Manual de técnica policíaca*. Editorial MAXTOR.

McEwan, J., Bruce, K. A., Pitts, K., & Sauzier, G. (2025). A multi-modal spectroscopic approach to forensic discrimination of liquid cosmetic complexion products. *Forensic Chemistry, 45*, 100677. https://doi.org/10.1016/j.forc.2025.100677

Najjar, K., & Bridge, C. M. (2020). SEM-EDS analysis and characterization of glitter and shimmer cosmetic particles. *Forensic Science International, 317*, 110527. https://doi.org/10.1016/j.forsciint.2020.110527

Onursoy, S. (2023). *Likit göz kalemlerinin adli amaçlı Fourier Transform Infrared spektrofotometresi (FTIR) ile incelenmesi* [Yüksek lisans tezi, Üsküdar Üniversitesi].

Paşaoğlu, E. (2022). *Tırnak cilalarının Fourier dönüşümlü kızılötesi spektrometresi kullanılarak incelenmesi* [Yüksek lisans tezi, Üsküdar Üniversitesi].

Sharma, S., Chophi, R., Kaur, H., & Singh, R. (2020). Differentiation of cosmetic foundation creams using attenuated total reflection Fourier-transform infrared spectroscopy: A rapid and nondestructive approach in trace evidence analysis. *Journal of Forensic Sciences, 65*(3), 751–761. https://doi.org/10.1111/1556-4029.14257

Shimamoto, G. G., Terra, J., & Bueno, M. I. M. (2013). Use of portable X-ray fluorescence to discriminate brands of nail polishes: A potential forensic tool. *Journal of the Brazilian Chemical Society, 24*(5), 731–735.

Soluk, M. (2023). *Fondötenlerin FTIR (Fourier Dönüşümlü Kızılötesi Spektroskopisi) kullanılarak adli amaçlı incelenmesi* [Yüksek lisans tezi, Üsküdar Üniversitesi].

Terlier, T., Lee, K.-B., & Lee, Y. (2020). Chemical recognition based on high-accuracy matching factors as per time-of-flight–secondary-ion mass spectrometry: Application to trace cosmetic residues in human forensics. *Microchemical Journal, 159*, 105446. https://doi.org/10.1016/j.microc.2020.105446

Turkay, Ş. (2023). *Adli bilimlerde dudak kozmetik ürünlerinin farklı ortamlardaki stabilitesine zamanın etkisinin incelenmesi* [Yüksek lisans tezi, Üsküdar Üniversitesi].

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

USING MICROSOFT EXCEL IN TEACHING ELECTROSTATICS: IMPACT ON GRADE 11 STUDENTS' ACHIEVEMENT AND PERCEPTIONS

Lorena Kelo
Entela Vinçani
0009-0004-6995-6382, "Fan S. Noli" University, Faculty of Natural and Human Sciences, Department of Mathematics and Physics, Korçë, Albania
Dhimitraq Gjata" Unified School, Korçë, Albania

Abstract

The integration of digital technologies into physics teaching creates opportunities to connect mathematical formulations with numerical, graphical, and vector representations of physical phenomena. This article presents the use of Microsoft Excel as a didactic tool for modeling Coulomb's law and the electric field of a dipole and examines changes in Grade 11 students' achievement and perceptions following an Excel-supported learning activity. The study involved 17 students and employed a one-group pretest–posttest design using a PRE-TEST and POST-TEST, a 30-item Likert-scale questionnaire, and open-ended questions. The mean score increased from 9.94 to 14.41 points; a paired-samples t test showed a statistically significant difference, $t(16) = -7.849$, $p < .001$. Students' perceptions were generally positive, particularly regarding conceptual understanding, active learning, reasoning, and visualization. Alongside these benefits, initial difficulties in using Excel and interpreting the physical meaning of results were identified. Because the study did not include a control group, the findings demonstrate improvement after the activity but do not permit attribution of that improvement solely to Excel. The article argues that Excel can function as a complementary tool for modeling, virtual experimentation, and interpretation when used with appropriate pedagogical guidance.

Keywords: Microsoft Excel; physics teaching; Coulomb's law; physical modeling; visualization; active learning.

INTRODUCTION

Physics teaching requires students to move beyond memorizing formulas and to understand relationships among physical quantities, the conditions under which laws apply, the direction of change, and the physical meaning of results. This requirement is particularly evident in electrostatics, where a problem may simultaneously involve scalar quantities, vectors, distances, charge signs, and representations in a coordinate system. Coulomb's law is a fundamental relationship in electrostatics and provides a basis for understanding electric force, electric field, and the principle of superposition.

For students, the difficulty does not lie only in numerical substitution into a formula. They must understand how force changes when charge or distance changes, why the force is attractive or repulsive, how components along the coordinate axes are determined, and how the resultant force is constructed when several charges are involved. In this context, a static representation in a textbook or table can be complemented by an environment in which parameters can be changed and results recalculated immediately.

Microsoft Excel provides functions for calculation, data organization, graphical representation, and automation of mathematical relationships. In physics teaching, spreadsheets can be used for data manipulation, visualization, and simulation of physical systems, creating an accessible environment for linking mathematical models with system behavior (Katoch, 2020). More recent work also shows that Excel can be used to construct

parameterized physics simulations in which changes in input data are accompanied by immediate changes in results and representations (Saputra, 2025).

In this study, the "Physics with Excel" approach treats the program as an intermediary between the formula and the interpretation of the phenomenon. Students can change an input quantity, observe the immediate change in the result, and compare it with a physical prediction. This logic is consistent with the literature on computer simulations, which emphasizes the value of parameter exploration and the integration of technology with pedagogical support (Rutten et al., 2012; Smetana & Bell, 2012).

The study focuses on two topics in electrostatics: Coulomb's law and the electric field of a dipole. For Coulomb's law, an application was developed to analyze the action of three charges on a test charge and to calculate the components and resultant force. For the dipole, a model was developed to calculate field intensity at different points and to represent field components and field lines. These applications were used as supporting tools in the learning process, while the outcomes of the activity were examined through pre- and post-activity achievement and students' perceptions.

The purpose of this article is to present, in a concise scientific format, the development and pedagogical use of the Excel applications and to analyze the empirical data collected from students. Particular attention is given to changes in performance on Coulomb's law, students' evaluation of the tool, and the limits that should be observed when interpreting the results.

Research Questions and Hypothesis

The study was guided by two research questions: (1) How do students' knowledge and skills related to Coulomb's law change after an instructional activity supported by an Excel application? and (2) How do students perceive the use of the Excel application in learning the physics concepts addressed? The first question is linked to PRE-TEST and POST-TEST data, whereas the second is addressed through the questionnaire and open-ended responses.

For the quantitative comparison, H0 was formulated as follows: there is no statistically significant difference between pretest and posttest scores after the Excel-supported activity. The alternative hypothesis, H1, predicts a statistically significant difference between the two measurements.

MATERIALS AND METHODS

Theoretical Framework and Modeling Electrostatics in Excel

Coulomb's Law and Vector Analysis

Coulomb's law describes the electrostatic force between two point charges. The magnitude of the force is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them. The force acts along the line joining the charges, while its direction depends on their signs: charges with the same sign repel, whereas charges with opposite signs attract.

When several charges act on a test charge, the solution requires the principle of superposition. Each force is analyzed separately, resolved into components along the x- and y-axes, and the components are then added to determine the resultant force. This procedure is well suited to spreadsheet modeling because each step can be represented by a formula linked to the coordinates and values of the charges.

In the application developed for this study, the cells in a selected Excel area were conceptualized as a coordinate grid. The ROW() and COLUMN() functions were used to identify charge positions, while distances were calculated from coordinate differences. SQRT() was used for square roots, SUM() for adding

components, ATAN2() for the angle of the resultant force, and IF() for handling logical conditions. In this way, spreadsheet formulas were used to create a model whose outputs changed automatically in response to input data.

The didactic value of this organization lies in connecting three levels: the physical formula, the numerical calculation, and the vector representation. Rather than seeing only the final result, students can follow the components that produce it and observe how changing a position or charge changes the entire system. Research on learning with multiple representations suggests that combining symbolic, numerical, and visual forms can support understanding of complex concepts, provided that the relationships among the representations are made explicit to learners (Ainsworth, 2006; van der Meij & de Jong, 2006). The original spreadsheet interface is shown in Figure 1.

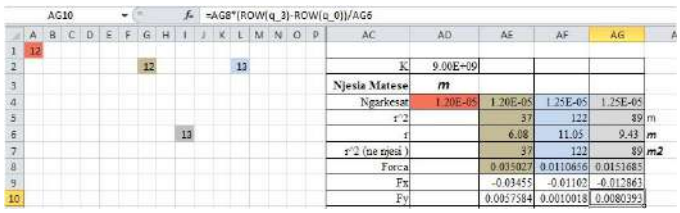


Figure 1. Original Excel model for Coulomb's law: charge configuration, force components, and resultant-force calculations. Source: authors' application.

Electric Field and the Dipole

The concept of the electric field makes it possible to describe the action of a system of charges in space. Electric field intensity at a point is a vector quantity and, for a system of charges, the resultant field is obtained from the vector sum of the contribution of each charge. Field lines provide a visual representation of field direction: they originate from positive charges and terminate on negative charges without crossing one another.

An electric dipole consists of two charges with opposite signs. In the Excel model, the field at a point P is calculated by separately determining the field components produced by each charge and then adding them. In this way, students can change the observation point or the parameters of the dipole and analyze how the magnitude, components, and direction of the field change.

The use of such an environment is not intended to replace theoretical explanation. Its purpose is to make relationships that may remain abstract on paper more concrete. Representing the vector, its components, and the field lines creates opportunities to connect mathematical symbolism with physical interpretation. This approach is consistent with findings that simulations are more effective when they complement instruction and are accompanied by guidance, reflection, and structured tasks (Smetana & Bell, 2012; Rutten et al., 2012). A view of the dipole modeling worksheet is provided in Figure 2.

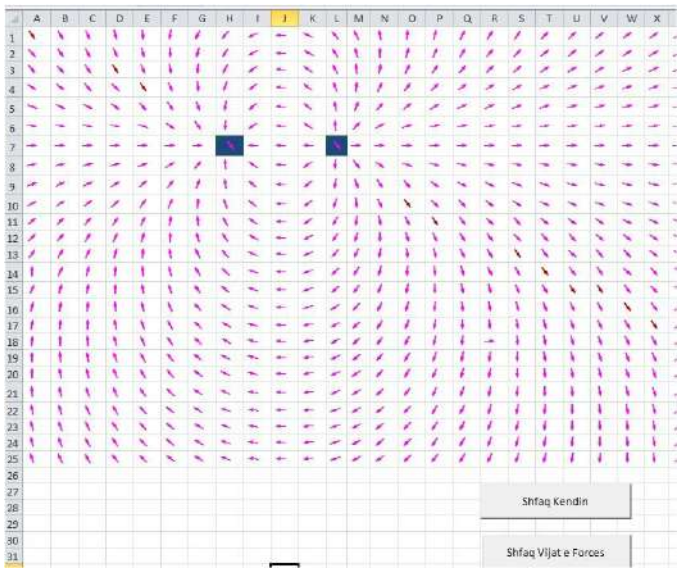


Figure 2. Original Excel worksheet for exploring the electric field of a dipole. Source: authors' application.

Excel as a Complementary Didactic Tool

Excel is a general-purpose program rather than a specialized virtual physics laboratory. This characteristic makes pedagogical design particularly important: formulas should be constructed transparently, input and output cells should be distinguishable, and students should be guided to interpret the results. In the present study, spreadsheet functions and automation were therefore treated as a computational infrastructure serving the physics content rather than as an end in themselves.

Within the curriculum context, technology has value when it is linked to learning objectives rather than used as an end in itself. For this reason, the study activity was built around Grade 11 physics concepts, and Excel was used in the service of physical analysis. This choice is supported by literature emphasizing that simulations and digital tools are more effective when integrated into the instructional scenario and accompanied by appropriate teacher support (Rutten et al., 2012; Smetana & Bell, 2012).

Study Design and Methodology

Design and Participants

The study was empirical and used both quantitative and qualitative data. Seventeen Grade 11 students participated. The same students took part in all stages, allowing each individual's results to be compared before and after the activity. The design can be described as a one-group pretest–posttest design.

This design is suitable for identifying whether scores change after an activity, but it has an important limitation: without a control group, the effect of Excel cannot be isolated from other factors such as repeated exposure to the content, practice time, or teacher intervention. Pre- and post-intervention measurements have a long tradition in physics education research for evaluating changes in performance and conceptual understanding (Hake, 1998); however, interpretation in the present study remains limited by the absence of a comparison group.

Data Collection Instruments

The first instrument was a PRE-TEST on Coulomb's law, administered before the Excel activity. The second was a POST-TEST, administered after the activity. Both tests assessed the same learning areas: conceptual understanding, physical reasoning, numerical application, the effects of changing charge and distance, and determining the direction of electric forces. Each test had a maximum score of 20 points.

The third instrument was a questionnaire containing 30 statements organized into six domains, with five statements in each domain: understanding of physical concepts; reasoning and problem solving; visualization and interpretation; active learning and motivation; difficulties and limitations; and overall impact. Responses were given on a five-point Likert scale ranging from 1 = Strongly disagree to 5 = Strongly agree.

When interpreting the questionnaire, it is important to distinguish the difficulties domain from the other five domains. For positive statements, a higher mean indicates a more positive evaluation. In the "Difficulties and limitations" domain, a higher value indicates a greater presence of difficulties and should not be read as a positive result. The questionnaire was supplemented by several open-ended questions used to identify perceived benefits, difficulties, and student suggestions.

Instructional Activity Procedure

Initially, Coulomb's law was taught in the usual manner and the PRE-TEST was administered to establish the students' initial level. The students then worked with the Excel application. During the activity, they changed charge values and positions on the grid, observed changes in distances, forces, and components, and compared different physical situations.

An important feature of the activity was automatic recalculation. Changing an input parameter immediately changed the outputs, creating opportunities to test predictions. Rather than ending with a single numerical value, the model allowed the same scenario to be repeated with new data. This type of interaction is similar to simulation environments in which learners systematically explore relationships among variables (Zacharia & Anderson, 2003; Rutten et al., 2012).

After the activity, the POST-TEST was administered. Students then completed the questionnaire and the open-ended questions. This sequence allowed the assessment of performance to be complemented by data on students' experience and on how they perceived the usefulness and difficulty of the tool.

Data Analysis

Descriptive statistics and a paired-samples t test were used for the test scores because the two measurements were obtained from the same 17 students. Means, minimum and maximum scores, standard deviations, and individual differences were compared. For the questionnaire, item means and means for the six thematic domains were calculated. Open-ended responses were grouped into descriptive themes related to benefits, difficulties, the role of visualization, and the need for guidance.

RESULTS

PRE-TEST–POST-TEST Comparison

In 16 of the 17 cases, the POST-TEST score was higher than the PRE-TEST score. The group mean increased from 9.94 to 14.41 points, with a mean difference of approximately 4.47 points. The maximum score increased from 16 to 20 points. The standard deviation was 4.2 on the PRE-TEST and 4.8 on the POST-TEST. These data indicate an overall shift toward higher scores after the activity.

Table 1. Descriptive Statistics for Test Scores

Indicator	PRE-TEST	POST-TEST	Change
N	17	17	—
Mean	9.94	14.41	+4.47
Standard deviation	4.20	4.80	—
Maximum score	16	20	+4

The paired-samples t test yielded $t(16) = -7.849$ and $p < .001$; in the calculation reported in the study, $p \approx 7.09 \times 10^{-7}$. This result indicates that the difference between the two measurements is statistically significant. The negative sign of the statistic reflects the order in which the variables were subtracted rather than the pedagogical direction of change. On the basis of this result, H0 is rejected and H1 is supported for the sample studied.

Statistical significance should be interpreted together with the study design. The t test indicates that the pre- and post-activity scores differ in a way that is not readily explained by random variation within this sample. It does not, however, demonstrate that Excel is the sole cause of the change. This distinction is essential for a cautious interpretation of the findings.

Students' Perceptions

The questionnaire results showed generally positive evaluations across the five positively worded domains. The highest means were recorded for Understanding of physical concepts and Overall impact, both at 4.67/5. Active learning and motivation had a mean of 4.59/5, Reasoning and problem solving 4.55/5, and Visualization and interpretation 4.51/5.

Table 2. Mean Scores for the Six Questionnaire Domains

Domain	Items	Mean
Understanding of physical concepts	P1–P5	4.67
Reasoning and problem solving	P6–P10	4.55
Visualization and interpretation	P11–P15	4.51
Active learning and motivation	P16–P20	4.59

Note. The difficulties domain is interpreted in the opposite direction from the positive domains.

At the item level, one of the highest ratings concerned the opportunity to check results independently, with a mean of 4.82/5. The rating of Excel as a useful complementary tool in physics learning reached 4.76/5. These results are consistent with the way the activity was designed: students could change parameters, observe recalculation, and check the relationship between an action and its result.

The Difficulties and limitations domain had a mean of 3.53/5 and requires separate interpretation. It shows that a positive evaluation of the tool coexists with real difficulties. Students reported a need for guidance during their initial use of the program and when interpreting the physical meaning of results. This finding suggests that the interface and automation do not replace the role of the teacher.

Open-Ended Responses

The open-ended responses complemented the quantitative results. Students identified as benefits the ability to change parameters, compare cases, check calculations, and view graphical or vector representations. These responses indicate that the perceived usefulness was not limited to calculation speed but was also related to the way the problem could be explored.

Another theme was the need for explanation. Some students noted that using the program can initially be difficult and that numerical results need to be explained physically. The responses also indicated a preference for traditional explanation to remain the foundation, with Excel used for concretization, experimentation, checking, and verification. This places technology in a complementary rather than a substitutive role.

DISCUSSION

The test results show that the Excel-supported activity was associated with a noticeable increase in group performance. The fact that 16 of the 17 students improved their scores and that the mean increased by approximately 4.47 points indicates a consistent change within the sample. This finding is consistent with a broader literature reporting benefits of interactive environments and simulations for conceptual understanding in physics, although those studies do not demonstrate that the improvement in our sample was caused solely by Excel (Banda & Nzabahimana, 2021; Zacharia & Anderson, 2003).

One possible pedagogical mechanism, supported by the design of the activity itself, is the dynamic nature of the model. In a traditional solution, changing one parameter requires the calculations to be repeated. In Excel, the same formula structure immediately produces a new result. This gives students an opportunity to explore "what if...?" hypotheses, a feature that the simulation literature associates with active exploration and testing relationships among variables (Rutten et al., 2012; Katoch, 2020).

The high rating for the "Understanding of physical concepts" domain is important because use of the program was not conceived merely as a computer exercise. The model was built around the relationships in Coulomb's law and required students to connect cells and outputs with physical quantities. In this sense, Excel functions serve as computational infrastructure while the content remains physics.

The 4.55/5 result for reasoning and problem solving suggests that students perceived the tool as helpful in analyzing problems. This may be related to the possibility of breaking a complex problem into steps: coordinates, distance, individual forces, components, and the resultant. Such organization makes the solution process more visible and may help identify errors.

Visualization and interpretation received 4.51/5. In electrostatics, vector representation is particularly important because a numerical result for the magnitude of a force is not sufficient; its direction and sense must also be understood. When the F_x and F_γ components are linked to the resultant vector and the positions of the charges, students work with multiple representations of the same phenomenon. This is consistent with the multiple-representations framework, according to which combining representations can support learning when

the relationships among them are integrated and understandable (Ainsworth, 2006; van der Meij & de Jong, 2006).

The mean of 4.59/5 for active learning and motivation is related to the interactive nature of the activity. Students are not limited to following a single example; they can generate new scenarios by changing the input data. The opportunity to test a prediction, compare results, and interpret changes places students in a more active role. In a broader STEM context, the meta-analysis by Freeman et al. (2014) shows that active-learning strategies are associated with higher performance than traditional lecturing; in physics, Hake (1998) also reported benefits from interactive-engagement approaches.

At the same time, the difficulties domain reveals a limitation of this approach. If students do not understand the formula or do not know what a cell represents, automation may conceal the process rather than clarify it. Didactic use should therefore include initial orientation, explanation of formulas, and questions that require interpretation. This conclusion is consistent with literature reviews emphasizing that the effects of simulations depend on pedagogical support, integration into instruction, and the promotion of reflection (Smetana & Bell, 2012; Rutten et al., 2012).

The open-ended responses reinforce this interpretation. Students did not call for replacing physical explanation with the program; rather, they viewed Excel as a tool for concretization and verification. This result is consistent with the orientation of the study, in which technology is used as a complementary tool. The literature on simulations in science education likewise recommends that technology complement, rather than necessarily replace, instruction and other learning activities (Smetana & Bell, 2012; Banda & Nzabahimana, 2021).

From a teaching perspective, the application can be used at several stages of a lesson. Before calculation, students can predict the effect of changing a parameter. During the activity, they can check the prediction using the model. After the calculation, they can explain why the result changed and relate it to the physical law. This structure preserves the role of reasoning even when calculation is automated.

Limitations of the Study

The main limitation is the small sample of 17 students and the absence of a control group. For this reason, the results should not be automatically generalized to broader populations and cannot be used to claim that Excel, isolated from other factors, caused the increase in scores. The study documents a pre–post change in a specific group and the perceptions of that group.

A second limitation concerns duration and content. The quantitative assessment of knowledge focused on Coulomb's law, whereas the dipole application represents part of the modeling developed in the study. Future studies could use separate instruments for the dipole field and assess retention of knowledge after a longer period.

A third limitation concerns the questionnaire, which measures students' perceptions. Positive evaluations are important for understanding their experience, but they are not equivalent to objective measurement of learning. For this reason, the questionnaire in this study is interpreted together with the tests and open-ended responses rather than as the sole evidence of effectiveness.

CONCLUSION

The study shows that Microsoft Excel can be used as a didactic and modeling tool in teaching electrostatics. In the sample analyzed, the activity was associated with an increase in scores from the PRE-TEST to the POST-TEST and with generally positive perceptions regarding conceptual understanding, reasoning,

visualization, active learning, and overall impact. The statistical difference was significant; however, because the design did not include a control group, it should not be interpreted as evidence of an exclusively causal effect of Excel.

The applications developed demonstrate that a spreadsheet can be used for more than numerical calculation. By linking coordinates, formulas, vector components, and graphical representations, Excel can create an environment in which students experiment with parameters and observe the consequences of changes. This is particularly useful in topics where mathematical relationships and vector representations need to be understood simultaneously.

For pedagogical use, it is recommended that teachers introduce the model gradually, clarify the meaning of cells and formulas, ask students to make predictions before changing parameters, and require physical interpretation after obtaining a result. Excel should be used as a complement to explanation, exercises, and discussion rather than as a replacement for them.

Future studies could include larger samples, several classes, longer implementation periods, and a control or comparison group. Different forms of technology use could also be compared, long-term retention of knowledge could be assessed, and similar models could be examined in other areas of physics.

REFERENCES

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. Learning and Instruction, 16(3), 183–198. https://doi.org/10.1016/j.learninstruc.2006.03.001

Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature. Physical Review Physics Education Research, 17(2), 023108. https://doi.org/10.1103/PhysRevPhysEducRes.17.023108

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics, 66(1), 64–74. https://doi.org/10.1119/1.18809

Katoch, S. K. (2020). MS-Excel spreadsheet applications in introductory undergraduate physics—A review. Journal of Science & Technology, 5(3), 48–52. https://doi.org/10.46243/jst.2020.v5.i3.pp48-52

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. Computers & Education, 58(1), 136–153. https://doi.org/10.1016/j.compedu.2011.07.017

Saputra, I. G. P. E. (2025). Development of circular motion simulation assisted by Microsoft Excel spreadsheets to create fun physics learning. Jurnal Pendidikan Fisika Undiksha, 15(1). https://doi.org/10.23887/jjpf.v15i1.91456

Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. International Journal of Science Education, 34(9), 1337–1370. https://doi.org/10.1080/09500693.2011.605182

van der Meij, J., & de Jong, T. (2006). Supporting students' learning with multiple representations in a dynamic simulation-based learning environment. Learning and Instruction, 16(3), 199–212. https://doi.org/10.1016/j.learninstruc.2006.03.007

Zacharia, Z. C., & Anderson, O. R. (2003). The effects of an interactive computer-based simulation prior to performing a laboratory inquiry-based experiment on students' conceptual understanding of physics. American Journal of Physics, 71(6), 618–629. https://doi.org/10.1119/1.1566427

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

SECRET MESSAGES IN PRIMARY EDUCATION: USING THE CAESAR CIPHER TO SUPPORT LOGICAL THINKING AND INTERDISCIPLINARY LEARNING

Tea Pavičić Zajec
Tamara Ređep
I Primary School Varaždin, Varaždin, Croatia

Abstract

This paper presents a practice-based interdisciplinary teaching activity using the Caesar cipher to foster logical thinking and problem-solving in primary education. The activity was implemented with fourth-grade pupils during a Science and Social Studies lesson on energy. Working in small groups, pupils decoded messages identifying renewable energy sources—solar, hydro, and wind energy—using a shared cipher key. They subsequently explored how these energy sources work, discussed their advantages and everyday applications, and presented their findings to classmates. In the final stage, each group created and encoded a message promoting responsible energy use, exchanged it with peers, and decoded another group's message. The learning sequence integrated elements of mathematics, computing, language, and environmental education through inquiry, collaboration, and creative communication. Classroom observations suggested that the cipher-based challenges encouraged active participation and engagement, while allowing pupils to apply pattern recognition and logical reasoning in a meaningful curricular context. However, no standardized assessment or experimental comparison was conducted; therefore, the activity is presented as an illustrative example of educational practice rather than evidence of measured learning gains. The paper discusses the pedagogical potential of introductory cryptography as an accessible tool for differentiated, interdisciplinary learning, including opportunities for gifted and potentially gifted pupils. It also identifies directions for future systematic evaluation of pupil learning and motivation.

Keywords: primary education; Caesar cipher; cryptography; logical thinking; interdisciplinary learning; educational practice.

INTRODUCTION

Education in a knowledge-based society increasingly emphasizes pupils' ability to reason logically, solve unfamiliar problems, and apply knowledge in new contexts. In primary school, meaningful opportunities to develop these abilities can be created through activities that require learners to explore, test ideas, and explain their reasoning. Croatian subject curricula encourage active learning and connections among disciplines (Ministry of Science and Education, 2019a, 2019b, 2019c). Cryptography offers a particularly accessible context for such work. Although usually associated with information security, simple substitution systems can be used in classrooms without advanced mathematics. Decoding a hidden message requires pupils to identify a rule, apply it consistently, check the result, and revise their approach if needed. The appeal of discovering a secret message can also provide a meaningful reason to persist with a task. Inquiry-based approaches benefit from appropriately structured guidance and opportunities for explanation (Hmelo-Silver, Duncan, & Chinn, 2007).

Cryptographic challenges can be differentiated by adjusting the length of the message, the amount of support, or whether the encryption rule is supplied. This flexibility makes them potentially useful for mixed-ability classes and for pupils seeking more complex challenges. Talent development, in this context, is understood as creating opportunities to explore and extend capabilities rather than as a claim that the participating pupils were formally identified as gifted (Renzulli, 2011). The purpose of this paper is to describe and critically reflect on a classroom activity that used the Caesar cipher to connect logical reasoning with a fourth-grade unit on renewable energy. It is a report of educational practice, not an experimental evaluation of the method.

THEORETICAL AND CURRICULAR BACKGROUND

Cryptography concerns techniques for protecting information by transforming a readable message into a form that is not readily understood without the relevant key (Singh, 1999). Modern cryptographic systems are mathematically sophisticated, but elementary historical ciphers offer an age-appropriate introduction to the idea that information can be encoded according to a rule. A Caesar cipher replaces each letter with another letter a fixed number of positions away in an agreed alphabet. For example, with a shift of three positions in the standard Latin alphabet, A becomes D, B becomes E, and C becomes F. Decryption reverses the shift. When used in Croatian-language lessons, the teacher must explicitly define the alphabet and how letters with diacritics and digraphs are treated, so that the task has one consistent solution.

The activity calls for several kinds of thinking: pupils identify patterns, follow a sequence of steps, monitor their work, and test whether a decoded sentence makes sense. These processes are consistent with problem-solving practices discussed by Pólya (2004), although participation in a single activity cannot by itself establish measurable improvement in those abilities. The approach also crosses subject boundaries. Mathematics contributes patterns and ordered sequences; computing introduces rule-based procedures and elementary information-security concepts; language learning supports attention to letters, words, and meaning; and Science and Social Studies provides substantive content that pupils must understand and explain. The value of this integration lies in using the cipher as a means of learning and communicating about a topic, rather than treating decoding as an isolated puzzle.

Pupils differ in their prior knowledge, confidence, reading fluency, and need for challenge. A simple cryptographic task can therefore be organized at several levels. Some pupils may use a prepared alphabet strip and an explicit shift; others may infer the key, compare alternative shifts, or design their own substitution rule. Group discussion allows pupils to explain why a solution works, while individual extensions provide additional depth without separating learners into fixed categories. For pupils who enjoy intellectual challenges, constructing a cipher and evaluating whether classmates can decipher it may encourage flexible thinking and creative problem-solving. This is compatible with educational approaches that emphasize enrichment and the development of potential (Renzulli, 2011). Nevertheless, the present classroom example does not constitute an assessment of giftedness or a study of talent development outcomes.

The teacher's role is to select suitable tasks, model the procedure when necessary, ask questions that reveal reasoning, and maintain an environment in which pupils can test ideas. Such guided inquiry also provides opportunities for communication, cooperation, and digital-age competencies highlighted in international educational frameworks (OECD, 2019). The instructional design is consistent with guided inquiry: the teacher provides an accessible entry point and structured support, while pupils make sense of information and communicate explanations. Scaffolding is particularly important when a lesson introduces both an unfamiliar decoding procedure and substantive science content (Hmelo-Silver et al., 2007). The cipher is therefore not treated as an end in itself but as a purposeful means of initiating subject-related inquiry.

MATERIALS AND METHODS

Study design. This contribution is a descriptive, reflective report of an implemented teaching activity, rather than a quantitative or qualitative research study with a formally recruited sample. The report documents the instructional sequence and discusses its pedagogical rationale. It does not include a pre-test, post-test, control group, structured interview, validated questionnaire, or systematic observational coding. Accordingly, the findings below concern the activity and informal classroom observations, not measured effects.

Educational setting and materials. The activity was conducted with fourth-grade pupils during a Science and Social Studies unit on energy. Pupils worked in small groups. Materials included teacher-prepared Caesar-cipher messages, a shared decoding key, curricular learning resources, and paper or other writing materials for preparing new messages. Textbooks, teacher-selected information sources, and digital resources supported the subsequent inquiry. The number of pupils and the duration of each phase were not documented in the source account and are therefore not estimated here.

Cipher procedure. A Caesar cipher shifts letters by a fixed number of positions within a predefined alphabet. To reproduce the activity, the teacher should state the exact alphabet, shift, and handling of Croatian diacritics and digraphs before distributing messages. The descriptions below are English translations of the meanings of the original Croatian messages; they are not the original encrypted worksheets. This distinction is important for transparent reporting and classroom replication.

Procedure, phase 1: decoding. Each group received an encrypted message and the agreed key. By applying the substitution rule, pupils identified one renewable energy source: solar energy, hydropower, or wind energy. The task required consistent rule application and checking whether the resulting message made sense.

Procedure, phase 2: guided inquiry. After decoding, groups examined how their energy source can be used to generate electricity, considered advantages and everyday applications, and presented their findings to classmates. The teacher connected the separate group contributions to the broader topic of renewable energy.

Procedure, phase 3: message creation and exchange. Groups formulated short recommendations for responsible energy use, encoded them using the agreed rule, exchanged messages, and decoded messages produced by peers. This final step moved from applying a supplied code to constructing an understandable message for a real classroom audience.

RESULTS: DOCUMENTED CLASSROOM OUTPUTS AND OBSERVATIONS

The implemented lesson generated three types of classroom outputs: decoded descriptions of renewable energy sources, short group presentations on the assigned topics, and pupil-created encrypted recommendations about responsible resource use. The decoded content addressed solar, water, and wind energy. The following statements represent the meaning of the lesson messages in English, not verbatim transcriptions of the Croatian encrypted strings:

• Solar energy: The Sun provides light and heat that can be converted into electrical energy.

• Hydropower: Flowing water drives turbines in hydroelectric power plants to generate electricity.

• Wind energy: Wind turns the blades of wind turbines, which generate electricity.

Examples of energy-conservation messages from the classroom account, rendered in English, include turning off lights when leaving a room, unplugging a charger after use, using daylight when possible, and turning off the tap to avoid wasting water. These examples illustrate the intended connection between coding and environmental responsibility; they should not be read as a systematically collected dataset. The teacher's informal impressions suggested that the secret-message format attracted pupils' interest and supported participation in group discussion. Pupils engaged in decoding, discussed information about energy, presented findings, and exchanged encoded messages. No frequencies, ratings, individual scores, or comparative outcomes were collected. Consequently, this section reports observed participation and examples of learning tasks rather than statistically tested improvements in logical thinking, motivation, or achievement.

DISCUSSION

The central pedagogical contribution of this example is the sequence linking a short rule-based puzzle to disciplinary inquiry and peer communication. The initial cipher creates a concrete information gap; decoding reveals the subject of the investigation; and encoding a new recommendation requires pupils to apply the rule with an intended reader in mind. This sequence gives the cryptographic element a curricular purpose instead of using it as an isolated recreational task. The activity affords opportunities to practise ordered procedures, error checking, pattern recognition, explanation, and collaboration. These are opportunities embedded in task design, not independently verified learning gains. The problem-solving emphasis is compatible with Pólya's account of understanding a problem, devising a plan, carrying it out, and reviewing the solution (Pólya, 2004). Likewise, the guided inquiry stage illustrates why scaffolding can be valuable when pupils encounter unfamiliar concepts (Hmelo-Silver et al., 2007).

Differentiation is possible without changing the underlying learning goal. For pupils needing support, a visible alphabet strip, a short message, and an explicit key reduce decoding demands. Pupils ready for greater

complexity can infer a shift, compare candidate solutions, create longer messages, or explain why a rule works. Such enrichment is consistent with the broader idea of developing pupils' potential through appropriately challenging experiences (Renzulli, 2011); it does not identify any participant as gifted or demonstrate talent development.

Several limitations affect transferability. This report describes one classroom implementation, with no documented sample size, structured observations, pupil feedback instrument, assessment scores, or comparison condition. Teacher impressions may be affected by expectancy and selection effects. Furthermore, decoding accuracy may depend on literacy and prior familiarity with letter sequences, while group work can obscure individual contributions. The lesson therefore supports a pedagogical illustration, not causal inference. Future studies could preserve the same instructional sequence while documenting participant characteristics, the precise cipher alphabet and key, task-completion accuracy, time on task, and pupil reflections. A short pre/post problem-solving task and a comparison lesson could provide more defensible evidence about specific learning outcomes. Any research involving children should follow institutional procedures for permissions, informed parental consent where required, and appropriate protection of pupil data.

CONCLUSION

The described fourth-grade lesson demonstrates a feasible way to connect introductory cryptography with the study of renewable energy. Pupils decoded messages to identify energy sources, investigated and presented information, and created encoded recommendations for responsible energy use. The sequence integrates rule-based thinking, subject learning, and communication within a single classroom activity. Its value as a practice report lies in an adaptable instructional design and explicit opportunities for differentiation. Claims that the activity improves logical thinking, motivation, or achievement remain hypotheses for future systematic investigation. Teachers wishing to adapt the approach should define the cipher convention precisely, provide graduated support, and assess both the quality of decoding and the understanding of energy concepts.

REFERENCES

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). Educational Psychologist, 42(2), 99–107.

Ministry of Science and Education. (2019a). Curriculum for the subject of Informatics in primary schools and gymnasiums in the Republic of Croatia. Narodne novine, 22/2019. [In Croatian].

Ministry of Science and Education. (2019b). Curriculum for the subject of Mathematics in primary schools and gymnasiums in the Republic of Croatia. Narodne novine, 7/2019. [In Croatian].

Ministry of Science and Education. (2019c). Curriculum for the subject of Science and Social Studies in primary schools in the Republic of Croatia. Narodne novine, 7/2019. [In Croatian].

OECD. (2019). OECD future of education and skills 2030: OECD learning compass 2030. OECD Publishing.

Pólya, G. (2004). How to solve it: A new aspect of mathematical method (Expanded Princeton Science Library ed.). Princeton University Press. (Original work published 1945).

Renzulli, J. S. (2011). Reexamining the role of gifted education and talent development for the 21st century: A four-part theoretical approach. Gifted Child Quarterly, 55(3), 150–159.

Singh, S. (1999). The code book: The science of secrecy from ancient Egypt to quantum cryptography. Doubleday.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

A FUZZY LOGIC APPROACH TO SPORTS PERFORMANCE EVALUATION

Elda Maraj
Armida Brakaj
Fizeleni Lekli
Shkelqim Kuka
https://orcid.org/0009-0002-1143-9126, Polytechnic University of Tirana, Faculty of Mathematical Engineering and Physical Engineering, Department of Mathematical Engineering, Tirana, Albania
https://orcid.org/0009-0006-2872-4969, Polytechnic University of Tirana, Faculty of Mathematical Engineering and Physical Engineering, Department of Mathematical Engineering, Tirana, Albania
https://orcid.org/0009-0005-5091-6863, Polytechnic University of Tirana, Faculty of Mathematical Engineering and Physical Engineering, Department of Mathematical Engineering, Tirana, Albania
https://orcid.org/0009-0005-5068-9314, Polytechnic University of Tirana, Faculty of Mathematical Engineering and Physical Engineering, Department of Mathematical Engineering, Tirana, Albania

Abstract

Sports performance evaluation is a multidimensional process that requires the analysis of various physical, technical, and physiological parameters. Traditional evaluation methods often rely on precise numerical indicators and predefined criteria, making it difficult to adequately represent the uncertainty, subjectivity, and variability inherent in human performance. This paper proposes a fuzzy logic-based approach for evaluating sports performance, aiming to develop a flexible and comprehensive model capable of integrating both quantitative and qualitative performance indicators.

The proposed fuzzy inference system uses age, weight, and triglycerides as input variables to estimate sports performance. These variables are transformed into linguistic categories, such as “very young”, “young”, “medium”, and “old” using appropriate fuzzy membership functions. A set of fuzzy inference rules is then developed to establish relationships between the input variables and generate an overall performance assessment. The final fuzzy output is defuzzified into a numerical performance score, allowing the results to be easily interpreted and compared. The fuzzy inference system was implemented in MATLAB using the Fuzzy Logic Toolbox.

The proposed approach provides an alternative to conventional deterministic evaluation models by explicitly addressing uncertainty and gradual transitions between performance levels. It can support coaches, sports analysts, and researchers in identifying athletes’ strengths and weaknesses, monitoring performance development, and supporting evidence-based decision-making. The proposed fuzzy inference system provides a flexible framework that can be adapted to the specific performance characteristics of different sports disciplines. The expected results demonstrate the potential of fuzzy logic as an effective methodology for developing intelligent and adaptable sports performance evaluation systems.

Keywords: sports performance, fuzzy logic, membership function.

INTRODUCTION

Sports performance evaluation is an essential component of modern sports science and plays a significant role in athlete development, training optimization, talent identification, and competitive decision-making. The assessment of an athlete's performance generally involves the analysis of multiple factors, including physical abilities, technical skills, tactical effectiveness, physiological characteristics, and psychological aspects. Since these factors interact with each other and may vary considerably among athletes and sports disciplines, obtaining an accurate and comprehensive assessment of performance represents a complex challenge. Fuzzy logic provides an effective framework for addressing such problems because it allows variables to be represented using degrees of membership rather than strictly defined binary categories (Khan et.al, 2026).

Fuzzy logic has been extensively applied to the evaluation of sports performance in previous studies.

Sîrb and Nastor (2015) proposed a fuzzy logic model for forecasting the process of performance within football sports. The proposed fuzzy methodology was applied in a concrete and exemplary way within a third-league football club in Romania, with the name F.C. Nuova Mama Mia Bechicerecu Mic, of Timiş county.
Nurjaya et. al (2022) designed a smart model in talent identification and selection for rowing athletes based on the weighting of priority criteria generated from the analytic hierarchy process (AHP) of anthropometric, biomotor, psychological, physiological, and technical variables of fuzzy logic.
Sukeinee et. al (2023) implemented an athletic performance system for the measurement of vital signs like Heart rate, temperature, and kinetic parameters like the number of revolutions of a fixed bike wheel for football players. The fuzzy system was applied to three player states: rest, during exercise, and after the effort, to evaluate the final player assessment.
Singh et. al (2011) proposed a fuzzy logic based technique to evaluate the performance of cricket players. This model had 8 input variables and one output variable.
Sałabun et.al (2020) designed a fuzzy logic model to evaluate players in team sports. The study showed that this method can be used effectively in assessing players based on their performance.
The objective of this study is to develop a fuzzy logic-based framework for evaluating sports performance by integrating relevant performance indicators into a unified assessment model. The proposed approach aims to provide a systematic and flexible method for combining different dimensions of athletic performance and translating them into an overall performance assessment. The proposed fuzzy inference system uses age, weight, and triglycerides as input variables to estimate sports performance.
The proposed approach may provide useful support for coaches, sports analysts, researchers, and other practitioners involved in athlete assessment and performance monitoring. By combining measurable performance data with a flexible decision-making mechanism, fuzzy logic can contribute to a more comprehensive interpretation of athletic performance. The study therefore explores the potential of fuzzy logic as a decision-support methodology for sports performance evaluation and as a basis for developing adaptable models for different sporting contexts.

MATERIALS AND METHODS

Fuzzy Logic: Lotfi Zadeh was the first scientist to gave the idea of fuzzy logic in 1965 (Zadeh 1965, Maraj and Kuka 2022). Fuzzy expert systems provide an accurate and effective method for describing human perceptions (Lin et.al 2003, Walid 2005, Maraj and Kuka 2022). The theory of fuzzy set is different from classical set theory. Whereas the theory of classical sets uses numbers 0 and 1 to determine whether an entity is an element of a set or it is not, the theory of fuzzy sets uses the interval [0,1]. In the theory of fuzzy sets, every entity gets a membership degree in the interval [0,1] that is defined by the membership function *f(x)* (Arslankayal 2021, Demirhan 2010, Maraj and Kuka 2022).

In this paper are used two membership functions in the part of implementation in MATLAB (Sen 2010, Maraj and Kuka 2022). Triangular function: It is the simplest membership function, that is a function of a variable x and depends on 3 scalar parameters (a_1, a_2, and a_3). The triangular membership function is given by the following expression (Sen 2010, Maraj and Kuka 2022):

$$g(x)=\begin{cases}0, & x\le a_1\\ \dfrac{x-a_1}{a_2-a}, & a_1\le x\le a_2\\ \dfrac{a_3-x}{a_3-a_2}, & a_2\le x\le a_3\\ 0, & a_3\le x\end{cases} \qquad (1)$$

$$g(x)=\begin{cases}0, & x\le a_1\\ \dfrac{x-a_1}{a_2-a_1}, & a_1\le x\le a_2\\ 1, & a_2\le x\le a_3\\ \dfrac{a_4-x}{a_4-a_3}, & a_3\le x\le a_4\\ 0, & a_4\le x\end{cases} \qquad (2)$$

In this paper the centroid method was used in the defuzzification process. This method is used for regulating a point that defines the centre of gravity of the fuzzy set (Mahdi 2019, Maraj and Kuka 2022). The centre of gravity is calculated from the following formula.

$$l^* = \frac{\int g_A(z) \cdot z dz}{\int g_A(z) dz} \qquad (3)$$

where l^* is the point of the center of gravity that presents the output of the system by a numerical value, $f_A(z)$ gives the membership value of point z in the output fuzzy set (Mahdi 2019, Maraj and Kuka 2022).

Input variables: *Age:* ranges from 18 to 80 years, *Weight:* ranges from 25 to 100 kg, and triglycerides ranges, from 50 to 600 in mg/dl.
Output variable: *Sports Performance evaluation:* The output variable is assessed using a scale ranging from 0 to 100.

RESULTS

Fuzzy logic Model Development and Implementation. The fuzzy logic model developed in this study for evaluating the sports performance consists of three input variables and one output variable. The input variables considered in the model are age, weight, and triglycerides, while the output variable represents the evaluation of sports performance. The structure of the Mamdani Fuzzy Inference System (FIS) implemented in this paper, including the membership functions associated with the input variables (age, weight, and triglycerides), is shown in Figure 1.

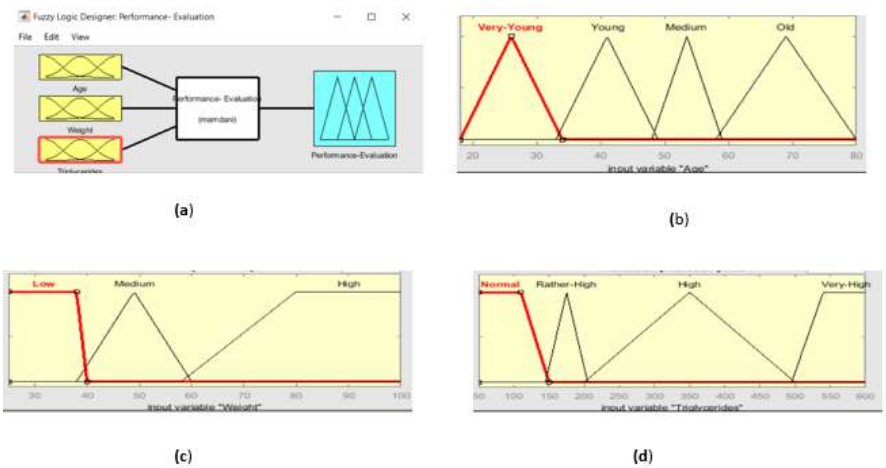


Figure 1. (a) Mamdani FIS model; (b) Membership Function of the Input Variable "Age"; (c) Membership Function of the Input Variable "Weight", (d) Membership Function of the Input Variable "triglycerides".

The membership functions of the output variable "Performance Evaluation", the Rule Viewer, and the Surface Viewer are presented in Figure 2:

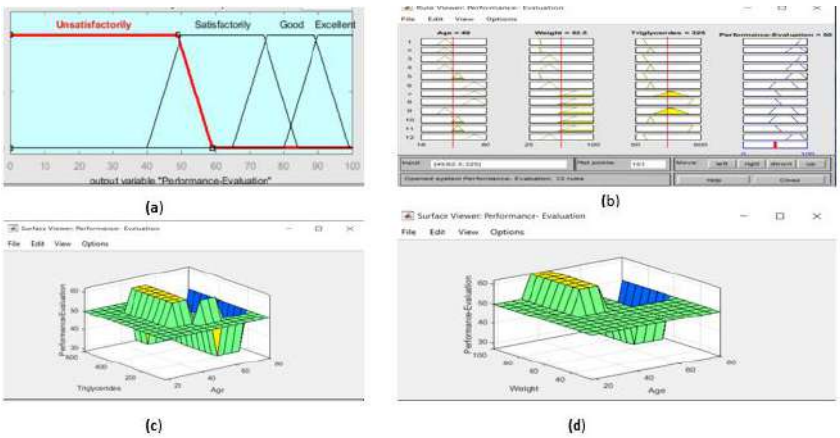


Figure 2. (a) Membership Function of the Output Variable "Performance Evaluation"; (b) Rule Viewer; (c), (d) Surface Viewer

Figure 2(b) presents the Rule Viewer, which provides a visualization of the input variables, output variable, and the IF–THEN rule set implemented in the proposed fuzzy model. The developed system consists of 12 fuzzy rules. The figure above represents the case in which the input variables are set to Age = 49, Weight = 62.5, and triglycerides = 325. Under the given input scenario, the fuzzy model generates a predicted value for the output variable Performance Evaluation = 50. Figures 2(c) and 2 (d) illustrate the Surface Viewer.

Discussion

The fuzzy logic model is employed to evaluate sports performance with three input variables, such as age, weight, and triglycerides. The fuzzy model was developed based on the Mamdani inference method and consists of 12 fuzzy rules.

The evaluation of sports performance is inherently complex because athletic performance is influenced by a combination of physical, technical, tactical, and physiological factors. These factors do not contribute independently to performance, and their relative importance may vary according to the characteristics of the sport, the athlete, and the competitive context. Therefore, a comprehensive evaluation method should be capable of integrating multiple indicators while accounting for uncertainty and gradual differences in performance levels.

The fuzzy logic approach proposed in this study provides a flexible mechanism for addressing these challenges. In contrast to conventional threshold-based methods, fuzzy logic allows an athlete to belong to different performance categories to different degrees, providing a more continuous representation of performance.

An important characteristic of the proposed approach is its ability to combine heterogeneous performance indicators within a single evaluation framework. Physical and technical variables, for example, may be measured using different units and scales. Through normalization and the definition of appropriate membership functions, these variables can be incorporated into the same fuzzy inference system. The resulting assessment can therefore provide a more comprehensive picture of an athlete's performance than the analysis of individual indicators separately.

The fuzzy rule base also represents an important component of the proposed methodology. Expert knowledge can be incorporated into the evaluation process through rules that describe relationships between different performance factors. This allows the model to reflect practical knowledge from coaches and sports specialists while maintaining a systematic computational structure. Nevertheless, the application of fuzzy logic also presents several challenges. The definition of membership functions and fuzzy rules may introduce subjectivity

if they are established exclusively on the basis of expert opinion. Different experts may assign different importance to the same performance indicators, potentially leading to different evaluation outcomes. To reduce this limitation, future implementations should combine expert knowledge with empirical data, statistical analysis, and objective performance measurements.

The proposed approach should also be validated using data collected from real athletes and different competitive environments. Such validation would allow the reliability and sensitivity of the model to be assessed and would provide an opportunity to compare fuzzy-based evaluations with conventional performance assessment techniques. Furthermore, the integration of machine learning or optimization methods could be investigated to automatically adjust membership functions and fuzzy rules based on historical performance data. Overall, the discussion indicates that fuzzy logic offers a suitable methodological framework for dealing with the multidimensional and partially uncertain nature of sports performance evaluation. Its main value lies not in replacing traditional performance indicators, but in providing a structured mechanism for integrating and interpreting them within a unified evaluation system.

Conclusions

This study presented a fuzzy logic-based framework for sports performance evaluation. The proposed approach addresses the complexity of athletic performance by considering multiple performance indicators and integrating them into a unified evaluation model. The use of fuzzy sets and linguistic variables makes it possible to represent performance levels gradually and to account for the uncertainty and imprecision that may occur in conventional evaluation procedures.

The main advantage of the proposed methodology is its flexibility. Rather than relying exclusively on fixed thresholds, the fuzzy logic model can incorporate different degrees of performance and establish relationships between multiple indicators through a set of inference rules. This allows the evaluation process to provide a more comprehensive and interpretable representation of overall athletic performance.

The framework is also adaptable to different sports disciplines. Since the relevance of performance indicators depends on the characteristics of each sport, the model can be customized by modifying its input variables, membership functions, and fuzzy rules. This adaptability makes the approach suitable as a general decision-support framework rather than as a model restricted to a single type of sport.

The proposed methodology may be particularly useful for coaches, sports analysts, and researchers who need to integrate multiple sources of performance information into a single assessment. By combining quantitative measurements with expert knowledge, fuzzy logic can facilitate the interpretation of complex performance profiles and support systematic performance monitoring.

However, the reliability of the proposed framework depends on the quality of the input data and on the appropriate design of the fuzzy system. The selection of performance indicators, membership functions, and inference rules should therefore be supported by empirical evidence and expert knowledge. Future research should focus on validating the model using real-world athlete datasets, comparing its outcomes with established evaluation methods, and investigating adaptive approaches for automatically optimizing the fuzzy parameters.

In conclusion, fuzzy logic provides a flexible and interpretable framework for sports performance evaluation. Its ability to integrate multiple indicators and handle gradual or uncertain performance information makes it a promising approach for developing comprehensive and adaptable performance assessment systems in sports science.

REFERENCES

Khan A, Longa FEA, Zubair M, 2026. Impact of Sports Science-Based Training Programs on Athletic Performance and Injury Prevention. Annual Methodological Archive Research Review, 4 (4), pp. 367-386.

Sîrb L, Nastor F, 2015. The Exercise of Prediction Process of Performance within Football Sports Management by Using Fuzzy Logic from the Perspective of Value Analysis on Tactical Compartments of Game of the Football Players. Journal of Knowledge Management, Economics and Information Technology, 5(2), pp. 1-31.

Nurjaya DR, Mamun A, Rusdiana A, Abdullah AG, Mutohir T CH, 2022. A Fuzzy Logic Model for Talent Identification and Selection Indonesian Junior Rowing Athletes. Decision Making System in Talent Identification, 11(1), pp. 1-12.

Sukeinee RJ, Marhoon AF, Mshatat RM, 2023. A Fuzzy Logic- Based Athletic Performance Assessment for Football Players Using a Wearable Technology. AIP Conference Proceedings, pp. 1-16.

Singh G, Bhatia N, Singh S, 2011. Fuzzy Logic based Cricket Player Performance Evaluator. IJCA Special Issue on "Artificial Intelligence Techniques - Novel Approaches & Practical Applications" , pp. 11-16.

Sałabun W, Shekhovtsov A, Pamuˇcar D, W¸atróbski J, Kizielewicz B, Wi¸eckowski J, Bozani´c D, Urbaniak K, Nyczaj B, 2020. A Fuzzy Inference System for Players Evaluation in Multi-Player Sports: The Football Study Case. Symmetry, pp. 1-49, doi:10.3390/sym12122029.

Zadeh, L.A, 1965. Fuzzy Sets. Information and Control, 8, pp. 338-353.

Maraj E, Kuka SH, 2022. Prediction of Coronary Heart Disease Using Fuzzy Logic: Case Study in Albania. Proc. of the International Conference on Electrical, Computer and Energy Technologies (ICECET 2022), 978-1-6654-7087-2/22/$31.00 ©2022 IEEE.

Lin, J W. Hwang M I, and Becker J D 2003. A fuzzy neural network for assessing the risk of fraudulent financial reporting, Managerial Auditing Journal 18(8), pp. 657-665.

Walid AH, 2005. Accuracy Enhancement of Integrated MEMS-IMU/GPS Systems for Land Vehicular Navigation Applications, Ph. D. Thesis, Department of Geomatics Engıneering, Unıversity of Calgary, Calgary, Alberta, Canada.

Arslankayal S, Çelik TM, 2021. Prediction of Heart Attack Using Fuzzy Logic Method and Determination of Factors Affecting Heart Attacks. International Journal of Computational and Experimental Science and Engineering (IJCESEN), 7(1), pp. 1-8.

Demirhan A, Kılıç YA, Güler İ, 2010. Tıpta Yapay Zeka Uygulamaları. Artificial Intelligence Applications in Medicine, 9(1), pp. 31-41.

Sen Z, 2010. Fuzzy Logic and Hydrological Modeling, pp. 58 - 60.

Mahdi MS, Ibrahim MF, Mahdi SH M, Singam P, Huddin BA, 2019. Fuzzy Logic System for Diagnosing Coronary Heart Disease, International Journal of Engineering &Technology, 8 (1.7), pp.119-125.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

AN ANALYSIS OF TEACHERS` BENEFITS AND CHALLENGES IN INTEGRATING AI TOOLS IN EDUCATIONAL SETTINGS

Eriona Çela
ORCID ID: 0000-0003-2710-5489, University of New York Tirana (Albania), Faculty of Law and Social Sciences, Department of Psychology and Education, Tirana, Albania

Abstract

The aim of this paper is to explore the transformative impact of Artificial Intelligence (AI) on contemporary educational practices, with a focus on personalization, inclusivity and pedagogical innovation. The scope encompasses an analysis of the benefits and challenges associated with integrating AI into educational environments, alongside recommendations for effective implementation. To achieve this, the study employs a comprehensive theoretical framework that highlights the potential and risks of AI in education, complemented by an empirical methodology that involves the review of current literature and the analysis of primary data derived from the survey completed by teachers in primary, elementary and secondary schools. The data collection process focuses on the incorporation of quantitative and qualitative techniques, including the questionnaire and the statistical analysis to examine the challenges that teachers face when adopting AI tools in education setting. The results reveal that infrastructural deficiencies, data privacy concerns, ethical issues, and resistance from educators constitute significant barriers to AI integration. Considering the findings, the study recommends strengthening technological infrastructure, fostering AI literacy and ethical awareness among teachers, establishing clear policies on the usage of AI tools in education. As a conclusion, the study emphasizes that despite the promising potential of AI to revolutionize education, its implementation depends on strategic planning, collaboration, and continuous evaluation in order to address the challenges effectively.

Keywords: educational environments, AI implementation challenges, pedagogical applications, standardization of AI systems, critical thinking and problem-solving skills.

INTRODUCTION

Benefits of Artificial Intelligence (AI) in education

November 2022 is considered as the year when AI in education is exemplified by the release of several AI platforms but the most important one ChatGPT. These platforms brought and led to a profound transformation in educational practices and methodologies. Specifically, this AI driven tool represents a significant departure from traditional educational frameworks by introducing unprecedented levels of personalization in learning experiences. Personalized learning, support for diverse learning needs, integration into educational systems is some of the benefits of using ChatGPT. More specifically, ChatGPT sophisticated natural language processing capabilities and created the possibility to create customized educational experiences tailored to individual students` needs, strengths and weaknesses. As a result of this individualized approach, students foster their active participation and engagement shifting into more dynamic learning strategies. On the other hand, the implementation of Large Language Models (LLM) including ChatGPT has shown promise in catering to students with special needs by providing specialized resources that address diverse learning challenges (MacDowell et al., 2024). This capability enhances accessibility and inclusivity within educational environments, enabling students who typically struggle in traditional classroom settings to engage meaningfully with their coursework. Furthermore, the incorporation of AI language models into pedagogical frameworks is not merely an enhancement but may become integral to modern educational practices. While this shift presents challenges, it also offers substantial benefits to students, educators and the educational

system at large, indicating a potential evolution in how knowledge is imparted and acquired (Walter, 2024 and Zhang et al., 2024).

However, despite the promising implications of AI in education, there are also significant downsides and concerns that must be addressed. These include the potential for over-reliance in technology, issues related to data privacy, the digital divide among students, and the need for educators to adapt to new teaching tools and methodologies. These challenges necessitate careful consideration and strategic planning to ensure that the integration of AI enriches educational experiences without compromising integrity and effectiveness. While ChatGPT and AI tools in general offer transformative opportunities for creating a more personalized, inclusive, and effective educational landscape, stakeholders must remain vigilant about the accompanying challenges and work collaboratively to mitigate potential risks. As education evolves through these advancements, it is imperative that the focus remains on enhancing learning outcomes and preparing students for an increasing complex future.

Teachers` challenges regarding AI usage in education

Teachers encounter a multifaceted array of challenges when integrating AI tools into classroom settings, which can significantly hinder effective adoption and utilization. One primary obstacle is the infrastructural deficiency prevalent in many educational institutions, particularly in underfunded or rural areas. This includes limited access to reliable internet connectivity, outdated hardware, and insufficient technical support, which collectively undermine the seamless deployment of AI technologies. Additionally, the complexity and lack of standardization of AI systems pose significant operational barriers, leading to difficulties in system selection, implementation, and maintenance. Furthermore, a critical challenge lies in the limited professional development opportunities tailored to AI integration. Many teachers report feeling inadequately prepared to leverage AI tools effectively, owing to insufficient training that addresses both technical competences and pedagogical applications. This skill fosters apprehension and resistance, as educators express concerns about their low digital literacy, lack of confidence, and fear of technical failure (Eusebio et al., 2025).

Beyond infrastructural constrains, teachers often struggle with the complexity and lack of standardization of AI systems. These systems can be difficult to interpret, and their outcomes sometimes lead to difficulties in understanding and trusting AI-generated results. The absence of clear guidelines or policies further complicates teachers ability to utilize these tools responsibly and effectively. This is the reason why sometimes teachers experience feelings of uncertainty and apprehension regarding their capacity to manage AI systems within their instructional practices (Novianti, 2025).

Furthermore, psychological resistance stemming from fears of increased workload and perceived threats to professional autonomy makes the process of AI implementation more difficult. Teachers often worry that AI might lower the value of their teaching skills or make learning less personal and more machine-like. This fear, along with the worries of high cost in buying and keeping AI tools in educational settings, makes them more hesitant toward the implementation of AI tools, mostly for those schools that have got a very limited budget. In order to adopt the teachers and students` needs, schools must provide better technological support and proper training for teachers, clear rules about how to use AI ethically correct, and policies to help teachers to use AI responsibly and effectively (Karimov et al., 2024).

Proposed solutions to AI integration in education

In regard to the transformative impacts of AI in academia the establishment of a robust “culture of AI” is a must. This culture`s aim is to create an academic environment in which AI is embraced, understood, and critically evaluated rather than feared. The academic community must cultivate an environment where AI is integrated into everyday academic life. This may be possible through regular workshops and meeting with teachers, supervisors, and students that focus on current AI developments, ethical considerations, and best practices. Such initiatives will foster a collaborative understanding of AI`s technical, practical and societal challenges. On the other hand, educational programs should move beyond superficial engagement with AI to

include in-depth discussions of real-world scenarios that illustrate the convergence of theory and practice (Brandão et al., 2024).

This approach ensures that both students and educators gain a thorough understanding of AI`s multifaceted role in society and education. Furthermore, AI topics should be systematically integrated into every academic model if applicable. This strategy enables consistent exposure to AI and its relevance across various disciplines, thus preparing students for a future where AI is integral to professional fields. Also, establishing mandatory AI literacy classes for all students could serve as a cornerstone of this educational model. These classes should encompass a range of topics, from foundational principles to advanced applications and ethical implications, ensuring that every student has a minimum level of understanding regarding AI, irrespective of their major (Walter, 2024 and Sperling et al., 2024).

Mandatory training in AI literacy and ethics is recommended not only for higher education instructors but also for in-service educators of all levels. By cultivating a culture of ethical AI integration through ongoing education, educators can enhance student learning outcomes and navigate the complexities introduced by these advanced technologies (Brandão et al., 2024).

Encouraging student-led initiatives and enhancing the collaborations with AI experts play also a significant role in this regard. Beyond classroom instruction, establishing voluntary partnerships with AI experts, technology companies, and other educational institutions can provide valuable insights and resources. Such collaborations would help bridge the gap between theoretical knowledge and practical applications, enriching students` understanding of AI`s applications. In addition, fostering a culture of AI should also involve encouraging student-led initiatives, such as projects and clubs focused on AI (Rütti-Joy et al., 2024 and Casal-Otero et al., 2023). These initiatives promote active learning, peer collaboration, and innovation, allowing students to develop critical thinking and problem-solving skills which are essential for navigating a rapidly evolving digital landscape.

Policy framework

The recent 2023 AI index report from Standford Institute for Human-Centered AI highlights the significant surge in investment in AI and an enhanced focus on ethical considerations, especially concerning fairness and transparency. This increases attention to ethics stems from the recognition of the potential problems that AI poses in various sectors, including education. The findings of this report underscore a global interest in establishing legislative frameworks regarding AI from the USA. On the other hand, in Europe, the European commission has issued ethical guidelines regarding the use of AI and data in educational contexts, reflecting a similar commitment to addressing the ethical challenges posed by AI technologies (MacDowell et al., 2024). The rapid advancement of AI necessitates a responsive policy framework that not only encompasses broad societal implications but also focuses on the unique circumstances and challenges present within the educational sector. For instance, as AI systems increasingly automate recommendations and actions to facilitate learning, educators must navigate and comply with existing federal and state privacy laws (Cardona et al., 2023).

MATERIALS AND METHODS

The paper employs a quantitative methodological approach, and the primary data were gathered through a structured questionnaire among educators in Albania. The cross-sectional design was adopted to identify and analyze prevalent patterns regarding the challenges that teachers face when using AI tools in their educational settings. Teachers who participated in this research belonged to public and private schools as well as representatives from rural and urban areas, who have used at least once or usually use AI tools in their classes. The data analysis procedure involved the application of non-parametric statistical tests, specifically the Mann-Whitney U test and the Kruskal-Wallis test, utilizing SPSS software to generate the results. The Mann-Whitney U test was employed to compare distributions between two independent groups, whereas the Kruskal-Wallis test facilitated comparisons among multiple groups. Descriptive statistics, including frequency distributions and cross-tabulations, were utilized to examine patterns of AI adoption and exposure across the sample. The

assumptions underlying non-parametric testing were duly respected, and effect sizes were reported to contextualize the practical significance of the findings.

RESULTS

Based on the data gathered, besides the lack of training or resources, teachers focused on other challenges like data privacy concerns. This is the second most common challenge in the group. It suggests a meaningful portion of respondents are worried about how student or school data might be handled when using AI tools. On the other hand, it has resulted that teachers have got limited access to technology, mostly those who teach in public schools. This typically reflects constraints like device availability, internet reliability, or lack of access to approved/usable software tools in the school context. Resistance from colleagues and school leaders is another result from the data analyzed, however, this is rare in this sample. It exists, but it's not a dominant barrier compared to training/resources, privacy, or access.

Table 1. The frequency of participation in training activities and the challenges faced by teachers to implement AI tools in class.

	Professional development to integrate AI in education							
			Never	Rarely	Sometimes	Usually	Often	Total
Challenges of AI integration in education								
	Lack of training or resources	count	6	9	28	20	8	71
		expected count	3.5	8.1	23.2	25.7	10.6	71.0
	Limited access to technology	count	1	6	3	12	5	27
		expected count	1.3	3.1	8.8	9.8	4.0	27.0
	Resistance from colleagues/managers to not use them	count	0	0	0	1	2	3
		expected count	.1	.3	1.0	1.1	.4	3.0
	Concerns about data privacy	count	0	1	15	18	6	40

		expected count	2.0	4.5	13.0	14.5	6.0	40.0
	Total	count	7	16	46	51	21	141
		expected count	7.0	16.0	46.0	51.0	21.0	141.0

The data suggests that the moment teachers understand how to use AI tools in classrooms properly and embrace the importance of these tools, are more likely to require more practical activities, training and workshops. Said that, the stronger the belief of teachers on usefulness of AI tools in students` learning outcomes and performance, the higher the interest teachers show in engaging in training activities. However, issues like time, access to resources provided by educational schools and confidence, which is personal, might raise or weaken the interest that teachers might have regarding the usage of AI tools. In addition, if teachers feel supported with materials, they are more willing to participate in training activities and more likely to learn new skills regarding AI. However, when these human and institution support is missing, their interest in participating holds back. Relevance and self-efficacy are two other issues that the results imply. Training sessions affect the engagement of teachers. When they are well explained, the tools would support the lesson planning or assessment or students in their learning process and moreover when the usage of these tools is explained step by step, teachers might feel more confident and willing to use them. However, the data also reveals some barriers that teachers face. Besides the advantages, some responses highlight the lack of school support or time pressure in using these tools or even uncertainties regarding AI ethics and data privacy. These results emphasize the fact that teachers' interest in participating in training activities can be reduced and the interest might be lowered if education institutions do not provide them with specific activities that would improve their skills or clear policies on how to properly use AI tools in class.

DISCUSSION

Considering the primary and secondary data it is recommended to enhance teachers` ethical awareness in AI tools by implementing mandatory training programs focused on developing their skills and emphasizing technical proficiency. This means that educational institutions must help teachers understand AI functionalities, data privacy, and responsible usage to foster ethical integration of AI tools in teaching practices. On the other hand, it is also recommended to implement continuous monitoring and evaluation by establishing mechanisms to regularly assess the effectiveness, equity, and ethical compliance of AI applications in education. Lastly, it is also recommended to foster a supportive school culture for AI adoption by creating an organizational environment that encourages experimentation, peer learning, and innovation related to AI. Establish communities of practice to share experiences, resources, and best practices as well as recognize and award teachers who effectively integrate AI tools in class.

CONCLUSIONS

The study provides transformative potential, challenges and considerations associated with the integration of AI in education practices. The analysis underscores that AI technologies have introduced significant opportunities for personalized, inclusive, and dynamic learning experiences. AI facilitates tailored instruction that addresses diverse student needs and enhances engagement, thereby promising a substantial evolution in pedagogical approaches. Furthermore, the study also highlights the challenges that teachers face when using AI tools, starting from infrastructural deficiencies, limited access to internet and hardware with a long persistent digital divide. Additionally, the study revealed some concerns that teachers have when they must

decide whether to use AI tools or not, and these concerns relate to data privacy and ethical considerations. The findings suggest that addressing these issues necessitates a multi-faceted strategy. Key recommendations include strengthening technological infrastructure, fostering AI literacy and ethical awareness among educators, and establishing clear policies to safeguard data privacy. In conclusion, while AI holds transformative promise for education, its successful integration depends on overcoming significant infrastructural, ethical, and attitudinal barriers.

ACKNOWLEDGEMENTS

We sincerely thank the conference team for the support and the opportunity they gave us to participate. Your dedication and effort have made this experience truly valuable. We appreciate your assistance and look forward to future collaborations.

REFERENCES

Brandão A, Pedro L, Zagalo N 2024. Teacher professional development for a future with generative artificial intelligence – an integrative literature review. Digital Education Review, 45: 151–157. https://doi.org/10.1344/der.2024.45.151-157

Cardona MA, Rodríguez RJ, Ishmael K 2023. Artificial intelligence and the future of teaching and learning. Office of Educational Technology. Available at: https://tech.ed.gov/files/2023/05/ai-future-of-teaching-and-learning-report.pdf

Casal-Otero L, Catala A, Fernández-Morante C, Taboada M, Cebreiro B, Barro S 2023. AI literacy in K-12: A systematic literature review. International Journal of STEM Education, 10(1): 29. https://doi.org/10.1186/s40594-023-00418-7

Eusebio EJG, Baldera PR, Patiam AMC, Villanueva EF, Gaa NA, Solis AMF, Soriano ML, Ribon AL 2025. AI in the classroom: A systematic review of barriers to educator acceptance. International Journal of Learning, Teaching and Educational Research, 24(9): 126–147. https://doi.org/10.26803/ijlter.24.9.7

Karimov A, Saarela M, Kärkkäinen T 2024. Teachers' adoption of AI tools: Motivations, challenges, and skills required. In: eLearn 2024, Singapore, October 7–10, 2024, pp. 26–37. ISBN 978-1-939797-80-3.

MacDowell P, Moskalyk K, Korchinski K, Morrison D 2024. Preparing educators to teach and create with generative artificial intelligence. Canadian Journal of Learning and Technology, 50(4): 1–23. https://doi.org/10.21432/cjlt28606

Novianti I 2025. An exploratory study on the challenges of AI technology in education and its practical recommendations. International Journal of Social Science Research and Review, 8(3): 26–37. https://doi.org/10.47814/ijssrr.v8i3.2481

Rütti-Joy O, Winder G, Biedermann H 2023. Building AI literacy for sustainable teacher education. Zeitschrift für Hochschulentwicklung, 18(4): 175–189. https://doi.org/10.21240/zfhe/18-04/10

Sperling K, Stenberg C-J, McGrath C, Åkerfeldt A, Heintz F, Stenliden L 2024. In search of artificial intelligence (AI) literacy in teacher education: A scoping review. Computers and Education Open, 6: 100169. https://doi.org/10.1016/j.caeo.2024.100169

Walter Y 2024. Embracing the future of artificial intelligence in the classroom: The relevance of AI literacy, prompt engineering, and critical thinking in modern education. International Journal of Educational Technology in Higher Education, 21(1): 15. https://doi.org/10.1186/s41239-024-00448-3

Zhang H, Lee I, Moore K 2024. An effectiveness study of teacher-led AI literacy curriculum in K-12 classrooms. Proceedings of the AAAI Conference on Artificial Intelligence, 38(21): 23318–23325. https://doi.org/10.1609/aaai.v38i21.30380

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

PERCEIVED SOCIAL SUPPORT AND PARENT–EDUCATIONAL INSTITUTION PARTNERSHIPS: A QUALITATIVE STUDY OF PARENTS OF CHILDREN WITH DISABILITIES IN CROATIA

Emina Kovačić Ahmetović
Lecturer, Faculty of Teacher Education, University of Zagreb, Croatia
OCRID: 0000-0003-3490-8933

Abstract

Social support and high-quality partnerships between parents and educational institutions are important factors in promoting inclusive education for children with disabilities. The aim of this study was to explore parents' experiences regarding the availability of social support, the quality of communication, participation in decision-making processes, institutional barriers, and children's social inclusion. The study involved parents of preschool- and primary-school-aged children with disabilities. Data were collected through semi-structured interviews and analyzed using thematic analysis following the approach proposed by Braun and Clarke (2006, 2022). Five main themes were identified: emotional support, communication with educational professionals, parental participation in decision-making, institutional barriers, and children's social inclusion. The findings indicate that, although parents reported positive experiences of collaboration with educational institutions, they also expressed dissatisfaction with the availability of professional support and the opportunities for active participation in educational processes.

Keywords: social support, parents of children with disabilities, parent–educational institution partnerships, inclusive education.

Introduction

High-quality partnerships between parents and educational institutions are an essential component of inclusive education. Their importance is particularly evident in the context of children with disabilities, whose educational, developmental, and social needs often require continuous coordination of various forms of support. Under such circumstances, parents are not merely recipients of professional information but active participants in the planning, implementation, and evaluation of educational practices. The concept of family–professional partnerships is grounded in mutual trust, respect, open communication, and shared responsibility for children's development. Blue-Banning et al. (2004) identify six key dimensions of high-quality partnerships: communication, commitment, equality, professional competence, trust, and respect. These dimensions provide a framework for understanding partnerships as dynamic relationships that extend beyond formal collaboration between parents and professionals. Dunst and Trivette (2009) emphasize the importance of family-centered approaches that build upon families' strengths, needs, and priorities. Such approaches can contribute to strengthening parental competencies, self-efficacy, and their sense of control over decisions affecting their children's development. In this context, social support represents a multidimensional construct encompassing emotional, informational, and instrumental support. According to the theoretical model proposed by Cohen and Wills (1985), social support can buffer the negative effects of stressful experiences, while Cutrona and Russell (1987) highlight various social resources that contribute to feelings of security, belonging, and personal worth. Parents of children with disabilities may face additional demands related to accessing their children's rights and entitlements, the availability of rehabilitation and educational services, and the coordination of professional support. A systematic review conducted by Hayes and Watson (2013) demonstrated that parents of children with autism spectrum disorder report, on average, higher levels of

parenting stress compared with parents of typically developing children. Nevertheless, parental experiences are not homogeneous, and understanding them requires consideration of individual, familial, and institutional circumstances.

Within the Croatian and broader regional context, the study conducted by Međaković et al. (2024) is particularly relevant, as it included 953 parents and caregivers of children with disabilities from Croatia, Serbia, and North Macedonia. The findings highlighted challenges related to service accessibility, the realization of rights and entitlements, and the need for various forms of support. An additional perspective on social support and family–professional collaboration is provided by research examining family quality of life and the role of social networks in supporting parents of children with disabilities. Kyzar et al. (2012), in their synthesis of research on families of individuals with severe disabilities, identified significant relationships between family support and outcomes such as family functioning, satisfaction, quality of life, and stress. Their findings suggest that support should be understood not merely in terms of the availability of individual services but also in relation to its perceived usefulness and contribution to overall family well-being. Similarly, Turnbull et al. (2007) emphasized the importance of considering both internal family characteristics and external support resources when examining outcomes among families of individuals with intellectual disabilities.

The relationship between perceived social support and parental psychological well-being has also received considerable attention. Benson (2012), in a study involving mothers of children with autism spectrum disorder, found that characteristics of social support networks were associated with perceived support, which in turn was related to psychological adjustment. These findings highlight the importance of examining not only the objective availability of support but also parents' subjective perceptions of its adequacy and emotional significance. Consequently, educational professionals may play an important role in strengthening parents' perceived support through accessible communication, emotional responsiveness, and recognition of family needs.

From the perspective of family–school collaboration, Sheridan and Wheeler (2017) emphasized the importance of developing partnerships based on shared goals, collaborative problem-solving, and active family participation. Their work demonstrates how research on family–school relationships can inform practical interventions aimed at strengthening cooperation and supporting children's development. More recently, Mu et al. (2023), in a systematic literature review of partnerships among families, schools, and universities, highlighted the importance of addressing power imbalances and educational inequalities within collaborative relationships. These findings suggest that effective partnerships require more than opportunities for parental involvement; they also depend on institutional practices that recognize families as legitimate contributors to educational decision-making.

The importance of coordinated professional support is further emphasized by Castro-Kemp et al. (2022), whose scoping review examined cross-sector collaborative practices for children with special educational needs and disabilities. The authors identified different forms of multidisciplinary, interdisciplinary, and transdisciplinary collaboration, highlighting the importance of coordination across professional and institutional boundaries. Such findings are particularly relevant for families of children with disabilities, whose needs frequently involve educational, healthcare, rehabilitation, and social welfare services. Insufficient coordination between these systems may place additional organizational and emotional demands on parents. Empirical research has also examined strategies for improving communication between parents and teachers of children with autism spectrum disorder. Azad et al. (2021) investigated a school-based consultation model designed to strengthen parent–teacher communication and collaboration. Their findings provide preliminary support for structured approaches that facilitate information exchange and collaborative problem-solving. These insights reinforce the importance of establishing communication practices that extend beyond occasional meetings or problem-focused interactions and instead promote continuity, mutual understanding, and shared responsibility. Finally, parental involvement and family support should be considered in relation to children's opportunities for

meaningful participation in everyday activities. A systematic review of family factors associated with the participation of children with disabilities identified several potentially modifiable factors, including parental self-efficacy, support, family preferences, and parental well-being. These findings indicate that children's participation is shaped not only by individual characteristics but also by the resources and circumstances of their families. Accordingly, understanding parents' experiences of social support and educational partnerships may contribute to identifying conditions that facilitate children's active participation, peer relationships, and sense of belonging within inclusive educational environments. Despite the importance of quantitative indicators, a qualitative approach enables a deeper understanding of how parents interpret their own experiences. It is particularly valuable for exploring relationships of trust, communication patterns, experiences of acceptance, and perceptions of institutional barriers.

2. Research Aim and Research Questions

The aim of this study is to understand how parents of children with disabilities perceive the availability and quality of social support, as well as their partnerships with educational institutions.

The study addresses the following research questions:

1. How do parents describe the emotional support they receive from educational professionals?
2. How do parents perceive the quality and accessibility of communication with educational institutions?
3. To what extent do parents feel involved in decision-making processes concerning their children's education and upbringing?
4. What institutional barriers do parents identify in accessing and obtaining support?
5. How do parents perceive their children's social inclusion and acceptance within educational settings?

3. Methodology

3.1. Research Approach

The study adopted a qualitative research approach aimed at understanding the subjective experiences of parents of children with disabilities. Semi-structured interviews were used as the data collection method, allowing predefined thematic areas to be explored while maintaining flexibility to accommodate participants' individual experiences and perspectives.

Data were analyzed using reflexive thematic analysis as developed by Braun and Clarke (2006, 2022). This approach enables the identification and interpretation of patterns of meaning within qualitative data while acknowledging the active role of the researcher in the development and interpretation of themes.

3.2. Participants

The study involved 30 parents of children with disabilities. Participants were recruited using snowball sampling. Initial participants were contacted through the researcher's professional networks. Participation was voluntary, and participants were informed that they could withdraw from the study at any time without providing a reason.

Table 1. Sociodemographic Characteristics of Participants (N = 30)

Characteristic	Category	n	%
Parent's gender	Mothers	24	80.0
	Fathers	6	20.0
Educational setting attended by the child	Preschool institution (kindergarten)	12	40.0
	Primary school	18	60.0

Primary disability category	Autism spectrum disorder	10	33.3
	Speech and language disorders	7	23.3
	Intellectual disabilities	5	16.7
	Motor disabilities	4	13.3
	Multiple disabilities	4	13.3

3.3. Data Collection Procedure

Data were collected through semi-structured interviews conducted between June and September 2026. Prior to the interviews, participants were contacted by email or telephone and provided with information about the purpose of the study, participation procedures, expected interview duration, their right to withdraw, and measures taken to ensure data confidentiality.

The interviews were conducted face-to-face at times agreed upon with the participants. Each interview lasted approximately 30 to 45 minutes. With participants' prior consent, the interviews were audio-recorded for subsequent transcription and analysis. Interviews followed a previously developed interview protocol; however, participants were encouraged to elaborate freely on their responses and discuss experiences they considered particularly relevant.

3.4. Data Analysis Procedure

The analytical process followed the six phases of reflexive thematic analysis: familiarization with the data, generation of initial codes, construction of initial themes, reviewing and developing themes, defining and naming themes, and producing the analytical report.

The study was conducted in accordance with fundamental ethical principles of research involving human participants. All participants provided informed consent, and measures were implemented to protect their anonymity and ensure the confidentiality of the collected data. Data collection was discontinued upon reaching theoretical saturation, defined as the point at which additional interviews no longer generated new thematic insights.

Audio recordings of the interviews were transcribed verbatim. Data were analyzed using an inductive thematic analysis approach based on Braun and Clarke (2006), whereby themes were developed from the data rather than derived from predetermined analytical categories.

The analysis proceeded through six phases: familiarization with the data through repeated reading of interview transcripts; initial coding of meaningful text segments; grouping codes into potential themes; reviewing and evaluating themes in relation to the entire dataset; defining and naming themes; and producing the final analytical report.Data coding was conducted manually, without the use of specialized qualitative data analysis software.

4. Results of the Thematic Analysis

The qualitative analysis of interviews conducted with 30 parents of children with disabilities identified five main themes reflecting different dimensions of parental experiences. Participants' statements are identified by codes R01–R30. The analytical framework encompasses five main themes: emotional support, communication with educational professionals, partnerships and participation in decision-making, institutional barriers, and the social inclusion of children with disabilities.

Table 5. Thematic Structure of the Analysis

Main theme	Subthemes	Analytical codes
Emotional support	Understanding and acceptance; emotional availability; feelings of loneliness	Empathy, trust, security, lack of understanding
Communication	Timeliness of information; two-way dialogue; communication in challenging situations	Accessibility, clarity, active listening, lack of information
Partnerships	Recognition of parental expertise; shared decision-making; parental advocacy	Equality, participation, collaboration, initiative
Institutional barriers	Availability of professionals; administrative difficulties; continuity of support	Waiting lists, staff shortages, bureaucracy, fragmentation
Social inclusion	Peer acceptance; participation in activities; sense of belonging	Friendship, isolation, participation, inclusive climate

4.1. Emotional Support: Between Feelings of Acceptance and the Need for Understanding

The first theme concerns the emotional dimension of relationships between parents and educational professionals. Participants' accounts reveal two contrasting patterns of experience. The first involves feelings of understanding, acceptance, and emotional security in interactions with professionals, whereas the second encompasses experiences of being misunderstood, emotional distance, and the need to cope with challenges independently.

Parents who perceived emotional support positively emphasized the importance of professionals who acknowledged their concerns and approached them without judgment. In contrast, negative experiences were associated with situations in which parents felt that their concerns were not taken sufficiently seriously.

Table 6. Participants' Statements Related to Emotional Support

Participant code	Parent's statement	Subtheme
R01	"What means the most to me is when the preschool teacher listens to me and I feel that she understands how difficult things can sometimes be for us."	Understanding and acceptance
R04	"I don't always need advice. Sometimes it is enough for someone to say that they understand why I am worried."	Emotional availability
R09	"I feel that I constantly have to prove that my child needs support. It is extremely exhausting."	Feeling misunderstood
R15	"When I see that the teacher believes in my child, I feel more secure too."	Trust and security
R23	"Sometimes I feel completely alone, as though nobody understands what we are going through."	Feelings of loneliness

The analytical interpretation of these accounts suggests that emotional support is not limited to formal counseling services but is also established through everyday interactions between parents and professionals. Of particular importance is parents' perception that their concerns are acknowledged and that their experiences are regarded as relevant.

In this sense, emotional support can be understood as a relational process that contributes to the development of trust. However, when parents are repeatedly required to explain or justify their children's needs, communication itself may become an additional source of emotional burden.

4.2. Communication: Access to Information and Opportunities for Equal Dialogue

The second theme concerns the quality of communication between parents and educational professionals. Communication emerged as an important factor influencing parental satisfaction, but also as a potential source of uncertainty. Positive experiences included timely information exchange, professional accessibility, and willingness to engage in collaborative problem-solving. Negative experiences involved communication occurring primarily when problems arose, insufficiently explained decisions, and a lack of feedback regarding children's progress.

Table 7. Participants' Statements Related to Communication

Participant code	Parent's statement	Subtheme
R02	"The preschool teacher tells me every day how my child spent the day and what they managed to achieve."	Continuous communication
R06	"They usually contact me when there is a problem. I rarely hear anything positive."	Problem-focused communication
R11	"When I ask a question, I get an answer, but sometimes only after several days."	Timeliness of information
R17	"I would like the teacher to ask me what helps my child at home."	Two-way dialogue
R26	"Sometimes we agree on one approach, but a few days later I find out that something different is being done."	Inconsistent communication

These accounts indicate that parents distinguish between the frequency and quality of communication. Regular communication is not necessarily perceived as satisfactory when it consists primarily of one-way information sharing or reporting difficulties.

A particularly important dimension is the reciprocal nature of communication. Parents who have opportunities to share their observations and participate in planning educational strategies may develop a stronger sense of partnership. Conversely, inconsistent information and the absence of explanations or feedback may contribute to diminished trust in educational institutions.

4.3. Partnerships: Between Formal Involvement and Meaningful Participation

The third theme concerns parents' experiences of participating in decisions regarding their children's upbringing, education, and support. A distinction emerged between parents' formal involvement and their actual influence on educational practices.

Positive experiences were associated with recognition of parents' knowledge of their children, collaborative goal-setting, and professionals' openness to parental suggestions. Negative experiences included perceptions that decisions had already been made before parents were consulted or that parents had limited opportunities to influence the decision-making process.

Table 8. Participants' Statements Related to Partnerships

Participant code	Parent's statement	Subtheme
R03	"When we set goals for my child together, I feel that we really are a team."	Collaborative planning
R08	"I am invited to meetings, but I often feel that everything has already been decided."	Formal involvement
R13	"I know my child better than anyone, but sometimes I feel that my opinion is not taken seriously enough."	Recognition of parental expertise
R19	"The school support professional always asks me whether I agree with the proposed approaches."	Equality in decision-making
R28	"If I don't initiate the conversation myself, changes generally don't happen."	Parental advocacy

From an analytical perspective, these accounts illustrate the importance of distinguishing participation as a formal procedure from participation as a meaningful process of shared decision-making.

Parental advocacy may serve a dual function. On the one hand, it represents parents' active engagement in securing their children's rights and meeting their needs. On the other hand, it may indicate insufficient institutional proactivity when parents perceive that support would not be provided without their continuous initiative.

4.4. Institutional Barriers: Limited Availability and Continuity of Support

The fourth theme concerns organizational and systemic barriers that may restrict the quality of support available to children with disabilities and their families. Parents highlighted the limited availability of educational support professionals, lengthy administrative procedures, inconsistencies in support provision, and the need for improved coordination among different services.

Table 9. Participants' Statements Related to Institutional Barriers

Participant code	Parent's statement	Subtheme
R05	"Everyone is trying their best, but there simply aren't enough professionals."	Shortage of qualified professionals
R10	"For every form of assistance, we need new documentation and have to explain the same things all over again."	Administrative burden
R14	"Support often depends on who happens to be available at the time."	Lack of continuity
R21	"We waited for months before our child received the professional support they needed."	Limited access to services
R29	"The preschool, doctors, and therapists often don't have the same information."	Insufficient intersectoral coordination

These accounts highlight the importance of understanding parental experiences within a broader institutional context. Even when parents positively evaluate the work of individual professionals, they may simultaneously express dissatisfaction with the organizational conditions under which support is provided.

A particularly important distinction concerns the interpersonal and systemic dimensions of support. A positive relationship with an individual preschool teacher or schoolteacher cannot fully compensate for insufficient professional resources, administrative complexity, or inadequate coordination among institutions.

4.5. Social Inclusion: From Physical Presence to a Sense of Belonging

The fifth theme concerns parents' perceptions of their children's social inclusion within educational settings. Participants' accounts reveal a distinction between children's physical presence in a preschool group or classroom and their meaningful participation, peer acceptance, and sense of belonging.

Positive experiences were associated with friendships, participation in shared activities, and supportive peer relationships. Negative experiences involved social isolation, insufficient adaptation of activities, and limited opportunities for participation.

Table 10. Participants' Statements Related to Social Inclusion

Participant code	Parent's statement	Subtheme
R07	"What makes me happiest is when my child comes home and says they played with friends."	Peer acceptance
R12	"My child is in the classroom, but I often feel that they are merely an observer."	Physical presence without participation
R16	"The teacher adapts activities so that my child can participate alongside the other children."	Active participation
R22	"What hurts me the most is seeing that other children don't invite my child to play."	Social isolation
R30	"For me, success means that my child feels they belong to their group."	Sense of belonging

The analytical interpretation of these accounts emphasizes that social inclusion cannot be equated with the mere physical presence of a child in a mainstream educational institution.

Successful inclusion requires the active creation of opportunities for participation, the development of peer relationships, and the establishment of an environment in which children can develop a sense of belonging. Parents' perceptions of their children's inclusion may therefore represent an important source of information regarding the quality of inclusive educational practices.

5. Discussion

Emotional support represents an important component of relationships between parents and educational professionals, as it contributes to feelings of security, acceptance, and mutual understanding. The findings of this study indicate that parents distinguish between the formal availability of professionals and the experience of receiving genuine emotional support. This understanding is consistent with the theoretical model of social support proposed by Cohen and Wills (1985), according to which social support may serve as a protective factor in stressful life circumstances. The importance of different forms of support is further elaborated in the social provisions framework developed by Cutrona and Russell (1987), which encompasses emotional attachment, social integration, reassurance of worth, and access to reliable assistance.

In the context of parenting children with disabilities, the meta-analysis conducted by Hayes and Watson (2013) is particularly relevant, demonstrating that parents of children with autism spectrum disorder report higher levels of parenting stress compared with certain comparison groups of parents. These findings highlight the need for accessible forms of support that extend beyond professional interventions directed at children and also acknowledge parents' emotional needs. Blue-Banning et al. (2004) emphasize that trust and respect constitute fundamental dimensions of high-quality family–professional relationships. According to their model, effective partnerships cannot be reduced solely to professional competence but also encompass how

professionals communicate with parents, recognize their needs, and demonstrate a willingness to collaborate. In this context, the statement of participant R04, emphasizing the need for parental concerns to be acknowledged, illustrates the distinction between providing professional advice and demonstrating emotional understanding. Parents may value professionals who not only offer solutions but also demonstrate a willingness to listen to their experiences and acknowledge the challenges they encounter. Dunst and Trivette (2009) further emphasize the importance of family-centered approaches in which support is based on recognizing families' strengths and priorities. Such approaches may contribute to strengthening parental self-efficacy and promoting more active participation in processes related to supporting their children. Consequently, emotional support should be regarded as an integral component of professional relationships rather than an additional or optional aspect of working with parents. Communication between parents and educational professionals represents another central dimension of effective collaboration. The findings suggest that parents may positively evaluate the availability of information while simultaneously expressing dissatisfaction with its timeliness, clarity, or opportunities for active participation in discussions. Blue-Banning et al. (2004) identify communication as one of the six key dimensions of family–professional partnerships. Effective communication encompasses not only the frequency of contact but also openness, honesty, clarity, and a willingness to exchange different perspectives. Within the framework of school, family, and community partnerships, Epstein (2011) emphasizes the importance of continuous collaboration among stakeholders involved in the educational process. Communication facilitates the integration of parental experiences and expectations with educational goals and institutional practices. Particularly relevant findings are provided by Međaković et al. (2024), whose study reported that approximately 68% of parents and caregivers identified professionals working with their children as a source of information about their children's conditions, while approximately 53% used the internet. These findings highlight the importance of professionals as sources of informational support, as well as the need to ensure that parents have access to various reliable sources of information. Within the Croatian subsample of that study, teachers were more frequently identified as sources of information than in the comparison samples from Serbia and North Macedonia. This finding further emphasizes the potential role of educational professionals in providing informational support to parents. The statement of participant R06, describing communication focused almost exclusively on problems, raises the issue of balance in the content of information exchanged. When parents predominantly receive information about difficulties, they may develop the perception that the educational institution insufficiently recognizes their children's strengths and achievements. Conversely, the statement of participant R17 illustrates the importance of two-way communication in which parental experiences are acknowledged as relevant sources of information for developing educational practices. This understanding is consistent with family-centered approaches that emphasize mutual knowledge exchange rather than the one-way transmission of professional recommendations (Dunst & Trivette, 2009).

Partnerships between parents and educational institutions are grounded in the principle of shared responsibility for children's development and education. However, parents' formal involvement does not necessarily imply meaningful participation in decision-making processes. The statements of participants R08 and R13 describe situations in which parents may attend meetings while simultaneously feeling that their opinions are not sufficiently acknowledged. Blue-Banning et al. (2004) identify equality and respect as important dimensions of partnerships. In this context, equality does not imply that parents and professionals possess identical competencies but rather acknowledges the different forms of knowledge and experience that contribute to understanding children's needs.

Parents possess valuable knowledge regarding their children's everyday functioning, interests, communication patterns, and strategies that have proven effective within the family environment. Professionals, on the other hand, contribute specialized knowledge of development, learning, teaching, and different forms of support. High-quality partnerships emerge when these perspectives are integrated into collaborative planning. Dunst and Trivette (2009) emphasize that family-centered practices should strengthen parental capacities and facilitate active participation in decision-making processes. The importance of parental participation can also be linked to the findings of Međaković et al. (2024), who identified the realization and protection of the rights

of children with disabilities as an important area of parental challenges. Parental advocacy may serve a positive function by enabling parents to actively represent their children's needs. However, when parents perceive that appropriate support is provided only through their continuous initiative, advocacy may become an additional source of burden. It is therefore essential to develop institutional procedures that facilitate systematic and timely parental participation, rather than allowing involvement to depend on individual persistence or the availability of particular professionals. Institutional barriers represent an important contextual factor influencing the quality of partnerships. Parents' accounts related to this theme highlight the insufficient availability of professionals, lengthy administrative procedures, and inadequate coordination across different systems. The study by Međaković et al. (2024) found that approximately 60% of respondents who answered the relevant question reported difficulties related to the availability of services in their local communities or waiting lists. These findings confirm that access to support represents a significant concern for parents of children with disabilities in Croatia and neighboring countries. In the same study, some parents reported financial difficulties, reduced working hours, or the termination of employment by a family member due to responsibilities associated with caring for their child. These findings indicate the broader consequences of insufficient institutional support for families' everyday functioning. From the perspective of Bronfenbrenner's (1979) ecological theory of human development, the experiences of parents and children should be understood within interconnected systems. The quality of relationships between families and educational institutions depends not only on individuals but also on organizational, social, and institutional circumstances. This perspective enables a distinction between interpersonal and systemic levels of support. Parents may express satisfaction with individual preschool teachers, schoolteachers, or educational support professionals while simultaneously reporting dissatisfaction with the overall availability of services. The statement of participant R05 particularly illustrates this distinction: the participant acknowledges professionals' efforts while highlighting shortages of qualified personnel. This interpretation is important because it prevents institutional difficulties from being simplistically attributed to the individual responsibility of employees. Improving collaboration requires organizational changes, the availability of professional resources, and better coordination among different services.

The social inclusion of children with disabilities represents an important indicator of the quality of inclusive education. It extends beyond children's physical presence in mainstream preschool groups or classrooms and encompasses active participation, the development of peer relationships, and a sense of belonging. Ainscow, Booth, and Dyson (2006) emphasize that inclusive education requires the systematic identification and removal of barriers to participation and learning. In this context, inclusion cannot be understood solely in terms of children's administrative placement within mainstream educational settings. The statement of participant R12, describing a child who is physically present in the classroom but frequently remains an observer, illustrates the distinction between physical presence and meaningful participation. Conversely, the statements of participants R07 and R30 emphasize the importance of friendship, acceptance, and a sense of belonging. Such experiences may be particularly meaningful to parents because they provide opportunities to evaluate inclusive practices beyond narrowly defined academic achievements. The study by Međaković et al. (2024) demonstrated that communication difficulties and challenges in social interactions represent important areas of concern among parents of children with disabilities. The quality of inclusive educational environments therefore requires preschool teachers and schoolteachers to take an active role in promoting peer relationships, adapting activities, and fostering a supportive group climate. Parents can contribute to this process by providing information about their children's interests, communication patterns, and situations in which they are more successful in establishing social interactions.

6. Integration of Thematic Areas

The five thematic areas identified in the analysis can be understood as interconnected dimensions of parental experiences. Emotional support contributes to the development of trust, while effective communication facilitates information exchange and a shared understanding of children's needs. Trust and communication create the conditions necessary for parents' active participation in decision-making processes. However, the

development of high-quality partnerships may be constrained by institutional barriers, particularly when professional support is not available in a timely manner. Children's social inclusion represents an important area in which the outcomes of collaboration may become evident within everyday educational settings.

Table 11. Relationships Between Thematic Areas, Theoretical Concepts, and Scientific Literature

Thematic area	Theoretical concept	Relevant authors
Emotional support	Social support, stress buffering, trust	Cohen and Wills (1985); Cutrona and Russell (1987); Hayes and Watson (2013)
Communication	Family–professional partnerships, two-way dialogue	Blue-Banning et al. (2004); Epstein (2011); Međaković et al. (2024)
Partnerships	Equality, parental empowerment, shared decision-making	Dunst and Trivette (2009); Blue-Banning et al. (2004)
Institutional barriers	Ecological approach, service accessibility, systemic support	Bronfenbrenner (1979); Međaković et al. (2024)
Social inclusion	Participation, belonging, inclusive culture	Ainscow et al. (2006); Međaković et al. (2024)

7. Practical Implications for Inclusive Educational Practice

The analysis of the five thematic areas provides several important recommendations for improving collaboration between parents of children with disabilities and educational institutions.

First, it is necessary to foster an institutional culture in which parents are recognized as equal partners in the educational process. Such a culture involves acknowledging parental experiences, remaining open to different perspectives, and systematically involving parents in planning support for their children. Blue-Banning et al. (2004) emphasize that trust, respect, communication, and equality constitute key dimensions of effective family–professional partnerships.

Second, educational institutions should establish clear and accessible communication procedures that facilitate continuous information exchange. Timely feedback on children's progress, collaborative identification of challenges, and joint planning of support strategies are particularly important. Communication should not focus exclusively on difficulties and problems but should also acknowledge children's abilities, interests, and developmental achievements.

Third, meaningful parental participation in decision-making processes must be ensured. This includes collaboratively defining developmental and educational goals, considering different support options, and regularly evaluating their effectiveness. Family-centered approaches emphasize the importance of strengthening parental competencies and self-efficacy rather than reducing parents' roles to accepting decisions already made by professionals (Dunst & Trivette, 2009).

Fourth, improving partnerships also requires appropriate institutional conditions. The availability of educational support professionals, continuity of support, and coordination among educational, healthcare, and social welfare systems are essential prerequisites for providing high-quality support to families. The findings of Međaković et al. (2024) indicate that access to services and the realization of the rights of children with disabilities remain significant challenges in Croatia and the broader regional context.

Finally, the quality of inclusive educational practices should be evaluated not only in terms of the availability of educational accommodations but also in relation to children's meaningful participation, peer acceptance, and sense of belonging within the educational community. Consistent with the approach proposed by Ainscow,

Booth, and Dyson (2006), inclusion involves the continuous identification and removal of barriers to learning and participation.

8. Study Limitations and Recommendations for Future Research

Several methodological limitations should be considered when interpreting the findings of this study. One of the primary limitations concerns its geographical scope, as the study included parents of children with disabilities from only one region of the Republic of Croatia. This sample composition limits the transferability of the findings to the broader population of parents, particularly given potential regional differences in the availability of professional support, the organization of educational services, and the development of inclusive practices.

Another limitation concerns the composition of the sample, as participants did not necessarily represent a balanced distribution of parents in terms of the type and severity of their children's disabilities, children's ages, types of educational institutions attended, or socioeconomic and family circumstances. These differences may significantly shape parental experiences of social support and the perceived quality of partnerships with educational institutions. Since the study is based on parents' subjective experiences and perceptions, it is also important to acknowledge the potential influence of personal expectations, previous experiences, and emotional responses to particular situations on their accounts. Furthermore, the exclusive focus on parental perspectives does not provide a comprehensive understanding of the complexity of partnerships, as the experiences and views of preschool teachers, schoolteachers, educational support professionals, and other specialists involved in the educational process were not included. Within a qualitative research approach, it is also important to consider the researcher's role in data collection, analysis, and interpretation. Braun and Clarke (2022) emphasize the importance of researcher reflexivity and theoretical awareness in reflexive thematic analysis, viewing data interpretation as an active process of meaning-making. Despite these limitations, the qualitative approach enables an in-depth understanding of parents' experiences, needs, and expectations regarding social support and collaboration with educational institutions. Future studies should include more geographically diverse samples of parents from different regions of Croatia and facilitate comparisons between the experiences of parents of preschool-aged children and those of primary-school-aged children. It would be particularly valuable to investigate differences in perceptions of partnerships according to the type of disability, availability of professional support, and characteristics of educational institutions. Finally, incorporating the perspectives of preschool teachers, schoolteachers, and educational support professionals, together with triangulation of data sources, would contribute to a more comprehensive understanding of the factors that facilitate or hinder the development of high-quality partnerships between parents of children with disabilities and educational institutions.

9. Conclusion

Perceived social support and the quality of partnerships between parents and educational institutions represent important factors in creating supportive and inclusive environments for children with disabilities. The theoretical analysis of five interconnected areas—emotional support, communication, partnership participation, institutional barriers, and social inclusion—demonstrates that effective collaboration extends beyond the formal exchange of information between parents and professionals. It is particularly important to recognize parents as active participants in the educational process whose experiences, knowledge, and expectations can contribute to the development of more appropriate forms of support for their children. The scientific literature highlights the importance of trust, mutual respect, two-way communication, and shared decision-making as fundamental components of high-quality partnerships. At the same time, institutional barriers, such as the limited availability of professionals, administrative complexity, and inconsistencies in the continuity of support, may restrict opportunities for effective collaboration. Particular attention should be devoted to the social inclusion of children with disabilities, whereby physical presence in mainstream educational institutions should not be regarded as the sole indicator of successful inclusion. Active

participation, peer acceptance, and a sense of belonging represent equally important dimensions of high-quality inclusive practices. In conclusion, improving partnerships requires the simultaneous strengthening of professional competencies, the development of a supportive institutional culture, and the establishment of systemic conditions that ensure accessible and continuous support for families. Future research should further deepen the understanding of parental experiences and identify specific practices that contribute to more effective collaboration between parents and educational institutions.

10. References

Ainscow, M., Booth, T., & Dyson, A. (2006). *Improving schools, developing inclusion*. Routledge.

Azad, G., et al. (2021). Partners in school: Optimizing communication between parents and teachers of children with autism spectrum disorder. *Journal of Educational and Psychological Consultation, 31*(4), 438–462. https://doi.org/10.1080/10474412.2020.1830100

Benson, P. R. (2012). Network characteristics, perceived social support, and psychological adjustment in mothers of children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 42*(12), 2597–2610. https://doi.org/10.1007/s10803-012-1517-9

Blue-Banning, M., Summers, J. A., Frankland, H. C., Nelson, L. L., & Beegle, G. (2004). Dimensions of family and professional partnerships: Constructive guidelines for collaboration. *Exceptional Children, 70*(2), 167–184. https://doi.org/10.1177/001440290407000203

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Braun, V., & Clarke, V. (2022). *Thematic analysis: A practical guide*. SAGE Publications.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard University Press.

Castro-Kemp, S., & Samuels, A. (2022). Working together: A review of cross-sector collaborative practices in provision for children with special educational needs and disabilities. *Research in Developmental Disabilities, 120*, Article 104127. https://doi.org/10.1016/j.ridd.2021.104127

Cohen, S., & Wills, T. A. (1985). Stress, social support, and the buffering hypothesis. *Psychological Bulletin, 98*(2), 310–357. https://doi.org/10.1037/0033-2909.98.2.310

Cutrona, C. E., & Russell, D. W. (1987). The provisions of social relationships and adaptation to stress. In W. H. Jones & D. Perlman (Eds.), *Advances in personal relationships* (Vol. 1, pp. 37–67). JAI Press.

Dunst, C. J., & Trivette, C. M. (2009). Capacity-building family-systems intervention practices. *Journal of Family Social Work, 12*(2), 119–143. https://doi.org/10.1080/10522150802713322

Epstein, J. L. (2011). *School, family, and community partnerships: Preparing educators and improving schools* (2nd ed.). Westview Press.

Hayes, S. A., & Watson, S. L. (2013). The impact of parenting stress: A meta-analysis of studies comparing the experience of parenting stress in parents of children with and without autism spectrum disorder. *Journal of Autism and Developmental Disorders, 43*(3), 629–642. https://doi.org/10.1007/s10803-012-1604-y

Kyzar, K. B., Turnbull, A. P., Summers, J. A., & Gómez, V. A. (2012). The relationship of family support to family outcomes: A synthesis of key findings from research on severe disability. *Research and Practice for Persons with Severe Disabilities, 37*(1), 31–44. https://doi.org/10.2511/027494812800903247

Međaković, J., Čivljak, A., Zorčec, T., Vučić, V., Ristić-Medić, D., Veselinović, A., Čivljak, M., & Puljak, L. (2024). Perceptions on support, challenges and needs among parents and caregivers of children with developmental disabilities in Croatia, North Macedonia and Serbia: A cross-sectional study. *BMC Pediatrics, 24*, Article 297. https://doi.org/10.1186/s12887-024-04770-7

Mu, G. M., Gordon, D., Xu, J., Cayas, A., & Madesi, S. (2023). Benefits and limitations of partnerships amongst families, schools and universities: A systematic literature review. *International Journal of Educational Research, 120,* Article 102205. https://doi.org/10.1016/j.ijer.2023.102205

Sheridan, S. M., & Wheeler, L. (2017). Building strong family–school partnerships: Transitioning from basic findings to possible practices. *Family Relations, 66*(4), 670–683. https://doi.org/10.1111/fare.12271

Turnbull, A. P., Summers, J. A., Lee, S.-H., & Kyzar, K. (2007). Conceptualization and measurement of family outcomes associated with families of individuals with intellectual disabilities. *Mental Retardation and Developmental Disabilities Research Reviews, 13*(4), 346–356. https://doi.org/10.1002/mrdd.20174

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

GLOBAL COURTYARD OF TRADITIONAL GAMES: AN INTERCULTURAL APPROACH TO PHYSICAL EDUCATION

Dimitrios Kanaros
Polychronis Bourdaniotis
https://orcid.org/0009-0000-9996-2856, Varvakeio Model High School, Physical Education Teacher, Athens, Greece.
https://orcid.org/0000-0002-6266-4174, Experimental High School of the University of Patras, Physical Education Teacher, Patra, Greece.

Abstract

This paper presents the innovative initiative "A Global Schoolyard of Traditional Games," which uses Physical Education as a context for intercultural learning, social interaction, and inclusion. The initiative primarily aimed to introduce students to traditional movement-based games from different countries and cultures and to foster respect for cultural diversity. During its implementation, the students researched the origins, rules, and social significance of the games, presented their findings to the class, and actively participated in playing the games in the schoolyard. Through collaborative and experiential activities, they enhanced their motor skills while developing cooperation, communication, empathy, and acceptance of diversity. At the same time, the initiative highlighted common elements across the traditions of different peoples, demonstrating that play constitutes a universal form of expression, communication, and socialization. The action research was conducted from November 2025 to March 2026 with two groups of adolescents comprising a total of 48 students from a Model and an Experimental General Upper Secondary School in Greece. The students completed two anonymous questionnaires: one at the beginning of the initiative and another upon completion. Throughout the study, the researchers kept reflective journals in which they recorded their observations, the students' comments and remarks, and aspects of their behavior. As part of the initiative, the students completed theory-based assignments that involved researching traditional games from Greece, Europe, Asia, Africa, and Latin America using digital tools such as Canva and Google Slides. At the same time, they participated in these traditional games in the schoolyard. The findings indicated that exploring the cultures of different countries and continents through traditional games, combined with the use of contemporary digital applications, increased the adolescents' interest. The students learned and played traditional games with which they had previously been unfamiliar, while also engaging with the world's diverse cultural heritage. The initiative was evaluated through systematic observation, student self-assessment, analysis of the questionnaires and reflective journals, and an assessment of the students' participation and collaboration.

Keywords: traditional games, intercultural education, Physical Education, inclusion, experiential learning.

INTRODUCTION

Integrating innovative teaching methods, contemporary instructional approaches, and movement activities into Physical Education curricula remains an ongoing priority for fostering students' enthusiasm for sport and positive attitudes towards a healthy lifestyle (Pasek et al., 2022). Selecting movement activities that capture children's interest, support their physical development, and foster their social skills is therefore essential for promoting active engagement in Physical Education lessons (Darling-Hammond et al., 2020; García-Marín & Fernández-López, 2020). According to Bull et al. (2020), appropriate, well-designed movement activities not only contribute substantially to students' physical development but also foster skills and personal qualities such as empathy, perseverance, and problem-solving.

Traditional games should constitute an integral part of the annual Physical Education curriculum, as they encompass a range of physical activities, including ball games, jumping, and running, which promote motor skills, movement coordination, strength, speed, and children's overall physical fitness (Eigenschenk et al., 2019). These enjoyable and engaging games foster teamwork and offer children distinctive opportunities to learn through physical activity. They also enhance students' motor skills, coordination, and interpersonal interaction, contributing to their social, emotional, and cognitive development (Barba-Martín et al., 2020). Furthermore, traditional games form part of a country's cultural heritage, passed down from generation to generation and reflecting its history, traditions, values, and way of life. Through these games, children become familiar with local traditions and engage with their cultural identity, gaining an appreciation of enduring values and role models (Petrovska et al., 2013).

Nevertheless, despite their value for motor development, broader child development, and cultural learning, traditional games have been displaced by digital entertainment, exergames, and other activities involving lower levels of physical movement. Recent evidence indicates that many students demonstrate low levels of physical and motor literacy, highlighting the inadequacy of traditional opportunities for sport and movement in school playgrounds (Edwards et al., 2018; Lavega-Burgués et al., 2023). Traditional games represent a promising pedagogical approach within Physical Education, as they naturally integrate fundamental movement abilities and skills, emotional regulation, social interaction, and enjoyment within meaningful cultural contexts (Lavega-Burgués et al., 2023).

MATERIALS AND METHODS

The present study adopted an action research methodology, which, according to Shomekh (1995), connects the research process with practical application. The intervention was organized into four successive phases—Planning, Action, Observation, and Reflection (Bryman, 2017)—with the aim of identifying effective ways to address problems that might arise during the learning process.

This innovative intervention aimed to integrate traditional games into Physical Education lessons by combining the use of new technologies with conventional teaching in the school playground. Contemporary pedagogical approaches, including experiential, cooperative, and inquiry-based learning, were employed alongside instructional techniques such as group work, role-playing, case studies, and simulation. These approaches and techniques were selected on the basis of constructivist learning principles, which emphasize students' active participation in authentic, collaborative learning environments (Savery & Duffy, 1995; Ward & Tiessen, 1997).

The intervention involved 60 students from one model and one experimental upper secondary school, who were evenly allocated to experimental and control groups. It lasted four months during the 2025–2026 academic year. Students completed two anonymous questionnaires, one before the intervention and one after its completion, following a pretest–posttest design. In parallel, the teacher-researchers maintained reflective journals documenting students' activities, behaviors, attitudes, and broader responses while completing theoretical and practical tasks. Instruction followed a blended learning model, combining face-to-face teaching with synchronous and asynchronous distance learning activities delivered through Webex and e-class. Questionnaire data were collected using Google Forms. For the quantitative analysis, Cronbach's alpha was calculated to assess internal consistency, the Kolmogorov–Smirnov test was applied to examine data normality, and the non-parametric Friedman test was used to identify any statistically significant differences between measurements within each experimental group.

RESULTS

The assessment of students' theoretical assignments and practical tasks involving movement activities through traditional games, together with the analysis of the two teachers' journals, revealed increased knowledge of

traditional games from around the world, including their folklore, origins, and associated traditions. These findings also highlighted students' interest in exploring the cultural heritage of other countries and the history of their own country. Although some students were initially unfamiliar with several of the traditional games, they quickly and effectively met the demands of the intervention.

A large majority of students reported that the intervention had familiarized them with their own country's traditional games while also introducing them to the traditions, customs, and cultural practices of countries worldwide. They also gained an understanding of key aspects of these games, including their traditional significance and how and why they originated in different countries. A notable finding was a shift in the attitudes and behaviors of most students towards Greek traditional games. Students reported gaining basic historical knowledge and recognizing that participation in these games could improve fundamental motor skills, such as rhythmic movement, as well as their physical fitness. Students' accounts of their experiences also revealed a willingness to participate in similar interventions in the future, as they believed that these activities could effectively develop both their motor and social skills.

Students completed the innovative intervention with enthusiasm and enjoyment, as participation in traditional games was successfully combined with an exploration of their theoretical background, supported by contemporary digital applications. Applications such as Canva AI, ChatGPT, and Gemini, alongside other artificial intelligence tools, contributed to the intended learning outcomes. This was achieved despite some students' initial concerns, expressed in their responses to the online questionnaire, about whether they possessed the digital skills required to use these tools for learning.

Specifically, the posttest analysis revealed statistically significant differences between the control and experimental groups across all dimensions of physical literacy: physical, psychological, social, and cognitive. All corresponding p-values were below .05, indicating statistically significant differences in posttest scores between the two groups. These findings suggest that the intervention had a positive effect on physical literacy among students in the experimental group.

DISCUSSION

This four-month innovative intervention aimed to investigate the effects of blended learning and the use of contemporary digital tools on learning and playing traditional games from different countries. The findings indicated that new technologies positively influenced the learning process, with most students reporting high levels of satisfaction with both the teaching approach and the organization of instruction (Almusharraf & Khahro, 2020), as well as with the use of contemporary digital applications (Nie & Hu, 2018). This approach offers students multiple representations of reality, fosters reflection, supports collaborative learning, and facilitates the development of authentic learning activities centered on real-world situations (Bellou, 2011; Schmid & McGreevy-Nicholas, 2021; Li et al., 2022).

The findings of this action research study indicate that traditional games positively influence adolescents' physical literacy by strengthening its four dimensions—physical, psychological, social, and cognitive—while also fostering cultural awareness (Capel & Whitehead, 2015; Hassani & Afazeli, 2024). As enjoyable physical activities of low to moderate intensity, these games not only enhance physical capacities and motor skills but also play an important role in children's emotional development and psychological well-being (Hassani & Aydın, 2025). According to these researchers, traditional games combine simplicity with complexity and offer adjustable levels of difficulty, thereby sustaining interest and active participation while preventing boredom.

Traditional games can serve as a contemporary pedagogical approach that promotes both students' physical activity and cultural awareness. Their integration into Physical Education lessons and children's everyday lives is therefore particularly important, as they offer a valuable means of enhancing learning and encouraging constructive use of leisure time (Lavega-Burgués et al., 2023). Furthermore, the movement, communication,

and cooperation inherent in traditional games foster a range of motor and social skills while strengthening motivation to participate (Barnett et al., 2022).

Lavega-Burgués et al. (2023) argue that traditional games encourage teamwork, communication, and emotional regulation, all of which are essential to students' holistic development. They therefore serve both as opportunities for physical activity and as effective teaching strategies aligned with contemporary principles of inclusive curriculum design. This potential was also evident in the present action research study, in which students highlighted the dynamic, engaging, and interesting nature of traditional games compared with other forms of exercise and practice in Physical Education lessons (Ayaz-Alkaya & Akca, 2025). The findings also revealed higher levels of motivation and willingness to participate in sporting activities, which are crucial to sustaining healthy patterns of behavior among children and adolescents.

CONCLUSION

This four-month action research study highlighted the pedagogical value of integrating traditional games from different countries with blended learning and contemporary digital tools in Physical Education. Most students responded positively to the organization of instruction and the use of digital applications, suggesting that combining digital support with experiential physical activity can create an engaging and participatory learning environment.

The findings also suggest that traditional games have the potential to support adolescents' holistic development by connecting the physical and motor aspects of participation with its psychological, social, and cognitive dimensions. Students' interest, willingness to participate, and opportunities for communication and teamwork highlight the contribution of these games to positive experiences in Physical Education. Furthermore, introducing students to games from different countries provides a meaningful context for intercultural learning, enabling them to explore diverse cultural traditions through the shared experience of play. Physical activity can thus serve as a starting point for fostering mutual respect, acceptance of diversity, and a sense of belonging.

The flexibility of traditional games is particularly valuable from a pedagogical perspective, as adapting rules, roles, and levels of difficulty offers opportunities for differentiated instruction and meaningful participation among students with diverse abilities, experiences, and interests. Their systematic integration into Physical Education can therefore enrich the curriculum with activities that combine movement, enjoyment, cooperation, and cultural knowledge. Familiarizing children with accessible and adaptable forms of play can also encourage constructive use of leisure time and promote physical activity beyond the school setting.

However, the positive evaluation of the intervention should be interpreted within the context of this particular action research study. Satisfaction and increased willingness to participate are encouraging indicators, but they are insufficient on their own to establish long-term changes in physical literacy or physical activity habits. Longer-term research across diverse school settings, combining reflective journals, systematic observation, and appropriate measures, could examine whether the outcomes are sustained and clarify the respective contributions of blended learning and traditional games. This intervention provides a foundation for designing learning experiences that connect cultural tradition with digital innovation through a clear pedagogical purpose, expanding opportunities for active, collaborative, and inclusive participation in Physical Education.

REFERENCES

Alam MS, Kaur G, Jabbar., Javed K, Athar M 2007. *Eruca sativa* seeds possess antioxidant activity and exert a protective effect on mercuric chloride induced renal toxicity. Food and Chemical Toxicology, 45: 910-920.

Almusharraf, N., & Khahro, S. (2020). Students satisfaction with online learning experiences during the

COVID-19 pandemic. International *Journal of Emerging Technologies in Learning (iJET), 15*(21), 246–267.

Ayaz-Alkaya, S., & Akca, A. (2025). The impact of traditional children's games on internet use, social skills, and stress level: A cross-sectional design. *Journal of Transcultural Nursing, 36*(1), 84–91. https://doi.org/10.1177/10436596241274344

Barba-Martín, R. A., Bores-García, D., Hortigüela-Alcalá, D., & González-Calvo, G. (2020). The application of the teaching games for understanding in physical education. Systematic review of the last six years. *International Journal of Environmental Research and Public Health, 17*(9), Article 3330. https://doi.org/10.3390/ijerph17093330

Barnett, L. M., Mazzoli, E., Bowe, S. J., Lander, N., & Salmon, J. (2022). Reliability and validity of the PL-C Quest, a scale designed to assess children's self-reported physical literacy. *Psychology of Sport and Exercise, 60*, Article 102164. https://doi.org/10.1016/j.psychsport.2022.102164

Bryman, A. (2017). *Μέθοδοι κοινωνικής έρευνας* (Π. Σακελλαρίου, Μετ.; Α. Αϊδίνης, Επιστ. επιμ.). Gutenberg.

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., . . . Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine, 54*(24), 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Capel, S., & Whitehead, M. (Eds.). (2015). *Learning to teach physical education in the secondary school: A companion to school experience* (4th ed.). Routledge.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Edwards, L. C., Bryant, A. S., Keegan, R. J., Morgan, K., Cooper, S.-M., & Jones, A. M. (2018). 'Measuring' physical literacy and related constructs: A systematic review of empirical findings. *Sports Medicine, 48*(3), 659–682. https://doi.org/10.1007/s40279-017-0817-9

Eigenschenk, B., Thomann, A., McClure, M., Davies, L., Gregory, M., Dettweiler, U., & Inglés, E. (2019). Benefits of outdoor sports for society. A systematic literature review and reflections on evidence. *International Journal of Environmental Research and Public Health, 16*(6), Article 937. https://doi.org/10.3390/ijerph16060937

García-Marín, P., & Fernández-López, N. (2020). Motor skills competence in preschool education. *Apunts. Educación Física y Deportes, 141*, 21–32. https://doi.org/10.5672/apunts.2014-0983.es.(2020/3).141.03

Hassani, F., & Aydın, E. (2025). Exploring physical literacy: Insights from physical education teachers in Turkey on physical activity and curriculum practices for students with autism spectrum disorder—A brief study based on interviews. *Sport Sciences for Health, 21*(2), 807–814. https://doi.org/10.1007/s11332-024-01317-2

Hassani, F., Sheikh, M., & Shahrbanian, S. (2022). The physical literacy and children with autism. *Early Child Development and Care, 192*(3), 470–480. https://doi.org/10.1080/03004430.2020.1766452

Lavega-Burgués, P., Magno-Ribas, J. F., & Pic, M. (Eds.). (2023). *Traditional sporting games and play in physical education: Enhancing cultural diversity, emotional well-being, interpersonal relationships and intelligent decisions, volume II*. Frontiers Media SA. https://doi.org/10.3389/978-2-8325-3852-4

Li, Q., Li, Z., Han, J., & Ma, H. (2022). Quality assurance for performing arts education: A multi-dimensional analysis approach. *Applied Sciences, 12*(10), Article 4813. https://doi.org/10.3390/app12104813

Μπέλλου, Ι. (2011). Παιδαγωγική αξιοποίηση των ΤΠΕ. Στο Α. Μικρόπουλος (Επιμ.), *Επιμορφωτικό υλικό: Αξιοποίηση των ΤΠΕ στην εκπαίδευση*. Παιδαγωγικό Ινστιτούτο.

Nie, T., & Hu, J. (2018). EFL students' satisfaction with the college English education in the MOOC: An empirical study. Advances in Social Science, Education and Humanities Research,, 182, 92–95.

Nie, T., & Hu, J. (2018). EFL students' satisfaction with the college English education in the MOOC: An empirical study. Advances in Social Science, Education and Humanities Research,, 182, 92–95.

Pasek, M., Bendíková, E., Kuska, M., Żukowska, H., Dróżdż, R., Olszewski-Strzyżowski, D. J., Zając, M., & Szark-Eckardt, M. (2022). Environmental knowledge of participants' outdoor and indoor physical education lessons as an example of implementing sustainable development strategies. *Sustainability, 14*(1), Article 544. https://doi.org/10.3390/su14010544

Petrovska, S., Sivevska, D., & Cackov, O. (2013). Role of the game in the development of preschool child. *Procedia–Social and Behavioral Sciences, 92*, 880–884. https://doi.org/10.1016/j.sbspro.2013.08.770

Savery, J. R., & Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. *Educational Technology, 35*(5), 31–38.

Schmid, D. W., & McGreevy-Nichols, S. (2022). Building the dance community virtually during COVID-19. *Arts Education Policy Review, 123*(3), 135–142. https://doi.org/10.1080/10632913.2021.1931598

Somekh, B. (1995). The contribution of action research to development in social endeavours: A position paper on action research methodology. *British Educational Research Journal, 21*(3), 339–355. https://doi.org/10.1080/0141192950210307

Ward, D. R., & Tiessen, E. L. (1997). Adding educational value to the Web: Active learning with Alive Pages. *Educational Technology, 37*(5), 22–31.

Dawson SS, Michler CH 2014. Afforestation, restoration and regeneration - Not all trees are created equal. Journal of Forestry Research, 25(1): 3-20.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

WORKPLACE HARASSMENT AND ITS LEGAL IMPLICATIONS: ABSENTEEISM AND TURNOVER INTENTION AMONG WOMEN

Maria Francisca Marcelino
NOVA School of Law, NOVA University Lisbon, Lisbon, Portugal
Eduardo Ortega
CEBER - Centre for Business and Economics, FEUC - Faculty of Economics, University of Coimbra, Coimbra, Portugal

Abstract

Despite the existence of legal frameworks designed to protect workers from workplace harassment, its prevention and the effective enforcement of employers' legal obligations remain important challenges. Workplace harassment can have consequences that extend beyond the immediate harm experienced by workers, potentially affecting their attendance, organizational commitment, and willingness to remain in their jobs. This study examines the relationship between workplace harassment, absenteeism, and turnover intention among 509 Portuguese women, focusing on the organizational and legal implications of these responses. Using a quantitative cross-sectional design, the study investigates the association between workplace harassment and two forms of organizational withdrawal: absenteeism and turnover intention. The findings indicate that workplace harassment is positively associated with both outcomes, with a stronger association observed for turnover intention. These results suggest that experiences of harassment may be linked to employees' decisions to withdraw from their work environment, either through increased absence or through a greater intention to leave their organization.
From a legal perspective, these findings highlight the importance of effective measures to prevent and address workplace harassment, protect workers' rights, and ensure compliance with employers' applicable legal obligations. They also emphasize the relevance of organizational policies, accessible reporting mechanisms, and appropriate responses to complaints, helping to create working environments in which harassment is not tolerated. Addressing workplace harassment should therefore involve not only responding to individual incidents but also implementing preventive strategies that promote dignity, equality, and respect in the workplace. By examining absenteeism and turnover intention in connection with workplace harassment, this study contributes to understanding its broader organizational consequences and their relevance to workplace protection. The findings underline the importance of integrating effective prevention and response mechanisms into organizational practices, with the aim of safeguarding workers and reducing the adverse consequences associated with workplace harassment.

Keywords: Workplace Harassment; Legal Implications; Absenteeism; Turnover Intention.

INVISIBLE CONTAMINANTS, UNCLEAR RESPONSABILITIES: THE LEGAL CHALLENGES OF DRUG RESIDUES IN WASTEWATER

Tiago Zambujeira Mancha
NOVA School of Law, NOVA University Lisbon, Lisbon, Portugal
Maria Francisca Marcelino
NOVA School of Law, NOVA University Lisbon, Lisbon, Portugal

Abstract
The presence of pharmaceutical and illicit drug residues in wastewater represents an emerging environmental and public health challenge that remains insufficiently addressed by existing legal frameworks. Following consumption and excretion, these substances enter wastewater systems, where conventional treatment processes may not fully remove them before discharge into the aquatic environment. Their persistence raises concerns regarding water quality, aquatic ecosystems, and potential human health implications, while creating challenges for environmental governance and legal accountability.
This article examines the environmental and regulatory implications of drug residues in wastewater, focusing on the responsibilities of public authorities and pharmaceutical companies, existing water protection regimes, and the potential of wastewater-based epidemiology (WBE) as a monitoring tool. Drawing on European and Portuguese legal frameworks, alongside examples from Lisbon and Porto, it explores how wastewater monitoring can identify patterns of contamination and support evidence-based environmental and public health policies. Particular attention is given to the European Union Water Framework Directive, the polluter-pays principle, the Portuguese Environmental Liability Regime, and the regulation of medicinal products.
The analysis identifies significant regulatory gaps, particularly regarding the monitoring of emerging contaminants and the allocation of responsibility for diffuse pollution resulting from ordinary pharmaceutical use and human excretion. Although existing legal instruments establish environmental protection obligations and mechanisms for preventing and remedying environmental damage, they do not fully address the specific challenges posed by these contaminants. Furthermore, while WBE offers a non-invasive and cost-effective monitoring method, its implementation must consider potential privacy and data protection concerns.

The article concludes that a more integrated regulatory approach is necessary to strengthen wastewater monitoring, clarify the responsibilities of public and private actors, and improve coordination between environmental law, public health regulation, and pharmaceutical governance. These measures are essential to enhance regulatory accountability and protect water resources and public health.

Keywords: Wastewater Pollution; Pharmaceutical Residues; Illicit Drugs; Environmental Regulation.

STRENGTHENING ADMINISTRATIVE LEADERSHIP THROUGH INTERDISCIPLINARY PRACTICES: ENHANCING ORGANIZATIONAL EFFECTIVENESS IN LIBERIA'S PRIVATE SECTOR

Deacon Torh E. Q. Kalloh
ORCID: 0009-0006-9518-3170
Consolidated Group / Sinkor Palace, Sinkor Monrovia, Liberia
Author: Deacon Torh E. Q. Kalloh

Abstract

Administrative leadership has become increasingly important in promoting organizational sustainability, efficiency, and innovation in today's rapidly evolving workplace. As organizations adapt to technological advancement, globalization, and changing workforce expectations, interdisciplinary approaches have emerged as valuable tools for addressing complex administrative challenges. This study investigates how interdisciplinary administrative practices influence organizational effectiveness in Liberia's private sector, with particular reference to organizational management and service delivery.

The study adopts a qualitative case study approach based on practical administrative experience at Consolidated Group/Sinkor Palace. Data were drawn from organizational observations, administrative records, and relevant literature on management, organizational behavior, communication, information technology, and human resource development to examine how interdisciplinary practices contribute to administrative effectiveness.

The findings indicate that integrating interdisciplinary administrative practices enhances decision-making, strengthens communication, improves employee collaboration, and increases operational efficiency. The study further finds that continuous professional development, digital transformation, ethical leadership, and evidence-based management significantly contribute to organizational resilience, improved service delivery, and sustainable institutional performance. Within the Liberian private sector, organizations that adopt collaborative and multidisciplinary administrative strategies are better positioned to respond to changing economic conditions, improve customer satisfaction, and promote long-term organizational growth.

The study concludes that interdisciplinary administrative leadership provides a practical framework for strengthening organizational effectiveness and fostering innovation in developing economies. It recommends increased investment in professional training, technology adoption, cross-sector collaboration, and research-informed decision-making to enhance administrative capacity and support sustainable organizational development in Liberia.

Keywords: Administrative Leadership; Interdisciplinary Research; Organizational Effectiveness; Private Sector; Liberia.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE CONDITIONAL ROLE OF STORE INTERIOR DESIGN IN CUSTOMER EXPERIENCE AND BEHAVIORAL INTENTIONS: A QUALITATIVE STUDY IN ISTANBUL

Mahtab IRANI
ORCID: 0009-0009-5617-0942
Istanbul Nişantaşı University, Graduate School, Department of Business Administration, International Business, Istanbul, Türkiye.

Abstract

This study examines how customers interpret the role of store interior design in approaching a store, experiencing the shopping environment, and forming behavioral intentions. A generic qualitative research design grounded in an interpretive epistemology was adopted. Fourteen-question semi-structured interviews were conducted between 12 June and 16 July 2026 with 16 adults in Istanbul who had recent physical-store experience and were selected through purposive criterion sampling. No audio recordings were made; detailed contemporaneous notes were expanded on the day of each interview, anonymized, and analyzed using conventional and inductive qualitative content analysis. Five themes were developed: spatial legibility and access; sensory comfort and product interaction; the joint conditioning of reported behavior and behavioral intentions; design-generated meanings of quality, trust, and brand that are subsequently tested by performance; and variation according to the user, shopping purpose, budget, and cultural context. The findings do not support a linear claim that interior design independently causes purchases or revisit behavior. Instead, design shapes conditions for intermediate evaluations such as entrance legibility, circulation, accessibility, comfort, product assessment, and initial brand meaning. Reported purchases, purchase abandonment, and revisit intentions were interpreted together with product fit, price, stock availability, information, service, budget, and prior experience. The study proposes a conditional experiential chain that analytically separates design conditions, intermediate customer evaluations, reported outcomes, and contextual constraints. This distinction offers a more defensible explanation of how interior design contributes to physical retail experience while preserving the boundary between self-reported experience, intention, observed behavior, and causal effect. The findings can help retailers prioritize readable layouts, inclusive access, sensory comfort, and product evaluation without treating design as a substitute for product value or service performance.

Keywords: Store interior design; store atmosphere; customer experience; behavioral intentions; qualitative content analysis.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

SALESPERSON CAPABILITIES AND CUSTOMER OUTCOMES IN ISTANBUL'S READY-TO-WEAR RETAIL SECTOR: A CROSS-SECTIONAL CUSTOMER SURVEY

Parvin FEIZI
ORCID: 0009-0008-7729-0866, Istanbul Nişantaşı University, Graduate School, Department of Business Administration, International Business (Master's Program with Thesis), Istanbul, Türkiye.

Abstract

This study examines associations between customers' perceptions of salesperson communication skills, product knowledge, and motivation/professionalism and two customer outcomes: satisfaction and loyalty. A cross-sectional survey was administered face to face and online to 300 customers of ready-to-wear retail stores in Istanbul, selected through convenience sampling. The focal analysis used 22 five-point Likert items measuring communication skills, product knowledge, motivation/professionalism, customer satisfaction, and customer loyalty. Internal consistency was high across the five constructs (Cronbach's alpha = .838-.901). Communication skills (r = .691, 95% CI [.627, .746]), product knowledge (r = .637, 95% CI [.564, .700]), and motivation/professionalism (r = .715, 95% CI [.655, .766]) were positively associated with customer satisfaction. Satisfaction was also strongly associated with loyalty (r = .734, 95% CI [.677, .782]); all focal tests were significant at $p < .001$. The findings indicate that customers who perceive stronger frontline capabilities also report more favorable retail experiences and stronger loyalty intentions. For managers, the results support sustained investment in communication, product-knowledge, and professional-service development. Because the design is cross-sectional, based on non-probability sampling, and relies on a single customer-reported instrument, the results should be interpreted as associations rather than causal effects.

Keywords: salesperson capabilities; customer satisfaction; customer loyalty; ready-to-wear retail; frontline employees; Istanbul.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

PARENTAL ALIENATION AND DOMESTIC ABUSE: AN EVIDENCE-BASED LITERATURE REVIEW OF THEIR INTERSECTIONS, CONTROVERSIES, AND IMPLICATIONS FOR PRACTICE

Xhensila LATO
Edvin LAME
Ass. Lecturer, "Barleti University", Tirana
Faculty of Social Sciences, University of Tirana, Albania

Abstract

Disputes concerning parental alienation and domestic abuse often merge three questions: what contact difficulty a child displays, what adults have done, and what caused the child's response. This evidence-weighted narrative review examines their intersections, outcome evidence, family-court and gender controversies, and implications for assessment and intervention. Targeted searching through September 8, 2026, prioritized reviews, longitudinal and meta-analytic research, court-record studies, contrary interpretations, and authoritative guidance. Parent–child contact resistance emerged as a heterogeneous outcome requiring explanation, not a diagnosis or proof of manipulation or abuse. Domestic abuse, coercive control, maltreatment, deficient parenting, developmental factors, conflict, child agency, and relationship-undermining conduct may be distinct, co-occurring, or mutually reinforcing pathways. Evidence linking childhood intimate partner violence exposure with adverse adjustment is stronger than evidence attributing outcomes to parental alienation as a distinct causal construct. Court studies report associations in non-equivalent selected samples but cannot establish allegation truth, causation, or a uniform gender pattern. Evidence for intensive alienation-specific treatment, compelled reunification, or residence transfer remains very low-certainty. Practice should therefore be child-centred, safety-first, multi-hypothesis, and proportionate. Allegations, observations, corroborated facts, professional opinions, and legal findings should remain separate, and responses should be reviewable and matched to demonstrated conduct and risk.

Keywords: parental alienation, domestic abuse, differential assessment, Theme/Session: Social Sciences / Psychology and Family Studies.

Parental Alienation and Domestic Abuse: An Evidence-Based Literature Review of their intersections, controversies, and Implications for practice

Post-separation contact resistance can expose children and caregivers to serious harm, but a strained or absent parent–child relationship does not identify its cause. Maltreatment, intimate partner violence (IPV), coercive control, deficient parenting, developmental affinity, loyalty conflict, litigation pressure, relationship-undermining conduct, and child agency may operate alone or together. Interdisciplinary guidance therefore recommends description and individualized inquiry rather than an immediate causal label (Association of Family and Conciliation Courts [AFCC] & National Council of Juvenile and Family Court Judges [NCJFCJ], 2022; Family Justice Council [FJC], 2024).

The controversy cannot be resolved by denying either concern. Sustained denigration, interference, or loyalty pressure may damage relationships, and some scholars have characterized it as family violence (Harman et al., 2018). Domestic abuse may also continue after separation through intimidation, economic or technological control, litigation, exchanges, or use of children as leverage (Department of Justice Canada, 2024; Spearman et al., 2024). Critics report that alienation allegations may discredit protective conduct or obscure violence against women and children (Sheehy & Boyd, 2020). This review asks what distinctions clarify these intersecting pathways, how strong the evidence is on outcomes, courts, and interventions, and what safety-preserving practice follows. It neither diagnoses individuals nor offers legal advice.

Conceptual and Terminological Framework

Parent–child contact problem (PCCP) and **reluctance, resistance, or refusal (RRR)** describe a presentation without assigning cause. RRR requires explanation; it is not a diagnosis, credibility finding, or proof of manipulation or abuse. **Parental alienating behaviors (PABs) mean** specific alleged or observed conduct that may undermine a parent–child relationship. Evaluation should address the act, source, context, pattern, impact, corroboration, and plausible protective rationale. A checklist cannot establish causation.

Parental alienation (PA) usually adds a contested causal conclusion: rejection is disproportionate or unjustified, substantially attributable to another parent's conduct, and inadequately explained by maltreatment or seriously deficient parenting. It is not an established psychiatric diagnosis. Critics question circularity and discrimination from abuse-related estrangement, although construct-affirming scholarship treats severe PABs as family violence (American Professional Society on the Abuse of Children [APSAC], 2022; Harman et al., 2018; Marques et al., 2020; Robson et al., 2026). **IPV** includes physical, sexual, psychological, or economic abuse. **Coercive control** is a patterned course of domination constraining autonomy; it is not ordinary conflict or an incident count. **Post-separation abuse** is abuse that continues, begins, or escalates after separation (Department of Justice Canada, 2024; Spearman et al., 2024).

Four inference levels should remain separate: the child's observable conduct, documented adult behavior, the mechanism connecting conduct to the response, and a clinical or legal classification. Evidence at one level does not automatically establish the next. Contact restriction may be protective, controlling, mixed, or unclear. Likewise, a failure to substantiate an abuse claim does not establish intentional fabrication. **Unsupported**, **unsubstantiated**, **not proven**, **mistaken**, and **false** are not synonyms; investigator judgments of fabrication in one Canadian child-welfare sample were neither independently verified nor automatically generalizable to family-court IPV claims (Trocmé & Bala, 2005).

Method

This evidence-weighted narrative review is not a registered systematic review or meta-analysis. Targeted web and scholarly-source searches through September 8, 2026, addressed PA, PABs, PCCPs, IPV, coercive control, post-separation abuse, family courts, outcomes, assessment, and intervention. Selection favored reviews, longitudinal or meta-analytic evidence, court-outcome studies, contrary interpretations, and authoritative guidance. Records were checked through publisher, DOI, repository, and issuing-body pages; eight thematic reports were reconciled, and only sources used here were cited.

Claims were compared by construct definition, sampling frame, ascertainment, temporal ordering, control of alternatives, and outcome. Convergent reviews and prospective designs received greatest weight for outcomes. Selected-record, qualitative, cross-sectional, retrospective, or self-selected studies informed associations and mechanisms but not strong causal conclusions. Uncontrolled intervention reports were treated as very low-certainty; guidance informed process and ethics, not effectiveness. Limitations include no comprehensive database search, registered protocol, duplicate de novo screening, source-by-source formal risk-of-bias assessment, or quantitative synthesis. The included mapping review's more systematic procedures are not imputed to this review (Ames et al., 2021).

Results

Overlapping Pathways to contact resistance

PCCPs are heterogeneous. Experienced or witnessed harm, poor parenting, developmental factors, relational injuries, family conflict, adult influence, and child agency can be alternative, co-occurring, or reinforcing explanations (FJC, 2024; Sullivan et al., 2024). Domestic abuse can explain resistance, coexist with interference, or include relationship-undermining conduct. After separation, coercive control may continue through stalking, controlling parenting, or children's use as information or leverage (Katz et al., 2020; Spearman et al., 2024). Restrictions may likewise be protective, retaliatory, controlling, or mixed. An "either/or, neither/nor, both/and" formulation better fits the evidence than mutually exclusive labels (Sullivan et al., 2024).

Both institutional risks matter. Court-focused research reports that some abused women experienced alienation allegations as discrediting abuse accounts and damaging mother–child relationships (Sheehy & Boyd, 2020).

These selected cases establish a plausible safety concern, not its frequency or a claimant's motive. Conversely, scholarship characterizing severe PABs as family violence is strongest when tied to independently supported acts and demonstrated impact rather than inferred from rejection alone (Harman et al., 2018).

Evidence summary and outcome asymmetry

Table 1. *Summary of Evidence by Domain*

Domain	Best-supported conclusion	Strength and principal limit
Presenting problem	RRR/PCCP is heterogeneous and requires differential explanation.	**High** for practice; pathway frequencies are unknown.
Child IPV exposure	Exposure prospectively predicts adjustment and social-emotional difficulties.	**High for association**; confounding remains.
Reported PA/PAB exposure	Reported exposure is associated with distress and relational difficulty.	**Low–moderate for association; very low–low for causation** because measures are often retrospective, cross-sectional, self-selected, or insufficiently discriminant.
Court outcomes	Claims or findings correlate with outcomes in selected decisions.	**Moderate within datasets**; truth, causation, representativeness, and uniform gender effects are unestablished.
Intervention	Intensive treatment, compelled reunification, and residence transfer lack adequate testing.	**Very low–low**; benefits, harms, and safety remain uncertain.

**Note.* Strength ratings apply to the limited proposition stated and do not determine an individual case.

Outcome evidence is asymmetric. A meta-analysis of 74 longitudinal studies found prospective associations between childhood IPV exposure and internalizing, externalizing, and total-adjustment problems (Vu et al., 2016). A systematic review found lower social-emotional competence and emotion regulation in most included studies (Bender et al., 2022). These are group associations, not deterministic predictions, and residual confounding remains.

PA/PAB studies report depression, anxiety, reduced well-being, and relational difficulty, but commonly rely on adult recollection, cross-sectional or self-selected samples, same-informant measures, and limited assessment of IPV, maltreatment, prior parenting, or the rejected parent's conduct (Marques et al., 2020; Miralles et al., 2023; Robson et al., 2026). A three-wave study of 837 Chinese adolescents improved temporal ordering: self-reported PABs preceded poorer well-being over two years, with mediation by attachment and emotion regulation (Wang et al., 2025). It did not independently verify behaviors, establish unjustified rejection, or exclude competing processes. Coercive-control exposure, by contrast, was associated with post-traumatic stress and depression in a systematic review and meta-analysis (Lohmann et al., 2024). Distress warrants support without making care conditional on a contested forensic label.

Family-Court and Gender Debate

Court records reveal decision patterns, not ground truth. Meier (2020) analyzed 4,338 selected published United States opinions and reported associations among mothers' abuse allegations, fathers' alienation crossclaims, and maternal custody loss. The design cannot establish allegation truth, decision correctness, representativeness, or causation. Canadian analysis similarly warns that IPV and women's fear may be discounted when alienation enters judicial reasoning (Sheehy & Boyd, 2020).

Other selected judicial-decision research reports adverse outcomes associated with alienation findings and challenges a uniform gender interpretation (Harman et al., 2023). However, samples conditioned on abuse allegations and samples conditioned on PA findings estimate different effects. Neither resolves allegation truth or a universal gender pattern. Assessment should recognize population-level gender patterning in severe IPV while considering all parties without stereotypes. Men may also experience IPV or relationship interference;

gender inclusion must not erase differences in power, severity, pattern, fear, entrapment, or institutional response. Abuse and alienation allegations are distinct propositions, and neither logically disproves the other.

Intervention Evidence

Intervention is the weakest domain. A systematic review described apparent benefits and recommended residence changes and specialized therapy, whereas a critical review found inadequate evidence of safety and effectiveness (Mercer, 2019; Templer et al., 2017). The mapping review found no randomized intervention trials, and FJC guidance identifies no evidence-based health-care intervention specific to PA (Ames et al., 2021; FJC, 2024). Relationship repair may help some families, but intensive programs, compelled contact, residence transfer, or separation from a preferred parent cannot claim high-certainty support. Safety, symptoms, functioning, trust, relationship quality, adverse events, and the child's experience matter more than contact frequency alone.

Discussion

The evidence supports a conduct-based, mechanism-sensitive synthesis. Specific relationship-undermining behavior may be harmful, while an alienation allegation may obscure abuse or recast protection as obstruction. Treating either possibility as categorically true repeats the same inferential error. IPV outcome evidence has greater methodological maturity than PA/PAB causal evidence, but that asymmetry does not negate reported suffering; it requires separating therapeutic need from forensic attribution.

Court findings should not be presented as scientific prevalence estimates, and group research cannot decide an individual case. Transparent reasoning should distinguish what is alleged, observed, corroborated, professionally inferred, legally found, and unknown. This calibrated approach accommodates competing risks without assuming that uncertainty is harmless.

Differential Assessment

Assessment should be iterative, developmentally informed, and safety-first. Universal and repeated screening is necessary because disclosure, danger, and tactics can change during proceedings or renewed contact (FJC, 2024).

Table 2. *Stages and Safeguards for Differential Assessment*

Stage	Core task	Safeguard
1. Describe	Define what the child resists, when, and with whom.	Do not infer manipulation or abuse from RRR.
2. Triage safety	Screen for IPV, coercive control, stalking, self-harm, abduction, retaliation, and maltreatment.	Use qualified risk processes and reviewable protections.
3. Build chronology	Map caregiving, relationships, alleged harm, interference, disclosures, and contact change.	Use dates and records; inconsistency is not deception.
4. Test hypotheses	Examine abuse, deficient parenting, development, conflict, child agency, PABs, and mixed pathways.	State evidence for and against each; absence of an alternative is not affirmative proof.
5. Integrate	Consider child accounts, adult conduct, collateral records, context, impact, and gaps.	Distinguish direct evidence, hearsay, opinion, and corroboration.
6. Respond and review	Identify facts, plausible mechanisms, uncertainty, and the least coercive proportionate response.	Include child feedback, outcomes, review dates, monitoring, and stopping rules.

**Note.* This sequence is an evidence-informed framework, not a substitute for jurisdiction-specific legal, child-protection, or clinical procedures.

The child's views are both evidence and a rights interest but are not automatically determinative. A child may accurately report frightening conduct, minimize danger, echo another person, express a developmentally ordinary preference, or face several pressures. Assessment should neither reduce the child to a programmed object nor assume that preference explains itself (AFCC & NCJFCJ, 2022; FJC, 2024).

Practice and Policy Implications

Professionals should describe behavior and investigate safety and relationship-undermining conduct independently. Records should separate allegations, accounts, observations, corroborated facts, opinions, and legal findings. Reports should state sources, methods, chronology, missing information, competing explanations, confidence, and limits. Standard psychological testing cannot determine whether abuse occurred, and scale reliability does not establish diagnostic discrimination.

Intervention should follow assessment. Credible abuse calls for safety planning, trauma-informed support, accountability, and appropriate contact safeguards. Independently supported harmful undermining without substantiated abuse may call for education, structured communication, behavioral boundaries, individual work, and monitored repair. Mutual conflict may warrant parallel parenting; uncertainty favors time-limited fact development and reversible arrangements over high-coercion responses. Plans should specify expected benefits and harms, outcomes, review dates, and stopping criteria, and evaluators should disclose financial interests in recommended programs.

Limitations

This targeted synthesis was neither exhaustive nor did it formally rate every source. PA/PAB studies combine non-equivalent exposures, including self-identification, remembered behavior, RRR, professional classification, and court findings. Court studies overrepresent selected decisions and cannot verify family histories. Domestic-abuse research is stronger in several outcome domains but remains observational and heterogeneous. Qualitative studies clarify mechanisms without estimating population frequency.

Future Research

Prospective, multi-informant studies should distinguish RRR, reported PAB exposure, justified estrangement, and adjudicated findings while measuring prior relationships, development, IPV, coercive control, maltreatment, adult conduct, and child functioning. Court research needs representative trial-level samples, transparent preregistered coding, and sensitivity analyses. Intervention trials should stratify by pathway, separate provider and evaluator roles, preregister child-centered outcomes, record adverse events, and provide long-term follow-up. Independent replication and full disclosure of funding and conflicts are essential.

Conclusion

The evidence supports neither dismissal of relationship-undermining conduct nor acceptance of PA as a diagnosis. Contact resistance is a serious outcome requiring explanation. Domestic abuse, coercive control, maltreatment, deficient parenting, development, conflict, child agency, and interference may be distinct or co-occurring. IPV outcome evidence is stronger than evidence for PA as a distinct causal exposure, although reported PAB-associated distress warrants attention.

The defensible standard is specific conduct, independent safety inquiry, competing hypotheses, calibrated conclusions, and proportionate, reviewable action. This preserves the possibility that severe PABs may constitute family violence while addressing the risk that alienation allegations may obscure abuse. It also keeps unsupported, unsubstantiated, and false claims distinct. The task is not rapid labeling but identifying supported mechanisms and responses that improve safety and well-being without further harm.

References

American Professional Society on the Abuse of Children. (2022). *APSAC position statement: Assertions of parental alienation syndrome (PAS), parental alienation disorder (PAD), or parental alienation (PA) when child maltreatment is of concern*. https://apsac.org/wp-content/uploads/2023/05/APSAC-Position-Statement-PAS.pdf

Ames, H. M. R., Hestevik, C. H., Langoien, L. J., & Rosness, T. A. (2021). *Understanding and helping children who resist or refuse post-separation parental contact: A systematic mapping review*. Norwegian Institute of Public Health. https://www.fhi.no/en/publ/2021/Understanding-and-helping-children-who-resist-or-refuse-post-separation-parental-contact/

Association of Family and Conciliation Courts, & National Council of Juvenile and Family Court Judges. (2022). *AFCC and NCJFCJ joint statement on parent-child contact problems*. https://www.afccnet.org/Resource-Center/Center-for-Excellence-in-Family-Court-Practice/afcc-and-ncjfcj-joint-statement-on-parent-child-contact-problems

Bender, A. E., McKinney, S. J., Schmidt-Sane, M. M., Cage, J., Holmes, M. R., Berg, K. A., Salley, J., Bodell, M., Miller, E. K., & Voith, L. A. (2022). Childhood exposure to intimate partner violence and effects on social-emotional competence: A systematic review. *Journal of Family Violence, 37*(8), 1263–1281. https://doi.org/10.1007/s10896-021-00315-z

Department of Justice Canada. (2024). *Family violence and post-separation parenting*. https://www.justice.gc.ca/eng/rp-pr/jr/mapafvc-cbapcvf/parenting-parental.html

Family Justice Council. (2024). *Guidance on responding to a child's unexplained reluctance, resistance or refusal to spend time with a parent and allegations of alienating behaviour*. Courts and Tribunals Judiciary. https://www.judiciary.uk/wp-content/uploads/2024/12/Family-Justice-Council-Guidance-on-responding-to-allegations-of-alienating-behaviour-2024-1-1.pdf

Harman, J., Giancarlo, C., Lorandos, D., & Ludmer, B. (2023). Gender and child custody outcomes across 16 years of judicial decisions regarding abuse and parental alienation. *Children and Youth Services Review, 155*, Article 107187. https://doi.org/10.1016/j.childyouth.2023.107187

Harman, J. J., Kruk, E., & Hines, D. A. (2018). Parental alienating behaviors: An unacknowledged form of family violence. *Psychological Bulletin, 144*(12), 1275–1299. https://doi.org/10.1037/bul0000175

Katz, E., Nikupeteri, A., & Laitinen, M. (2020). When coercive control continues to harm children: Post-separation fathering, stalking and domestic violence. *Child Abuse Review, 29*(4), 310–324. https://doi.org/10.1002/car.2611

Lohmann, S., Cowlishaw, S., Ney, L., O'Donnell, M., & Felmingham, K. (2024). The trauma and mental health impacts of coercive control: A systematic review and meta-analysis. *Trauma, Violence, & Abuse, 25*(1), 630–647. https://doi.org/10.1177/15248380231162972

Marques, T. M., Narciso, I., & Ferreira, L. C. (2020). Empirical research on parental alienation: A descriptive literature review. *Children and Youth Services Review, 119*, Article 105572. https://doi.org/10.1016/j.childyouth.2020.105572

Meier, J. S. (2020). U.S. child custody outcomes in cases involving parental alienation and abuse allegations: What do the data show? *Journal of Social Welfare and Family Law, 42*(1), 92–105. https://doi.org/10.1080/09649069.2020.1701941

Mercer, J. (2019). Are intensive parental alienation treatments effective and safe for children and adolescents? *Journal of Child Custody, 16*(1), 67–113. https://doi.org/10.1080/15379418.2018.1557578

Miralles, P., Godoy, C., & Hidalgo, M. D. (2023). Long-term emotional consequences of parental alienation exposure in children of divorced parents: A systematic review. *Current Psychology, 42*(14), 12055–12069. https://doi.org/10.1007/s12144-021-02537-2

Robson, N., Neilson, L., & Dalgarno, E. (2026). Methodologies and moon landings: A critical review of parental alienating behavior research. *Journal of Family Trauma, Child Custody & Child Development*, 1–28. Advance online publication. https://doi.org/10.1080/26904586.2026.2677135

Sheehy, E., & Boyd, S. B. (2020). Penalizing women's fear: Intimate partner violence and parental alienation in Canadian child custody cases. *Journal of Social Welfare and Family Law, 42*(1), 80–91. https://doi.org/10.1080/09649069.2020.1701940

Spearman, K. J., Vaughan-Eden, V., Hardesty, J. L., & Campbell, J. (2024). Post-separation abuse: A literature review connecting tactics to harm. *Journal of Family Trauma, Child Custody & Child Development, 21*(2), 145–164. https://doi.org/10.1080/26904586.2023.2177233

Sullivan, M. J., Pruett, M. K., & Johnston, J. R. (2024). Parent-child contact problems: Family violence and parental alienating behaviors either/or, neither/nor, both/and, one in the same? *Family Court Review, 62*(1), 68–85. https://doi.org/10.1111/fcre.12764

Templer, K., Matthewson, M., Haines, J., & Cox, G. (2017). Recommendations for best practice in response to parental alienation: Findings from a systematic review. *Journal of Family Therapy, 39*(1), 103–122. https://doi.org/10.1111/1467-6427.12137

Trocmé, N., & Bala, N. (2005). False allegations of abuse and neglect when parents separate. *Child Abuse & Neglect, 29*(12), 1333–1345. https://doi.org/10.1016/j.chiabu.2004.06.016

Vu, N. L., Jouriles, E. N., McDonald, R., & Rosenfield, D. (2016). Children's exposure to intimate partner violence: A meta-analysis of longitudinal associations with child adjustment problems. *Clinical Psychology Review, 46*, 25–33. https://doi.org/10.1016/j.cpr.2016.04.003

Wang, K., Huang, Y., Zhang, X., & Wang, X. (2025). Parental alienation behaviors and adolescent mental health: A two-year longitudinal investigation of parent-child attachment and emotion regulation. *Applied Research in Quality of Life, 20*(4), 1377–1398. https://doi.org/10.1007/s11482-025-10474-6

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

AI-DRIVEN TAX TECHNOLOGY: ENHANCING GOVERNANCE AND REDUCING EVASION

Brunilda Llaftiu
https://orcid.org/0009-0002-4001-0783
University of Tirana, Faculty of Economics, Department of Accounting, Tirana, Albania

Abstract

Artificial Intelligence (AI) technologies have enabled more efficient governance, reduced fraudulent activities and enhanced trust between taxpayers and governments, which supports good governance. By increasing the speed and accuracy of dealing with large volumes of financial data, AI can identify fraudulent activity and target areas of higher risk to tax authorities, contributing to tax fraud reduction. Implementing AI technologies encourages the values of transparency, accountability and fairness within auditing and policy implementation, including fiscal policy. However, ethical, legal and privacy issues must be regulated to reduce abuse. This paper will provide a review of current literature on how AI is being used within tax administration. A case study will also be included which looks at how AI has been used within Albania alongside the country's current digital tax system. Machine learning has allowed greater efficiency when identifying areas of risk to audit, whilst automating procedures to reduce discretion and prevent corruption. Ensuring security through model audits, appeal rights and privacy is crucial. Albania implemented AI supported risk analysis, auto filled tax forms, VAT reporting and industry specific audits in conjunction with their fiscalisation system. An increase in tax revenues was noted.

Keywords: Artificial intelligence (AI), Tax fraud reduction, Fiscal transparency, Good governance, Albania.

INTRODUCTION

Artificial intelligence (AI) is changing the nature of tax systems by giving governments new tools to curb fraud, raise productivity and build trust between taxpayers and the authorities (Belahouaoui and Alm, 2025). Because AI can handle financial data at a scale and speed that human auditors cannot match, it makes the detection of tax evasion more robust and reliable (Raikov, 2021). AI systems are now used in many countries to monitor risk, understand taxpayer behaviour and support unbiased audit decisions, which makes tax administration more open and effective (Aslett et al., 2024). At the same time, AI raises new issues. Its use requires strong regulation, clear protection of taxpayers and a responsible approach to implementation, so that the technology is not misused or harmful (Guglyuvatyy, 2025).

The issues that this paper covers include: how AI assists in reducing tax evasion, how AI improves governance in the tax administration process, and how the tax system can achieve innovation without sacrificing integrity. The paper then looks at Albania as a case study. There are three main reasons why Albania is a good case to look at. First, the country has implemented real-time fiscalisation of invoices between 2020 and 2021, thus creating the transactional data that AI applications need (Thomson Reuters, n.d.). Second, the country's government has made AI a key issue in their policy priorities, ranging from the National AI Strategy 2025-2030 (ATA, 2025) to appointing an AI-based "minister" in September 2025 (Reuters, 2025). Third, it is an accession candidate whose tax administration is harmonizing their legislation with the EU acquis (RTSH, 2026).

MATERIALS AND METHODS

The study is a narrative literature review coupled with an instrumental case study of a single country. The review is based on nine peer-reviewed and institutional articles on machine learning in fraud detection and AI governance in tax administration and taxpayer rights, published between 2021 and 2025. These articles were chosen due to their relevance to evasion, governance and integrity issues.

The case study involves the use of three types of sources: (i) official communications of the Albanian government and Ministry of Finance and Tax Administration, including statements mentioned in the national news agency; (ii) international and professional publications, including World Bank public finance review and advisory firm reports; and (iii) one peer-reviewed empirical article on Albanian enterprises (Alla, 2026). The sources have been gathered in November 2026 and date back to 2020 up to September 2026.

Analytical Framework and Limitations

Findings are organised around the three themes of the review: evasion reduction, governance enhancement and the balance between innovation and integrity. The same three lenses are then applied to Albania. Official statements are treated as claims by the administration rather than as independent evaluations, and quantitative figures are reported as published, without recalculation. The main limitation is that evidence on AI in the Albanian tax administration is still largely descriptive, and no independent impact evaluation was found.

RESULTS

AI Helping Tax Administration Reduce Evasion

AI techniques can detect the problematic conduct and patterns in large amounts of data which is not possible for traditional methods (Belahouaoui and Alm, 2025). Such AI models compare taxpayer's financial activity with the current and previous periods to identify discrepancies which can be regarded as fraudulent. This allows auditors to pay attention to the most problematic issues which are the most vulnerable to fraud (Baghdasaryan et al., 2022). AI can help administrators to predict how the incomes might be concealed. As a result, AI increases audit selection and enforcement probability (Battaglini et al., 2024). The speed and quality of analysis become higher if the analysis includes not only the financial reports, but also the network of interconnection between taxpayers that allows discovering the concealed transactions and relations (Baghdasaryan et al., 2022). Automated classification, clustering, and anomalies detection can be used to uncover schemes of fraud based on the small differences which are overlooked by the auditors during the routine process (Choudhary, 2025). This makes tax investigation more grounded in facts and less subjective which allows focusing on high-risk cases (Battaglini et al., 2024).

In various countries, AI has already been able to reduce the size of the shadow economy, as a greater chance of being caught leads to better compliance (Raikov, 2021). Moreover, with AI, it is possible to detect new fraud schemes in a timely manner, as the model adapts to the new schemes more quickly than the traditional system (Belahouaoui and Alm, 2025).

AI Enhancing Governance in Tax Administration

Governance is made better through AI technology due to the increased level of accountability, transparency and fairness of tax administration, since it lowers the human bias which leads to inconsistencies in ruling (Aslett et al., 2024). Good tax collection requires good processes, information and trust between government and the taxpayers, and AI provides objective algorithms that assist in prediction and audits (Puspita et al., 2024). AI and other technological tools provide governments with up-to-date information concerning economic activities and therefore allow tax authorities to identify trends and risks associated with tax administration as well as make policies based on actual data rather than assumptions (Battaglini et al., 2024). AI tools help with quality control of the process by evaluating auditor performance, mistakes in valuation and making sure that audit standards are uniform all over the world (Aslett et al., 2024).

The adoption of such kind of governance also reduces corruption. In cases when automated processes replace manual activities carried out by people individually, the opportunity for subjective interpretation and manipulation of the taxation rules gets minimized (Raikov, 2021). As AI reduces the number of repetitive tasks, it gives the administrator the chance to concentrate on more complex activities, communication with the public and development of new taxpayer services, making it easier for taxpayers to pay their taxes (Puspita et

al., 2024). Government can also use models to analyze the potential impact of certain tax policies and develop an evidence-based policy that is more consistent with social needs and goals of justice (Battaglini et al., 2024). Thus, AI contributes to greater accessibility of the tax system with clear rules and their consistent implementation that builds up people's trust in state bodies (Guglyuvatyy, 2025).

Balancing Innovation and Integrity in Tax Administration

The list of benefits brought about by the application of AI in tax administration processes is long, and so is the list of ethical and legal issues that need to be addressed in order to protect the taxpayers' rights and build trust in the tax administration system (Guglyuvatyy, 2025). The use of technology to detect tax fraud needs to be balanced with considerations of privacy, equity, and transparency, since using AI raises new issues of its own, which can only be prevented if the training of the models is done with these considerations in mind (Aslett et al., 2024). One of the main risks of AI is related to fairness, since the historical data used in algorithmic training might have imbalances, and thus bias and discrimination against some taxpayers would occur (Qu and Jing, 2025). In order to avoid this, AI in tax administrations needs to be implemented through protocols.

Well-developed governance frameworks should also ensure proper audits of these AI models, as automated risk scoring may be erroneous and either lead to unnecessary audits or evasion (Aslett et al., 2024). Effective data protection practices and safe systems should be also present, as privacy issues become an essential aspect of building trust in tax authorities (Puspita et al., 2024). The fact that corporations will use artificial intelligence technologies for seeking new methods for evasion and, therefore, for undermining the system and its efficiency should also be taken into account by policy makers (Qu and Jing, 2025). Collaboration between tax agencies and banks, IT companies and other governments is crucial for ensuring responsible usage of AI technologies (Guglyuvatyy, 2025). It is possible to conclude that achieving the proper balance between innovation and ethical approaches to the issue requires certain principles and continuous monitoring and verification of the impartiality of the AI tools being used (Aslett et al., 2024).

Case Study: AI in Albania's Tax Administration

Digital foundation: real-time fiscalisation

Albania's use of AI rests on a digital foundation. Law No. 87/2019 created a new invoicing and turnover-monitoring model in which invoices are reported to the General Directorate of Taxes in real time. It replaced older fiscal devices that could not report in real time and were not compatible with EU standards (Thomson Reuters, n.d.). The stated goals were better tax collection, efficient control of transactions and the elimination of tax evasion (Thomson Reuters, n.d.). Fiscalisation was introduced in phases between September 2020 and July 2021 (Table 1). The result is a continuous stream of transaction-level data, which is the kind of input that machine learning models depend on.

Table 1. Key milestones in Albania's digital tax administration, 2020–2026

Date	Measure	Source
Sep 2020	Real-time fiscalisation of cash sales begins for VAT and profit-tax payers with turnover above ALL 8 million	Thomson Reuters (n.d.)
Jan 2021	Fiscalisation extended to smaller cash taxpayers and to cashless invoices issued to public bodies (B2G)	Thomson Reuters (n.d.)
Jul 2021	Non-cash business-to-business (B2B) invoices reported in real time	Thomson Reuters (n.d.)
Aug 2025	National AI Strategy 2025–2030 names tax-evasion detection as a priority application	ATA (2025)
Jan 2026	Law No. 79/2025: automatic VAT return filing within 24 hours; lower cash payment limits	Fiscal Solutions (2026)

Date	Measure	Source
2026	Tourism Sector Plan uses AI-supported risk analysis to identify higher-risk taxpayers	HLB Albania (2026)

Policy commitment to AI

The government discourse portrays AI as the next logical development following fiscalization. As Prime Minister Edi Rama noted, fiscalization was necessary but was not complete without AI, enabling real-time analysis of all financial transactions and faster detection of any issues (Media and Information Agency, n.d.). Among the priority uses of AI outlined in the National AI Strategy for 2025-2030 is the effort to counter tax evasion, where AI will be used to detect irregularities in fiscal and invoice data and analyze the electronic invoices and customs declarations (ATA, 2025). The Ministry of Finance included broader application of AI in taxation and customs administration as one of its priorities for 2026 in order to increase revenues and reduce the informal economy (Media and Information Agency, 2026). Apart from taxes, Diella, an AI system created in January 2025 as the virtual assistant of the e-Albania website and having 972,000 interactions recorded as of September 2025, was appointed "Minister of State for Artificial Intelligence" to fight corruption in public procurement (Jukni, 2026; Reuters, 2025).

Institutional and international context

This is a responsibility divided among organisations. Real time transaction monitoring, auditing and inspections are done by the General Directorate of Taxes (DPT), an agency within the Ministry of Finance, while technical aspects of the state digital infrastructure, including fiscalisation, are covered by the National Agency for Information Society (AKSHI) (Banqup, 2026). AI-related policy initiatives have been integrated into long-term reforms as well. An Albanian medium-term revenue strategy to widen the tax base and combat evasion has been launched (World Bank, 2025), and the DPT, together with the Swedish Tax Agency, undertook an initiative to improve revenue mobilization which took place from November 2022 to June 2026 (Addis Tax Initiative, n.d.). These collaborations are important as AI systems require not only data and technology but also skilled personnel, auditing techniques and legislation as well.

AI applications in practice

Tax administration uses AI and data analytics to target high risk areas of non-compliance and evasion. The Tourism Sector Plan in 2026 is a good example of this. This plan includes risk-based controls and the use of advanced technology and AI to identify non-declarants and high-risk taxpayers, including a focus on declaring revenues, registering employees and ensuring compliance with electronic invoicing (HLB Albania, 2026). Taxpayer services have been automated. In 2025, taxpayers were able to have their personal income tax return filled in for them. The reimbursement process for farmers has also moved to digital. (RTSH, 2026). Law number 79/2025 (January 2026) requires that if a taxpayer does not submit a Vat return, then the system will auto-generate and submit it within 24 hours. This will be done using the sales and purchases information. Cash payment limits have also been reduced. This is now ALL 100,000 for B2B and ALL 500,000 for B2C, to increase traceability. (Fiscal Solutions, 2026). These measures help prevent evasion but also identify it making it harder to evade and easier to comply. Figure 1 shows a summary of these processes.

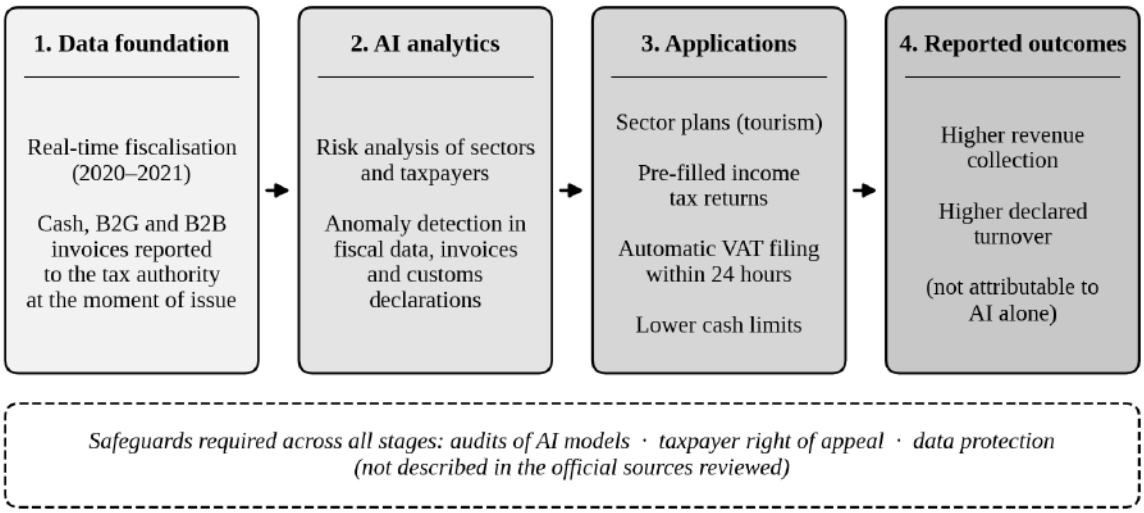


Figure 1. Stages of AI-enabled tax administration in Albania (compiled from the sources cited in the text)

Reported outcomes

The reported results are positive. The Tax Administration has managed to collect more than 4.7 billion euros in 2025, which is 11.8% compared to the previous year, and VAT refunds amounted to 262 million euros (RTSH, 2026). Taking into account social and health contribution, total tax and customs revenue was 6.7 billion euros in 2025, which is more than 560 million euros compared to the previous year, and the increase of almost 540 million euros was planned in 2026 without changes in taxes due to improved fiscal administration (Media and Information Agency, 2026). At the beginning of 2026, the Finance Minister once again linked the increase in revenue not with the higher tax rate but with improved tax and customs administration, and also announced an increase in the volume of business transactions of 7%, i.e. 1.3 billion euros more than in the previous year (IntelliNews, 2026). These numbers correspond to the formalization effect expected by the literature due to better detection (Raikov, 2021). But they cannot be explained by the use of AI alone, as fiscalization and economic growth were occurring simultaneously.

Independent evidence from Albanian enterprises

Some independent evidence starts emerging. Alla (2026) used regression analysis, Random Forest classification and Isolation Forest anomaly detection techniques to financial and fiscal indicators of 100 enterprises in trading, manufacturing, construction and service industries. The regression model explained 83.6% of the variance in the fiscal risk score. A negative connection of profit margin and operating cash flow to the fiscal risk and positive connection of the debt to assets ratio to the fiscal risk have been identified. Random Forest achieved the accuracy of 86.7% and AUC of 0.98, and Isolation Forest found out 19 enterprises with anomalous reporting behavior (Alla, 2026). The sample size is too small for assessing the performance of the production system. Nevertheless, it gives support to the idea that machine learning can be used for ranking taxpayers by risk and focusing on the cases with the highest probability of the compliance violation (Baghdasaryan et al., 2022). This is shown by the example of Albania provided by the World Bank (2025): the large bunching of personal income reported by individuals near the minimum wage suggests underreporting of their income.

Integrity risks and safeguards

The case of Albania serves to highlight some of the integrity concerns raised in the literature. Companies are also embracing AI technologies: in 2026, 12.4% of businesses employing ten or more people in Albania utilised AI technology, compared to 9% the previous year, and as much as 28.1% in large companies (Jukni, 2026). Companies, just as the tax authority, can then make use of AI to maximise their tax advantage (Qu and Jing, 2025). However, in the official documents reviewed, there is no information regarding measures that

according to Guglyuvatyy (2025), are absolutely necessary, such as the publication of the criteria for decision-making, the audit of the algorithm, and an appeals process for automated risk assessment. Scholars have highlighted that the critical issue here is if Albania will develop the necessary capacity of people, institutions, legislation and technology to control and utilise AI technologies (Jukni, 2026).

DISCUSSION

Table 2 summarises how the Albanian evidence maps onto the themes of the literature. The review and the case study point in the same direction on most of them, but not on integrity safeguards, where the available sources are silent.

Table 2. Literature themes compared with the Albanian evidence

Theme	Expected effect in the literature	Albanian evidence
Evasion detection	Risk-based audit selection and anomaly detection (Baghdasaryan et al., 2022; Choudhary, 2025)	Sector risk analysis and Tourism Sector Plan; machine-learning study of 100 enterprises (Alla, 2026)
Governance and trust	Less discretion and more consistent decisions (Aslett et al., 2024; Raikov, 2021)	Pre-filled returns, automatic VAT filing and a fully digital farmer reimbursement process (RTSH, 2026)
Integrity safeguards	Model audits, appeal rights and data protection (Guglyuvatyy, 2025)	Not described in the official sources reviewed
Taxpayer-side AI use	Firms may use AI to reduce their tax burden (Qu and Jing, 2025)	12.4% of enterprises and 28.1% of large enterprises use AI (Jukni, 2026)

Firstly, AI is more effective when utilised with quality data. The real-time fiscalisation in Albania has provided the administration with granular-level information, which has been used by the AI tools (risk profiling by sector, auto-complete and VAT automation) to shift the focus to using data to inform decisions. This is in line with the literature, which highlights risk-based sampling and transactional/network level data as the primary ways that detection has improved (Baghdasaryan et al., 2022; Battaglini et al., 2024).

Secondly, there are clear governance benefits. Auto-complete and automated returns reduce regular interaction between officials and taxpayers, decreasing the compliance burden and increasing the reduction of discretionary decision-making. This has increased fairness by reducing the opportunity for corruption by using automation (Raikov, 2021; Puspita et al., 2024). However, this does raise concerns about fairness. Although late filing and compliance checks are still enforced, they are being applied to returns that have been generated automatically. (Fiscal Solutions, 2026). Are taxpayers being properly protected?

Finally, there is an issue with the lack of verifiable impact. Although there are positive outcomes such as revenue growth, increased turnover being declared and favourable comments from officials, the fiscalisation, legal reform and economic growth were all taking place at the same time. Without published model documentation, measures of performance and independent assessment it is impossible to determine how much of an impact the AI had. This is an issue with transparency, which is mentioned in the integrity literature (Guglyuvatyy, 2025; Aslett et al., 2024).

Albania provides a good example for other countries looking to modernise their tax systems. They have first created a reliable digital invoicing and reporting system. Then added the risk profiling AI tool. Safeguards (criteria, appeals, routine audits of the model and data protection) have also been published. Future research should look at the impact of the AI-based sampling in Albania using independent data, and compare this to other countries in the region.

CONCLUSION

The introduction of AI technology has changed the tax system. Governments can now reduce tax avoidance, increase transparency and improve accountability, using this technology to create an open system (Belahouaoui and Alm, 2025). This technology improves the detection of fraud, creating more efficient policymaking and audit control. This creates a fairer, more transparent and predictable tax system (Battaglini et al., 2024). However, governments must also consider the benefits and drawbacks to ensure taxpayer rights are maintained. As AI technology becomes more advanced, governments must ensure they do not abuse this by protecting taxpayer rights (Guglyuvatyy, 2025). The relationship between the state and the citizen can continue to improve by efficiently using this technology. This reduces corruption and economic imbalance (Aslett et al., 2024).

An example of this can be seen in Albania. Risk analytics, auto-fill and automatic VAT filings have been implemented using AI technology. This has created a real-time fiscalisation system. During the same time frame, official data shows a significant increase in revenue (Media and Information Agency, 2026; RTSH, 2026). However, this can be improved by having an independent assessment and published protection. If AI technology continues to improve tax administration whilst keeping a high standard of ethics, it can help create a good governance system and a modern tax system that is trustworthy, transparent and efficient (Puspita et al., 2024).

REFERENCES

Addis Tax Initiative n.d. 2022–2025 project on tax administration: Swedish Tax Agency and General Directorate of Taxation of Albania. Available at: https://addistaxinitiative.net/node/101093

Alla M 2026. Artificial intelligence in detecting financial and tax reporting anomalies: Evidence from Albanian enterprises. *European Journal of Economics and Management Sciences*, (3): 15-20. https://doi.org/10.29013/EJEMS-26-3-15-20

Aslett J, Hamilton S, Gonzalez I, Hadwick D, Hardy MA 2024. Understanding artificial intelligence in tax and customs administration. *Technical Notes and Manuals*, 2024(006). https://doi.org/10.5089/9798400290435.005.A001

ATA 2025. National Strategy 2025–2030: Integrating AI in energy, public procurement, and fight against tax evasion. Albanian Telegraphic Agency, 21 August. Available at: https://en.ata.gov.al/2025/08/21/national-strategy-2025-2030-integrating-ai-in-energy-public-procurement-and-fight-against-tax-evasion/

Baghdasaryan V, Davtyan H, Sarikyan A, Navasardyan Z 2022. Improving tax audit efficiency using machine learning: The role of taxpayer's network data in fraud detection. *Applied Artificial Intelligence*, 36(1): 1-23. https://doi.org/10.1080/08839514.2021.2012002

Banqup 2026. E-invoicing requirements in Albania. Updated 21 September. Available at: https://www.banqup.com/resources/compliance-pulse/albania

Battaglini M, Guiso L, Lacava C, Miller DL, Patacchini E 2024. Refining public policies with machine learning: The case of tax auditing. *Journal of Econometrics*, 105847. https://doi.org/10.1016/j.jeconom.2024.105847

Belahouaoui R, Alm J 2025. Tax fraud detection using artificial intelligence-based technologies: Trends and implications. *Journal of Risk and Financial Management*, 18(9): 502. https://doi.org/10.3390/jrfm18090502

Choudhary H 2025. Hybrid approach to tax fraud detection using machine learning. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.5366577

Fiscal Solutions 2026. Albania updates tax procedures: Automated VAT returns and stricter cash limits. 4 March. Available at: https://www.fiscal-requirements.com/news/5091-albania-updates-tax-procedures-automated-vat-returns-and-stricter-cash-limits

Guglyuvatyy E 2025. Balancing innovation and integrity: AI in tax administration and taxpayer rights. *Humanities and Social Sciences Communications*, 12(1). https://doi.org/10.1057/s41599-025-06099-7

HLB Albania 2026. Albania's tourism sector under increased tax monitoring in 2026. Available at: https://www.hlb.al/albanias-tourism-sector-under-increased-tax-monitoring-in-2026/

IntelliNews 2026. Albania targets 4% growth in 2026. 29 July. Available at: https://www.intellinews.com/albania-targets-4-growth-in-2026-457797/

Jukni D 2026. Technological development in the age of artificial intelligence: Global debates, risks and prospects for Albania. Tirana Times. Available at: https://www.tiranatimes.com/technological-development-in-the-age-of-artificial-intelligence-global-debates-risks-and-prospects-for-albania/

Media and Information Agency 2026. Minister Malaj says economic growth continues as unemployment falls to lowest level in 30 years. Tirana: Media and Information Agency. Available at: https://mia.gov.al/en/minister-malaj-says-economic-growth-continues-as-unemployment-falls-to-lowest-level-in-30-years/

Media and Information Agency n.d. Albania making rapid progress in modernizing public administration through artificial intelligence (AI). Tirana: Media and Information Agency. Available at: https://mia.gov.al/en/albania-making-rapid-progress-in-modernizing-public-administration-through-artificial-intelligence-ai/

Puspita AF, Palil MRB, Puspaningrum A, Suman A 2024. Taxing artificial intelligence: Value impacts and governance in the tax sector (Study in Indonesia and Malaysia). *Pakistan Journal of Life and Social Sciences*, 22(1). https://doi.org/10.57239/pjlss-2024-22.1.00343

Qu G, Jing H 2025. Is new technology always good? Artificial intelligence and corporate tax avoidance – Evidence from China. *International Review of Economics & Finance*, 103949. https://doi.org/10.1016/j.iref.2025.103949

Raikov A 2021. Decreasing tax evasion by artificial intelligence. *IFAC-PapersOnLine*, 54(13): 172-177. https://doi.org/10.1016/j.ifacol.2021.10.440

Reuters 2025. Albania appoints AI bot as minister to tackle corruption. 11 September. Available at: https://www.reuters.com/technology/albania-appoints-ai-bot-minister-tackle-corruption-2025-09-11/

RTSH 2026. Albania collected 4.7 billion euros in tax revenue in 2025, waived 450 million euros in 2026. 22 September. Available at: https://rtsh.al/rti/en/albania-collected-4-7-billion-euros-in-tax-revenue-in-2025-waived-450-million-euros-in-2026/

Thomson Reuters n.d. Albania: Fiscalisation (invoicing and transaction monitoring). Available at: https://europe.thomsonreuters.com/compliance/world-map/albania/

World Bank 2025. Albania public finance review: Enhancing fiscal sustainability for resilience and human development. Washington, DC: World Bank.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

EMOTIONAL BRANDING BEYOND BORDERS: CULTURAL NARRATIVES IN MENA AND WESTERN LUXURY JEWELRY ADVERTISING

Josiane El Khoury
ORCID ID: 0009-0006-3263-1052, University of Balamand, Faculty of Arts and Sciences, Department of Mass Media and Communications, Koura, Lebanon.

Abstract

Luxury jewelry branding increasingly relies on emotion as a central mechanism of value creation, yet the cultural specificity of emotional appeals remains underexplored within humanities and social sciences scholarship. This qualitative comparative study examines how emotional branding operates as a form of cultural negotiation across collectivist and individualist contexts. Focusing on three Lebanese jewelry campaigns and contrasting them with three Western campaigns, the study analyzes how emotions such as love, empowerment, aspiration, and sustainability are culturally constructed and visually communicated. Drawing on emotional branding theory, cultural branding, consumer culture theory, archetypal analysis, and semiotic visual rhetoric, the research demonstrates that while emotion is central to all campaigns, its meaning is shaped by dominant societal discourses. In the MENA context, emotional branding privileges relational values such as family continuity, collective resilience, and social recognition, whereas Western campaigns foreground individual autonomy, self-expression, and ethical self-positioning. Adopting an interpretive qualitative approach, the study highlights how advertising narratives function as cultural texts that both reflect and actively shape social values, gender representations, and consumer identities across different cultural environments. The findings confirm the centrality of emotion in forging brand attachment while extending cultural branding theory by revealing how emotional narratives resolve distinct cultural tensions across regions. By engaging with Sustainable Development Goals related to gender equality, inclusivity, and responsible consumption, the study positions luxury jewelry advertising as a site where global ideals are locally negotiated rather than universally applied, offering theoretical and practical insights for scholars and practitioners interested in cross-cultural branding, visual communication, and contemporary consumer culture.

Keywords: Emotional branding, cultural branding, luxury jewelry, consumer culture theory, collectivism and individualism, societal discourse.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

COMMENT MANAGEMENT IN SOCIAL MEDIA MARKETING COMMUNICATION: A CRITICAL SYNTHESIS OF REPLIES, DELETION CUES, AND DISABLED COMMENTS

Işıl Altay
ORCID: 0000-0003-1667-4256, Maltepe University, Vocational School, Department of Marketing and Advertising,
Public Relations and Publicity Program, Istanbul, Türkiye.

Abstract

Existing reviews examine comment valence, managerial replies, and platform moderation separately, yet audiences may also judge actors by how they manage comments. This study examines replies, deletion claims and cues, and disabled comments across influencer, seller, organizational, and brand communication, including promotional, personal, and crisis contexts.

A structured critical synthesis of six purposively selected empirical publications compared actors, interventions, comment characteristics, contexts, and outcomes at the experiment level. Deletion claims, moderation cues, and acknowledgments of deletion are distinguished from actual deletion, which no included study manipulated. The comparison separates inferences about actors, actor evaluations, and communication outcomes.

The synthesis identifies two patterns: inferences about actors and sensitivity to conditions. First, deletion claims and cues were linked to greater perceived information control or ulterior motives, and disabled comments to lower perceived openness to consumer voice, with unfavorable evaluations or response intentions reported along these pathways. Reply studies measured evaluations, not these inferences, and the constructs are not treated as one mechanism. Restricting comments was also associated with fewer choices to learn about the endorsed brand or to support the influencer, outcomes distinct from purchase intentions and actual sales.

Second, accommodative replies to subjective complaints received higher influencer trustworthiness ratings than defensive replies, and adverse responses were weaker where self-protection seemed reasonable or when deletion acknowledgments included certain explanations. Reply effects also vary with comment valence. Disabling comments can produce less favorable evaluations than leaving negative comments visible.

Intervention types and actors largely overlap within the selected evidence, so differences between interventions cannot be separated from differences between actors. The synthesis separates what comments say from what their management signals about actors, without ranking strategies.

Keywords: digital marketing communication; comment management; social media.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

RISK TOLERANCE AS A BRIDGE BETWEEN PSYCHOLOGICAL CAPITAL AND RISKY INVESTMENT INTENTION

Müge KINAY
Yıldız Technical University, Faculty of Economic and Administrative Science, Department of Business Administrative, Istanbul-Türkiye
ORCID: 0000-0002-6478-3433
Hatice NAYMAN HAMAMCI
Asst. Prof., Yıldız Technical University, Faculty of Economic and Administrative Science, Department of Business Administrative, Istanbul-Türkiye
ORCID: 0000-0002-3044-3836
Selim AREN
Prof. Dr., Yıldız Technical University, Faculty of Economic and Administrative Science, Department of Business Administrative, Istanbul-Türkiye
ORCID: 0000-0002-3044-3836

Abstract

Financial markets are known as ecosystems where investors can behave irrationally. Investors may make decisions that deviate from established norms and patterns, tolerating specific risks or pursuing risky investments. Existing literature includes many studies that interpret these dynamics through factors such as tacit knowledge (e.g., financial literacy) and emotions (e.g., fear and stress). However, psychological resources—another element that can influence this relationship—have not been examined in sufficient depth. While these internal resources are often treated as mediating or moderating variables, the literature has not adequately explored the mediating mechanisms through which they might independently drive investment intentions. Are high levels of hope, self-efficacy, resilience, and optimism sufficient to drive risk-taking? Or must factors such as risk tolerance be considered for these internal resources to translate into risk-taking behavior? These questions await answers in the literature. To address them, this study examines how risk tolerance mediates the relationship between psychological capital (an internal psychological asset) and risky investment intention. Using data from 703 volunteer survey participants, the study tested its hypotheses using structural equation modelling and found that risk tolerance fully mediates the relationship between psychological capital and the intention to make risky investments.

Keywords: risk tolerance, psychological capital, psyCap, risky investment intention.

Introduction

Psychological capital refers to the positive psychological assets utilized to achieve success (Digan et al., 2019). In addition to being research- and theory-based and accurately measurable, it is also accepted that it positively affects individual behaviour and performance (Avey et al., 2011). It plays a critical role in an individual's achievement of their goals, encompassing confidence in their ability to undertake and succeed at challenging tasks (efficacy), belief in their ability to succeed now and in the future (optimism), belief in their ability to progress towards goals and, if necessary, to identify new paths to achieve them (hope), and resilience in the face of problems, including the determination to persevere, try again, and even overcome challenges (Luthans et al., 2007). Given these characteristics, psychological capital is expected to influence investors' decisions significantly. However, the impact of this concept, conceptualized and researched since 2003, on investor preferences and its relationship with other psychological variables in the investment context has been largely neglected. Psychological capital, defined as a person's cognition, ability, and evaluation of their coping skills in different situations (Harms et al., 2018), is a significant variable in investors' fundamental decisions such as risk-taking and risky investment intentions. Moreover, because it focuses on state-like variables rather than trait-like variables and is open to change and development (Luthans & Youssef-Morgan, 2004), it is a

characteristic investor can develop to make better financial decisions. However, this should not be taken to mean that every individual with high psychological capital will exhibit risky investment behaviour. Although individuals with risky investment intentions may have high psychological capital, one question remains: Why do individuals with high psychological capital tend to make risky investments? Studies indicate that individuals with high psychological capital exhibit higher risk tolerance, particularly in fields such as entrepreneurship (Kim & Noh, 2016). Therefore, risk tolerance may be the missing link in this chain. Individuals with high psychological capital may also possess higher risk tolerance, and their ability to tolerate greater risk may make them more inclined toward risky investments. This study aims to enrich understanding of investor behaviour by highlighting an overlooked area of the literature, specifically by examining the mediating role of risk tolerance in the relationship between psychological capital and the intention to make risky investment intention.

Conceptual Framework

Psychological capital is an individual's confidence in their ability to undertake and accomplish challenging tasks (efficacy), their belief in succeding now and in the future (optimism), their belief in their ability to progress towards goals and, if necessary, to identify new paths to achieve them (hope), and their determination to persevere, try again, and even overcome problems (resilience) (Luthans et al., 2007). It has four sub-dimensions: hope, efficacy, resilience, and optimism. Although each of these four psychological elements is expressed as a separate structure, their commonalities outweigh their differences (Avey et al., 2011). Conceptually and empirically, these four characteristics can form a higher structure, and most PsyCap research treats them as a single, general fundamental structure (Harms et al., 2018).

Hope is a positive belief and desire about a desired future outcome (Aren & Akgüneş, 2018b). Hope has two components: agency and pathways (Snyder et al., 1991). Agency is the desire and action related to the goal (Avey et al., 2011). Pathways are alternative plans and ways to achieve the goal (Luthans et al., 2008). Accordingly, creating desire for the goal and identifying alternatives to achieve it are fundamental elements. Building on this, Luthans and Youssef-Morgan (2004) add goals to these two characteristics, viewing hope as a motivational state based on the interaction among goals, agency, and pathways. Self-efficacy, on the other hand, is an individual's belief in their ability to accomplish a task (Harms et al., 2018), their belief in their abilities, motivation, and confidence in their cognitive resources and developed action plans (Luthans et al., 2007; Luthans et al., 2008; Avey et al., 2011). It depends on environmental and individual factors and is closely related to emotion, thought, and behavior (Chen et al., 2023). It is associated with increased risk-taking (Montford & Goldsmith, 2015) and risk-taking intention (Wong & Yang, 2020). When individuals perceive themselves as having high efficacy, they see risks as opportunities and take more risks; when they perceive themselves as having low efficacy, they perceive risks as threats and prefer to take fewer risks (Krueger & Dickson, 1994). Resilience is the ability to cope with and adapt to difficulties, uncertainty, failure, and even success (Luthans & Youssef-Morgan, 2004; Luthans et al., 2008). Therefore, it is the strength to cope not only with negative events but also with positive ones (Luthans et al., 2008). Resilience involves re-establishing confidence, hope, and optimism after difficulties (Luthans et al., 2008), but it differs from them. Hope is the belief that a future event will have a positive outcome. Hope involves an expectation, but resilience involves a reaction to a negative event. Optimism, considered closer to resilience, does not involve the belief that a negative outcome will occur (Luthans et al., 2008). Efficacy is proactive (Aliyev & Tunc, 2015; Kim et al., 2017), whereas resilience has both proactive and reactive aspects. In this context, individuals who can effectively regulate their emotions have greater psychological resilience in coping with difficulties (Guo et al., 2023).

Risky investment intention is defined as an individual's willingness to invest in high-risk assets and is generally seen an indicator of investment behaviour (Aydemir & Aren, 2017; Aren & Nayman Hamamci, 2020). Risk tolerance refers to the degree to which an individual is willing to take risks in pursuit of higher returns and is a fundamental element of the financial decision-making process (Jung et al., 2018). It is subjective and dynamic; it can fluctuate due to environmental factors (Jung et al., 2018). Risk tolerance directly affects risky investment intention. Numerous studies indicate that individuals with high risk tolerance are more willing to

invest in risky assets (Aydemir & Aren, 2017; Aren & Nayman Hamamci, 2020; Amonhaemanon & Vora-Sittha, 2023).

Methodology

This study examines the mediating role of risk tolerance in the effect of psychological capital on risky investment intention. The research aims to explain risky investment behaviour more comprehensively by examining the psychological processes in individuals' investment decisions. Data were collected from individuals residing in Turkey in November 2025 through voluntary convenience sampling. The study included 703 participants. Graduate students from our university voluntarily contributed to data collection; the online survey link via Google Forms was posted on social media platforms. Demographic data are presented in Table 1.

As shown in Table 1, 407 (57.90%) of the participants are single, and 296 (42.10%) are married. Of these, 461 (65.60%) are undergraduates, 136 (19.30%) are graduates, 92 (13.10%) are high school graduates, and 11 (2.00%) are primary school graduates. At the same time, 376 (53.50%) of the participants were in the "20-30" age group, 207 (29.40%) in the "31-40" age group, 75 (10.70%) in the "41-50" age group, and 45 (6.40%) in the "+51" age group. Finally, 369 (52.50%) were male, and 334 (47.50%) were female. The sample group consisted mostly of young participants with a high level of education.

Table 1. Demographic Variables

Variable	Category	Frequency	Percent (%)
Age Group	20–30	376	53.50
	31–40	207	29.40
	41–50	75	10.70
	+51	45	6.40
Gender	Male	369	52.50
	Female	334	47.50
Marital Status	Married	296	42.10
	Single	407	57.90
Education	Primary School	14	2.00
	High School	92	13.10
	Undergraduate	461	65.60
	Graduate	136	19.30

This study includes three variables: a dependent variable, an independent variable, and a mediating variable. Psychological capital is the independent variable, and risky investment intention is the dependent variable. Risk tolerance is studied as a mediator to examine its role in the relationship between the two. The scales used were adapted from valid and reliable scales found in the literature. For Risk Investment Intention, we used the 4-item scale developed by Aydemir and Aren (2017); for Risk Tolerance, we used the 5-item scale developed by Hamamci and Aren (2023). We developed the 20-item scale used for Psychological Capital.

Table 2 presents detailed information on all variables, item numbers, and references in the study. The research model using these variables is shown in Figure 1.

Table 2. Variables and Scales

Variables	Items	Scale
Psychological Capital	20	Developed by us
Risky Investment Intention	4	Aydemir and Aren (2017)
Risk Tolerance	5	Hamamci and Aren (2023)

Figure 1. Research Model

Analysis and Results

Structural equation modelling (SEM) was conducted using the AMOS program to analyse the research model, and the corresponding findings are presented. Initially, descriptive statistics and correlations among the variables in the research model were examined. Subsequently, the measurement model was evaluated to assess its validity and reliability. Finally, a mediation analysis of the structural model was performed, and the results are reported in detail.

Table 3: Exploratory Factor Analysis Results of PsyCAP

Items	Hope	Self-efficacy	Optimism	Resilience
HO1: I have strong hope that my investments will yield positive returns.	0.604			
HO2: I don't lose hope regarding my investments.				
HO3: I am hopeful that my investment decisions will yield positive results in the future.	0.702			
HO4: I wouldn't invest if I didn't have hope.	0.727			
HO5: Hope provides me with a strong motivation to invest.	0.640			
SE1: If I put in the necessary effort, I can make the right financial decisions, even if it's difficult.		0.689		
SE2: With enough effort, I can make sound financial decisions even under uncertainty.		0.679		
SE3: If I am to make an investment decision, I'll find a way to figure out how to make that decision.		0.580		
SE4: When making financial decisions, I can find different investment alternatives and evaluate them.		0.661		
SE5: I believe my knowledge and analytical skills enable me to make right financial decisions.		0.615		
RE1: Even though my financial decisions haven't yielded successful results, I can still achieve successful results in my next decisions.				
RE2: My unsuccessful investment decisions haven't discouraged me from investing.				0.686
RE3: I know how to cope with my poor investment decisions.				0.772
RE4: I believe I can learn from my unsuccessful financial decisions and make more successful ones in the future.				0.654
RE5: Even though my investments haven't yielded the returns I wanted, that doesn't mean my future investment decisions will fail.				
OP1: I am optimistic about the returns on my investments.			0.620	

OP2: I view the risks of investing as an opportunity, not a threat.			0.648	
OP3: I am optimistic about my investments.			0.614	
OP4: Although there is a possibility that my investments could fail, I see the probability of them succeeding as higher.			0.714	
OP5: Even if unforeseen developments occur in the future, the return on my investments will not be significantly affected.			0.657	
% of Variance	46.708	6.318	5.473	4.420
Reliability Analysis (Cronbach Alpha)	0.831	0.847	0.830	0.798
Bartlett's Test of Sphericity	$7459.871^{(0,000)}$			
KMO	0.951			

As shown in Table 3, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was examined, and Bartlett's Test of Sphericity was conducted to assess the suitability of the dataset for Exploratory Factor Analysis (EFA). The analysis yielded a KMO value of 0.951. In the literature, a KMO value above 0.90 indicates an excellent level of sampling adequacy. Furthermore, the results of Bartlett's Test of Sphericity were found to be statistically significant (χ^2=7459.871; p<0.001). These findings confirm that the dataset and the correlation structure among the variables are highly suitable for conducting factor analysis. The EFA results indicate that the psychological capital scale items clustered into four distinct factors. These factors represent the sub-dimensions of psychological capital: hope, optimism, self-efficacy, and resilience. Certain items (HO2, RE1, and RE5) were excluded due to factor loadings below 0.5. Finally, reliability analyses were conducted separately for each of the four factors, and Cronbach's alpha values were reported. The findings demonstrate that all sub-dimensions met the reliability criteria. Consequently, the newly developed scale met the validity and reliability requirements and was suitable for subsequent analyses. Table 4 presents the model fit indices derived from the Confirmatory Factor Analysis (CFA), which was conducted following the EFA to test the construct validity of the scales.

Table 4. Confirmatory Analysis Results of Variables

Variable	CMIN/DF	RMSEA	GFI	AGFI	CFI	TLI	NFI	RFI
Psychological Capital (PsyCAP)	3.638	0.061	0.928	0.906	0.948	0.940	0.930	0.919
Risk Tolerance (RT)	2.140	0.040	0.998	0.982	0.998	0.991	0.997	0.984
Risky Investment Intention (RII)	2.852	0.051	0.996	0.979	0.998	0.994	0.997	0.991

As shown in Table 4, the fit indices for the constructs of psychological capital (PsyCAP), risk tolerance (RT), and risky investment intention (RII) met the acceptable and excellent threshold values recommended in the literature. The ratio of the chi-square value to the degrees of freedom (CMIN/DF) was below 5 for all variables, and RMSEA values were found to range between 0.040 and 0.061. An examination of the comparative fit indices (CFI, TLI, NFI, RFI, GFI, AGFI) revealed that all values were well above the 0.90 threshold. These findings confirm that the unidimensional/conceptual measurement models for all three constructs fit the data well and that construct validity has been established. Before analysing the research model, we conducted descriptive statistics and correlation analyses for the variables and report the results in Table 5.

Table 5. Descriptive Statistics and Correlation

Variable	Mean	S.D.	1	2	3
1. Psychological Capital (PsyCAP)	3.4930	0.6867	1		
2. Risk Tolerance (RT)	3.0945	0.9009	0.530**	1	
3. Risky Investment Intention (RII)	2.8396	1.0608	0.383**	0.590**	1

Accordingly, psychological capital showed a positive and significant relationship with risk tolerance ($r = 0.530; p<0.01$) and risky investment intention ($r = 0.383; p<0.01$). The study also found a positive, strong correlation ($r = 0.590; p<0.01$) between risk tolerance—the study's mediating variable—and risky investment

intention, the dependent variable. The obtained correlation coefficients provide a suitable basis for testing the formulated hypotheses and the mediation model.
In the final stage, the research model was tested using structural equation modelling (SEM) via AMOS. The mediation analysis used modern approaches and was conducted using bootstrapping (Preacher and Hayes, 2008). Table 6 presents the findings.

Table 6. Mediation Analysis Results

Latent Variable	Types of Effect	Relationships	β	Standard Error (S.E.)	%95 Confidence Interval (CI)	
					Lower Bound	Upper Bound
Psychological Capital (PsyCAP)	Total Effect	PsyCAP → RII	0.672	0.075	0.524	0.819
	Direct Effect	PsyCAP → RII	0.039	0.088	-0.130	0.211
	Indirect Effect	PsyCAP → RT → RII	0.633	0.070	0.504	0.774

(Note: β=Standardized regression estimate values were considered; 5000 bootstrap samples; Percentile confidence intervals = 95)

Table 6 shows that the "indirect effect" indicates how much of the independent variable's effect on the dependent variable is mediated by the mediating variable, while the "direct effect" represents the portion of the independent variable's effect on the dependent variable that is not explained by the mediating variable. The "total effect" is the sum of all effects of the independent variable on the dependent variable and reveals whether there is a relationship between the dependent and independent variables without considering the mediating variable. In this context, mediation analysis was performed using bootstrapping as suggested by Preacher and Hayes (2008), and the model fit indices were examined. All indicators were found to demonstrate a good level of fit (CMIN/DF=3.827; RMSEA=0.063; GFI=0.875; AGFI=0.851; CFI=0.918; TLI=0.909; NFI=0.892; RFI=0.881). According to the findings, the direct impact of psychological capital on risky investment intention ($CI_{PS(Direct)}$ = (-0.130) - 0.211; β= 0.039) was not found to be significant, but its indirect effect ($CI_{PS(Indirect1)}$ = 0.504 - 0.774; β= 0.633) and its total effect ($CI_{PS(Total)}$ = 0.524 - 0.819; β= 0.672) were found to be statistically positive and significant, as the lower and upper confidence intervals did not contain 0. According to the data, it was determined that risk tolerance plays a full mediating role, as the indirect effect constitutes a large part of the total effect.

Conclusion and Discussion

The study's findings show that risk tolerance strongly influences the relationship between psychological capital and risky investment intention. This shows that psychological capital influences intentions to make risky investment decisions only through an individual's financial risk tolerance (as a mediating variable); thus, risk tolerance serves as the mediating mechanism. Psychological capital serves an internal resource that enables individuals to cope with challenges and reach their goals. Loi et al. (2025) suggest that psychological capital supports entrepreneurs' well-being, thereby contributing to decision-making processes and enabling them to capitalize on opportunities. Similarly, the study's findings indicate that, regarding investment decisions, psychological capital enhances risk tolerance, thereby allowing investors to pursue risky investments. In other words, while psychological capital alone is not a sufficient reason to opt for a risky investment, an individual may demonstrate an intention to make such an investment if their risk tolerance is high. In this context, risk tolerance emerges as a mechanism that facilitates the translation of psychological capital into an intention to make a risky investment; this underscores the importance of considering an individual's risk tolerance—alongside internal psychological resources (factors often overlooked in traditional approaches)—when analysing such intentions. Beyond introducing a new explanatory mechanism to the literature, the study makes a significant sectoral contribution by encouraging the development of holistic assessment approaches that account for investors' psychological resources. Although this study examines the relationship in question using a cross-sectional design, future research employing longitudinal and experimental designs could offer a more robust explanation of this mechanism, thereby enriching our understanding of investor behaviour.

Reference

Aliyev, R., & Tunc, E. (2015) Self-efficacy in counseling: The role of organizational psychological capital, job satisfaction, and burnout. *Procedia - Social and Behavioral Sciences*, 190, 97–105

Amonhaemanon, D., & Vora-Sittha, P. (2023). Predicting individual investor's intention to invest: A comparison between actual and perceived financial knowledge. *International Journal of Business and Society, 24*(2), 559–575. https://doi.org/10.33736/ijbs.5944.2023

Aren, S., & Nayman Hamamci, H. (2020). Relationship between risk aversion, risky investment intention, investment choices: Impact of personality traits and emotion. *Kybernetes*, *49*(11), 2651–2682. https://doi.org/10.1108/K-07-2019-0455

Aren, S., & Akgüneş, A.O. (2018). The Effect of Four Basic Emotional State on Risk Taking Behavior, *Journal of Business Research Turk*, 10(3), 362–378

Avey, J. B., Reichard, R. J., Luthans, F., & Mhatre, K. H. (2011). Meta-analysis of the impact of positive psychological capital on employee attitudes, behaviors, and performance. *Human Resource Development Quarterly*, 22(2), 127–152.

Aydemir, S.D., & Aren, S. (2017). Do the effects of individual factors on financial risk–taking behavior diversify with financial literacy?, *Kybernetes*, 46(10), 1706–1734

Chen P.L., Lin C.H. Lin I.H., & Lo, C.O. (2023). The Mediating Effects of Psychological Capital and Academic Self-Efficacy on Learning Outcomes of College Freshmen. *Psychological* Reports. 126(5), 2489-2510

Digan, S.P., Sahi, G.K., Mantok, S. & Patel, P.C. (2019), Women's Perceived Empowerment in Entrepreneurial Efforts: The Role of Bricolage and Psychological Capital. *Journal of Small Business Management*, 57, 206-229.

Guo, Z., Cui, Y., Yang, T., Liu, X., Lu, H., Zhang, Y., & Zhu, X. (2023). Network analysis of affect, emotion regulation, psychological capital, and resilience among Chinese males during the late stage of the COVID-19 pandemic. *Frontiers in Public Health*,11, 1144420. 1–10

Hamamcı, H.N. & Aren, S. (2023). Impact Of Financial Tribalism On Risk Tolerance: Mediating Role Of Confidence And Herd Behavior, UMTEB – XIV International Scientific Research Congress September 14-15, 2023 / Naples, Italy, 614–625

Harms, P.D., Krasikova, D.V. & Luthans F. (2018). Not Me But Reflects Me: Validating a Simple Implicit Measure of Psychological Capital. *Journal of Personality Assessment*, 100(5), 551-562.

Jung, W. H., Lee, S., Lerman, C., & Kable, J. W. (2018). Amygdala functional and structural connectivity predicts individual risk tolerance. *Neuron*, *98*(2), 394–404.e4. https://doi.org/10.1016/j.neuron.2018.03.019

Kim, J., & Noh, Y. (2016). The effects of psychological capital and risk tolerance on service workers' internal motivation for firm performance and entrepreneurship. *International Entrepreneurship and Management Journal*, *12*(3), 681–696. https://doi.org/10.1007/s11365-015-0369-0

Kim, M., Perrewé, P. L., Kim, Y. kyoum, & Kim, A. C. H. (2017). Psychological capital in sport organizations: Hope, Efficacy, Resilience, and Optimism among Employees in Sport (HEROES). *European Sport Management Quarterly*, 17(5), 659–680.

Krueger N.F.Jr, & Dickson, P. (1994). How Believing in Ourselves Increases Risk Taking: Self-efficacy and Perceptions of Opportunity and Threat. *Decision Sciences*, 25,385-400.

Loi, M., Martínez-Gregorio, S., Barbieri, B., & Fayolle, A. (2025). Psychological capital in entrepreneurship: A systematic literature review to take stock and move knowledge forward. *Journal of Small Business and Enterprise Development*. https://doi.org/10.1108/JSBED-11-2024-0588

Luthans, F., & Youssef-Morgan, C. M. (2004). Human, Social, and Now Positive Psychological Capital Management: Investing in people for competitive advantage. *Organizational Dynamics*, 33(2), 143–160

Luthans, F., Avolio, B. J., Avey, J. B., & Norman, S. M. (2007). Positive psychological capital: Measurement and relationship with performance and satisfaction. *Personnel Psychology*, 60(3), 541–572

Luthans, F., Norman, S. M., Avolio, B. J., & Avey, J. B. (2008). The mediating role of psychological capital in the supportive organizational climate-employee performance relationship. *Journal of Organizational Behavior*, 29(2), 219–238

Montford, W., & Goldsmith, R. E. (2015). How gender and financial self-efficacy influence investment risk taking. *International Journal of Consumer Studies*, 40(1), 101–106.
Snyder, C.R., Harris, C., Anderson, J.R., Holleran, S.A., Irving, L.M., Sigmon, S.X., Yoshinobu, L., Gibb, J., Langelle, C., & Harney, P. (1991). The Will and The Ways: Development and Validation of An Individual-Differences Measure of Hope. *Journal of Personality and Social Psychology*, 60 (4), 570-585
Wong, J. C. S., & Yang, J. Z. (2020). Seeing is believing: examining self-efficacy and trait hope as moderators of youths' positive risk-taking intention. *Journal of Risk Research*, 1–14.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE MEDIATING ROLE OF THRIVING AT WORK IN THE RELATIONSHIP BETWEEN PROSOCIAL MOTIVATION AND WORK ENGAGEMENT: A FIELD STUDY OF HEALTHCARE WORKERS

Veysel Mehmet GÜLTEKİN
B. Dilek ÖZBEZEK
Filiz DEMİR
Dr. Kahramanmaraş Provincial Directorate of National Education, Türkiye
ORCID: https://orcid.org/0000-0001-7296-5918
Assoc. Prof. Dr. Gaziantep University, Faculty of Islahiye Economics and Administrative Sciences,
ORCID: https://orcid.org/0000-0001-7176-1534
Assoc. Prof. Dr. Karamanoğlu Mehmetbey University, Faculty of Applied Sciences, Department of Tourism Guidance
ORCID: https://orcid.org/0000-0002-5906-6982

Abstract

This study investigated the mediating role of thriving at work in the relationship between prosocial motivation and work engagement among healthcare workers. The study was conducted using a quantitative research approach based on a correlational survey design. The study was conducted among healthcare workers working in various healthcare institutions in Gaziantep. An online survey was used for data collection, and convenience and snowball sampling techniques were employed in combination to select the sample. The sample group consists of 223 healthcare workers who voluntarily participated in the study. The data obtained were analyzed using SPSS 25, AMOS 24, and the SPSS PROCESS Macro. Prior to testing the hypotheses in the study, exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and reliability analyses were conducted to assess the construct validity and reliability of the scales used. Statistical analyses have revealed that prosocial motivation has a positive and significant effect on thriving at work and work engagement. Moreover, thriving at work was found to mediate the relationship between prosocial motivation and work engagement. These results indicate that healthcare workers with higher levels of prosocial motivation are more likely to experience thriving at work, which in turn enhances their engagement levels.

Keywords: Prosocial Motivation, Thriving at Work, Work Engagement.

PROSOSYAL MOTİVASYON İLE İŞE ADANMIŞLIK ARASINDAKİ İLİŞKİDE İŞTE KENDİNİ YETİŞTİRMENİN ARACILIK ROLÜ: SAĞLIK ÇALIŞANLARI ÜZERİNE BİR ALAN ARAŞTIRMASI

Özet

Bu çalışmanın amacı prososyal motivasyon ile işe adanmışlık arasındaki ilişkide işte kendini yetiştirmenin aracılık rolünü sağlık çalışanları bağlamında incelemektir. Araştırma nicel araştırma yaklaşımı benimsenerek ilişkisel tarama modeli çerçevesinde yürütülmüştür. Araştırma Gaziantep'te farklı sağlık kurumlarında görev yapan sağlık çalışanları üzerinde yürütülmüştür. Veri toplama yöntemi olarak çevrim içi anket yöntemi kullanılmış; örneklem seçiminde kolayda örnekleme ve kartopu örnekleme teknikleri birlikte uygulanmıştır. Örneklem grubu araştırmaya gönüllü olarak katılan 223 sağlık çalışanından oluşmaktadır. Elde edilen veriler, SPSS 25, AMOS 24 ve SPSS PROCESS Macro yazılımları kullanılarak değerlendirilmiştir. Araştırmada hipotezlerin test edilmesinden önce, kullanılan ölçeklerin yapı geçerliliği ve güvenirliğini değerlendirmek amacıyla sırasıyla keşfedici faktör analizi (KFA), doğrulayıcı faktör analizi (DFA) ve güvenirlik analizleri gerçekleştirilmiştir. İstatiksel analizler sonucunda, prososyal motivasyonun işte kendini yetiştirme ve iş adanmışlık üzerinde olumlu ve anlamlı bir etkiye sahip olduğunu ortaya koymuştur. Ayrıca işte kendini yetiştirmenin, prososyal motivasyonun işe adanmışlık arasındaki ilişkide aracı bir rol üstlendiği belirlenmiştir. Bu sonuçlar, prososyal motivasyon düzeyi daha yüksek olan sağlık çalışanlarının işte kendini yetiştirme

deneyimini daha fazla yaşama eğiliminde olduklarını ve bunun da onların işe adanmışlık düzeylerini artırdığını göstermektedir.

Anahtar Kelimeler: Prososyal Motivasyon, İşte Kendini Yetiştirme, İşe Adanmışlık.

GİRİŞ

Günümüz çalışma yaşamında çalışanların yalnızca görevlerini yerine getirmeleri değil, aynı zamanda işlerine psikolojik olarak bağlanmaları, gelişim göstermeleri ve başkalarına fayda sağlama isteğiyle hareket etmeleri de örgütler açısından önemli hâle gelmiştir. Özellikle insan yaşamına doğrudan dokunan sağlık sektöründe çalışanların sahip oldukları motivasyon kaynakları hem bireysel performans hem de hizmet kalitesi açısından kritik bir rol oynamaktadır. Bu nedenle çalışanların işlerine yönelik olumlu tutum ve davranışlarını şekillendiren motivasyon unsurlarının anlaşılması önem taşımaktadır.

Çalışan davranışlarını açıklamada son yıllarda dikkat çeken kavramlardan biri prososyal motivasyondur. Prososyal motivasyon, bireyin diğer insanların yaşamlarına olumlu katkı sağlama ve onlara fayda sunma isteğini ifade etmektedir (Grant, 2008). Özellikle sağlık çalışanları açısından değerlendirildiğinde, yardım etme ve topluma katkı sağlama arzusu mesleğin doğasıyla yakından ilişkilidir. Bu nedenle prososyal motivasyon düzeyi yüksek çalışanların işlerine daha fazla anlam yükledikleri, işlerini daha istekli gerçekleştirdikleri ve örgütsel süreçlere daha aktif katılım gösterdikleri düşünülmektedir.

Prososyal motivasyon, bireyin başkalarının yararını gözeterek yardım ve destek sunmaya yönelmesini ifade eder. Empatiyle bağlantılı olan bu motivasyon, duruma bağlı olarak ortaya çıkan kısa süreli bir güdü olarak değerlendirilmektedir (Karadirek, 2023). Prososyal motivasyon, özellikle çok disiplinli ekip üyelerinin uyum içinde çalışması gereken sağlık sektöründe büyük önem taşır. Prososyal motivasyon dışadönüklük ve sorumluluk alma ile de ilişkilidir (Kavala ve Tokatlıoğlu, 2025). Bir doktorun ve hemşirenin hastalara yardım etme endişesi şeklinde ortaya çıkabilmektedir (Karadirek, 2023). Bu motivasyon türü; çalışanların kendi bakış açılarının sınırlarını aşmalarına, başkalarının görüş ve ihtiyaçlarına karşı duyarlılıklarını geliştirmelerine ve görevlerini en iyi şekilde yerine getirmelerine yardımcı olur (Tian vd., 2021:2).

İşe adanmışlık ise bireyin işine yönelik yüksek enerji, güçlü bağlılık ve yoğunlaşma hissettiği olumlu psikolojik bir durumu ifade etmektedir (Schaufeli vd., 2002). İşe adanmış çalışanların daha yüksek performans sergiledikleri, iş tatmini düzeylerinin arttığı ve örgütlerine daha fazla katkı sundukları belirtilmektedir. Özellikle sağlık kurumlarında işe adanmışlığın yüksek olması, hasta memnuniyeti, hizmet kalitesi ve çalışan verimliliği gibi birçok kritik çıktıyı etkileyebilmektedir. Bu bağlamda çalışanların işe adanmışlık düzeylerini artırabilecek faktörlerin belirlenmesi önemli bir araştırma konusu olarak öne çıkmaktadır.

İşe adanmışlık kavramını açıklamada sıklıkla İş Talepleri ve Kaynakları Teorisi kullanılmaktadır. Bu teoriye göre, çalışanlar yeterli iş ve kişisel kaynaklara sahip olduğunda ve yüksek zorluklarla karşılaştıklarında işe adanmışlıkları artmakta ve bu durum iş performansını olumlu yönde etkilemektedir (Kara vd., 2025). Adanmışlık, çalışanların örgütsel amaçlara ulaşma sürecine etkin biçimde katılmalarını sağlayan önemli bir unsurdur. Bireyin işine yönelik sahiplenme düzeyini yansıtan bu kavram, çalışanın görevlerini yerine getirirken zamanını, enerjisini ve dikkatini işe yönlendirmesini ifade eder. Çalışanın işine fiziksel ve zihinsel açıdan yoğunlaşması, kendisinden beklenen sorumlulukları yerine getirmesinin yanı sıra çalışma arkadaşlarıyla kurduğu iş ilişkilerinin de güçlenmesine katkıda bulunur. Bu doğrultuda adanmışlık, bireyin sahip olduğu kaynakları iş rolüne aktarması ve görevlerini yerine getirirken yüksek düzeyde çaba göstermesiyle ortaya çıkan bir çalışma davranışı olarak değerlendirilebilir (Gül ve Güneş, 2024).

Bu çalışmada ele alınan bir diğer kavram olan işte kendini yetiştirme ise bireyin iş yaşamı içerisinde öğrenme, gelişim ve canlılık hissetmesine dayanan psikolojik bir deneyim olarak tanımlanmaktadır (Porath vd., 2012). Örgütsel davranış alanındaki güncel çalışmalar incelendiğinde, iş yerinde kendini yetiştirmenin, işletme ve kuruluşların sürdürülebilirliği, verimliliği ve çalışan performansı üzerinde önemli etkileri olduğu görülmektedir. Günümüzün karmaşık örgütsel yapılarında başarıya ulaşabilmek için çalışanların kendilerini geliştirmeleri gerekmektedir. Çalışanların gelişimi ve kendilerini eğitmeleri, örgüt içindeki işleyişlerini kolaylaştırmakta ve kuruma kolayca uyum sağlamalarını güvence altına almaktadır (Tarsuslu, 2024). İşte kendini yetiştirme, kişilerin yaptıklarının ve yapma biçimlerinin, gelişimlerini olumlu bir şekilde ilerletip ilerletmediklerinin değerlendirilmesini sağlayan öznel bir deneyimdir (Ayyıldız ve Baran, 2024). İşte kendini

yetiştirme deneyimi yaşayan çalışanların hem kişisel gelişimlerini sürdürdükleri hem de işlerine karşı daha olumlu tutum geliştirdikleri ifade edilmektedir. Özellikle öğrenme fırsatlarının yoğun olduğu sağlık sektöründe çalışanların işte kendini yetiştirme düzeyleri, onların işe yönelik motivasyonlarını ve adanmışlıklarını güçlendirebilecek önemli bir unsur olarak değerlendirilmektedir.
Literatürde prososyal motivasyonun işe adanmışlık üzerindeki etkisini inceleyen çalışmalar bulunmasına rağmen, bu ilişkinin hangi mekanizmalar aracılığıyla ortaya çıktığını açıklayan araştırmaların sınırlı olduğu görülmektedir. Özellikle işte kendini yetiştirmenin bu ilişkideki aracılık rolünü inceleyen çalışmaların yeterli düzeyde olmadığı dikkat çekmektedir. Ayrıca sağlık çalışanları örnekleminde bu değişkenleri birlikte ele alan çalışmaların sınırlı olması da araştırmanın önemini artırmaktadır. Bu doğrultuda mevcut çalışmada, prososyal motivasyon ile işe adanmışlık arasındaki ilişkide işte kendini yetiştirmenin aracılık rolünün incelenmesi amaçlanmıştır. Araştırmadan elde edilen bulguların hem ilgili literatüre katkı sağlaması hem de sağlık kurumlarında çalışanların işe yönelik olumlu tutumlarının geliştirilmesine yönelik uygulamalara ışık tutması beklenmektedir.

Yöntem

Bu çalışma prososyal motivasyonun işe adanmışlığa etkisini sağlık çalışanları incelemeyi amaçlamıştır. Araştırmanın evrenini, Gaziantep'te farklı sağlık kurumlarında görev yapan sağlık çalışanları oluşturmaktadır. Evreni oluşturan tüm sağlık çalışanlarına ulaşılmanın mümkün olmaması nedeniyle örnekleme yöntemine başvurulmuştur. Veri toplama sürecinde gönüllülük esasına dayalı olarak kolayda örnekleme yöntemi benimsenmiştir. Kolayda örnekleme, araştırmacının erişim sağlayabildiği katılımcıların örnekleme dahil edilmesine dayanan ve analiz için yeterli örneklem büyüklüğüne ulaşmayı amaçlayan bir örnekleme yaklaşımıdır (Gürbüz ve Şahin, 2018). Bu bağlamda, Ocak–Şubat 2026 tarihleri arasında farklı Gaziantep'te sağlık kurumlarında görev yapan toplam 223 sağlık çalışanı araştırmaya dahil edilmiştir. Veri toplama süreci öncesinde kurumdan sözlü izin alınmış, katılımcılara araştırma hakkında gerekli bilgilendirme yapılmış ve gönüllülük esasına dayalı katılım sağlanmıştır.
Araştırma kapsamında verileri toplamak için anket formu dört bölümden oluşmaktadır. Bu anket formunun birinci bölümde, çalışmaya gönüllü olarak katılmayı kabul eden sağlık çalışanlarının demografik özelliklerini belirlemeye yönelik altı soru yer almaktadır. İkinci bölümde, çalışanların prososyal motivasyon düzeylerini belirlemek amacıyla, Grant ve Sumanth (2009) tarafından geliştirilen ve Türkçe uyarlaması Kesen ve Akyüz (2016) tarafından gerçekleştirilen beş maddelik "Prososyal Motivasyon Ölçeği" kullanılmıştır. Üçüncü bölümde, sağlık çalışanlarının işte kendini yetiştirme düzeyini belirlemek amacıyla, Porath vd. (2012) tarafından geliştirilen ve Türkçe uyarlaması Koçak (2021) tarafından gerçekleştirilen "İşte Kendini Yetiştirme Ölçeği" kullanılmıştır. Canlılık ve öğrenme olmak üzere iki alt boyuttan oluşan bu ölçek toplam sekiz madde içermektedir. Dördüncü bölümde, sağlık çalışanlarının işe adanmışlık düzeylerini belirlemek amacıyla Schaufeli ve Bakker (2003) tarafından geliştirilen ve Türkçe uyarlaması Özkalp ve Meydan (2015) tarafından gerçekleştirilen "İşe Adanmışlık Ölçeği" kullanılmıştır. Dinçlik, adanmışlık ve özümseme olmak üzere üç alt boyuttan oluşan bu ölçek toplam sekiz madde içermektedir. Uygulama sırasında akademik personelden ölçeklere ilişkin maddeleri "1=Kesinlikle katılıyorum ile 5=Kesinlikle katılmıyorum" arasında değişen 5'li Likert tipinde ölçeğe göre katılım düzeylerini derecelendirmeleri istenmiştir.

Bulgular

Araştırma verileri üzerinde frekans ve yüzde analizleri gerçekleştirilerek katılımcıların sosyo-demografik özellikleri belirlenmiştir. Elde edilen bu bulgular, araştırmaya katılan sağlık çalışanlarının büyük çoğunluğu kadın (%62,8), 31-40 yaş arasında (29,1), lisans mezunu (%50,7), tıbbi sekreter (%44,4) ve 1-5 yıl arası mesleki deneyime sahip (%39,5) olduğuna işaret etmektedir. Katılımcılara ilişkin sosyo-demografik bulgular Tablo 1'de sunulmaktadır.

Tablo 1. Katılımcıların Sosyo-Demografik Özellikleri (n = 223)

Değişkenler	Gruplar	Frekans (n)	Yüzde (%)
Cinsiyet	Kadın	140	62,8
	Erkek	83	37,2
Yaş	25 yaş ve altı	45	20,2
	26-30 yaş arası	56	25,1
	31-40 yaş arası	65	29,1
	41-50 yaş arası	48	21,5
	51 yaş ve üzeri	9	4
Eğitim	Lise	15	6,7
	Ön lisans	61	27,4
	Lisans	113	50,7
	Lisansüstü	34	15,2
Meslek	Doktor	26	11,7
	Hemşire/Ebe	39	17,5
	Sağlık memuru	13	5,8
	Sağlık teknisyeni/teknikeri	26	11,7
	Tıbbi sekreter	99	44,4
	Diğer sağlık çalışanı	20	9
Mesleki Tecrübe	1-5 yıl arası	88	39,5
	6-10 yıl arası	43	19,3
	11-15 yıl arası	36	16,1
	16 yıl ve üzeri	56	25,1

Araştırma modeline ilişkin analizlere geçilmeden önce, çalışmada kullanılan ölçme araçlarının geçerlilik ve güvenilirlik kontrolleri yapılmıştır. Bu kapsamda açımlayıcı faktör analizi (AFA) ile doğrulayıcı faktör analizi (DFA) uygulanmıştır. Ölçeklerin iç tutarlılık güvenilirliğinin belirlenmesinde ise Cronbach Alfa katsayısı esas alınmıştır.

Tablo 2. Tablo 1. AFA Sonuçları

Ölçekler		**Soru**	**Faktör Yükleri**	**Açıklanan Varyans**	**K-M-O**	**Barlett Küresellik Testi**	**p**	**Cronbach α**	**Çarpıklık**	**Basıklık**
Prososyal Motivasyon		5	,652-,871	58,792	,743	447,770	,000	,823	-,574	-,187
İşte Kendini Yetiştirme	Canlılık	4	,699-,850	72,689	,867	1089,469	,000	,903	-,984	,839
	Öğrenme	4	,672-,868							
İşe Adanmışlık	Dinçlik	3	,729-,853	75,891	,780	924,734	,000	,798	-,731	,360
	Adanmışlık	3	,810-,891							
	Özümseme	3	,838-,872							

Tablo 2'de sunulan bulgular, verilerin normal dağılım varsayımını karşıladığını göstermektedir (Tabachnick ve Fidell, 2013). AFA sonuçlarına göre örneklem yeterliliğine ilişkin KMO katsayıları KMO katsayıları; prososyal motivasyon ölçeği için 0,743, işte kendini yetiştirme ölçeği için 0,867 ve işe adanmışlık ölçeği için 0,780 olarak hesaplanırken, Bartlett küresellik testinin her üç ölçek için de istatistiksel olarak anlamlı sonuç verdiği görülmüştür. Faktör yapıları açısından prososyal motivasyon ölçeğinin özgün formuyla tutarlı biçimde tek faktörlü yapıda toplam varyansın %58,792'sini; işte kendini yetiştirme ölçeğinin özgün formuyla tutarlı biçimde iki faktörlü yapıda toplam varyansın %72,689'unu; işe adanmışlık ölçeğinin ise özgün formuyla tutarlı biçimde üç faktörlü yapıda toplam varyansın %75,891'ini açıkladığı tespit edilmiştir. Ayrıca, tüm ölçeklerin Cronbach Alfa güvenilirlik katsayılarının 0,70 eşik değerinin üzerinde olduğu ve her bir maddeye ilişkin faktör yüklerinin 0,50'nin üzerinde olduğu belirlenmiştir.

Tablo 3. DFA Sonuçları

Değişkenler	**χ2/df**	**SRMR**	**RMSEA**	**AGFI**	**GFI**	**CFI**	**NFI**
Prososyal Motivasyon	2,161	0,016	0,072	0,945	0,993	0,995	0,990
İşte Kendini Yetiştirme	2,343	0,032	0,078	0,911	0,961	0,980	0,966
İşe Adanmışlık	1,890	0,035	0,063	0,921	0,958	0,976	0,952
Uyum Kriterleri	**χ2/df**	**SRMR**	**RMSEA**	**AGFI**	**GFI**	**CFI**	**NFI**
İyi Uyum	≤3	≤0,05	≤0,05	≥ 0,90	≥0,90	≥0,97	≥0,95
Kabul Edilebilir Uyum	≤4-5	0,06-0,08	0,06-0,08	0,89-0,80	0,89-0,85	≥0,95	0,94-0,90

Tablo 3'te prososyal motivasyon, işte kendini yetiştirme ve işe adanmışlık ölçekleri için gerçekleştirilen DFA sonuçları, elde edilen uyum iyiliği indekslerinin kabul edilebilir sınırlar içinde olduğunu ve genel olarak modellerin veriyle yeterli düzeyde uyum sağladığını göstermektedir (Meydan ve Şeşen, 2011). Ayrıca DFA sonuçları prososyal motivasyon ölçeğine ilişkin gözlenen değişkenlerin standartlaştırılmış faktör yüklerinin 0,486 ile 0,902 aralığında değiştiği tespit edilmiştir. İşte kendini yetiştirme ölçeğinde bu değerlerin 0,673 ile 0,904 arasında ve işe adanmışlık ölçeğinde ise 0,664 ile 0,880 aralığında olduğu belirlenmiştir.

Tablo 4. Tanımlayıcı İstatistikler ve Korelasyon Katsayıları

Değişkenler	**Ortalama**	**Std. Hata**	**Prososyal Motivasyon**	**İşte Kendini Yetiştirme**	**İşe Adanmışlık**
Prososyal Motivasyon	3,69	0,895	1		
İşte Kendini Yetiştirme	3,72	0,838	0,660**	1	
İşe Adanmışlık	3,40	0,696	0,578**	0,668**	1

**p<0,01

Tablo 4'te prososyal motivasyon ile işte kendini yetiştirme (r=0,660; p<0,01) ve işe adanmışlık (r=0,578; p<0,01) arasında pozitif yönlü ve orta düzeyde bir ilişki olduğu görülmektedir. Ayrıca işte kendini yetiştirme ile işe adanmışlık (r=0,668; p<0,01) arasında pozitif yönlü ve orta düzeyde bir ilişki olduğu belirlenmiştir.

Prososyal motivasyonun işe adanmışlığa etkisinde işte kendini yetiştirmenin aracılık rolü, Andrew F. Hayes (2018) tarafından geliştirilen PROCESS Makro programı kullanılarak analiz edilmiştir. Analizde, prososyal motivasyon bağımsız değişken (X), işe adanmışlık bağımlı değişken (Y) ve işte kendini yetiştirme aracı değişken (M) olarak modele dahil edilmiş; basit aracılık ilişkisini incelemeye olanak tanıyan Model 4 uygulanmıştır. Dolaylı etkinin istatistiksel anlamlılığı, %95 güven aralığında 5.000 bootstrap yeniden örnekleme yöntemi ile %95 güven düzeyinde hesaplanan bootstrap güven aralıkları üzerinden değerlendirilmiştir. Hesaplanan güven aralığının alt ve üst limitlerinin sıfır değerini içermemesi durumunda, dolaylı etkinin istatistiksel açıdan anlamlı olduğu kabul edilmiştir (Preacher ve Hayes, 2004). Ayrıca, tam standardize etki büyüklükleri (K^2) dikkate alınarak, K^2=0,01 düşük, K^2=0,09 orta ve K^2=0,25 yüksek düzeyde aracılık etkisi şeklinde yorumlanmıştır (Preacher ve Kelley, 2011).

Tablo 5. Prososyal Motivasyonun İşe Adanmışlık Üzerine Etkisinde İşte Kendini Yetiştirmenin Aracılık Rolü

	Etkiler				**BootCI**		**Model Özeti**		
	b	**Std. Hata**	**t**	**p**	**BootLLCI**	**BootULCI**	**R^2**	**Model F**	**Sig. F**
Sabit	1,739	0,162	10,725	0,000	1,419	2,058	0,334	110,644	0,000
(X) → (Y)	0,449	0,043	10,519	0,000	0,365	0,534			
Sabit	1,439	0,180	8,013	0,000	1,085	1,793	0,435	170,199	0,000
(X) → (M)	0,617	0,047	13,046	0,000	0,524	0,711			
Sabit	1,131	0,163	6,932	0,000	0,809	1,452	0,480	101,367	0,000
(X) → (Y)	0,189	0,050	3,745	0,000	0,089	0,288			
(M) → (Y)	0,422	0,054	7,855	0,000	0,316	0,528			

Tablo 5'te birinci model sonuçlarına göre, prososyal motivasyonun işe adanmışlık üzerindeki etkisi pozitif ve anlamlıdır (b = 0,449; t = 10,519; p < 0,001). Model sonuçları, ayrıca işe adanmışlıktaki toplam varyansın %33,4'ünün prososyal motivasyon tarafından açıklandığını göstermektedir (R^2 = 0,334).

İkinci model sonuçlarına göre, prososyal motivasyonun işte kendini yetiştirme üzerindeki etkisi pozitif ve anlamlıdır (b = 0,617; t = 13,046; p < 0,001). Model sonuçları, ayrıca işte kendini yetiştirmedeki toplam varyansın %43,5'inin prososyal motivasyon tarafından açıklandığını göstermektedir (R^2 = 0,435).
Üçüncü model sonuçlarına göre, prososyal motivasyonun işe adanmışlık üzerindeki etkisi işte kendini yetiştirme modele eklendiğinde azalmış ancak anlamlılığını sürdürmüştür (b = 0,189; t = 3,745; p < 0,001). İşte kendini yetiştirmenin işe adanmışlık üzerindeki etkisi de pozitif ve anlamlıdır (b = 0,422; t = 7,855; p < 0,001). Model sonuçları, ayrıca işe adanmışlıktaki toplam varyansın %48'inin prososyal motivasyon ve işte kendini yetiştirme tarafından açıklandığını göstermektedir (R^2 = 0,480).

Tablo 6. Prososyal Motivasyonun İşe Adanmışlık Üzerindeki Toplam, Doğrudan ve Dolaylı Etkileri

		BootCI	
	Etki	**BootLLCI**	**BootULCI**
Prososyal motivasyonun (X) işe adanmışlık (Y) üzerindeki toplam etkisi	0,449	0,365	0,534
Prososyal motivasyonun (X) işe adanmışlık (Y) üzerindeki doğrudan etkisi	0,189	0,089	0,288
Prososyal motivasyonun (X) işe adanmışlık (Y) üzerindeki dolaylı etkisi	0,261	0,172	0,353
Prososyal motivasyonun (X) işe adanmışlık (Y) üzerindeki tam standardize dolaylı etkisi	0,335	0,228	0,442

Tablo 6'da prososyal motivasyonun işe adanmışlık üzerindeki toplam etkisi anlamlıdır (b = 0,449; %95CI [0,365; 0,534]). İşte kendini yetiştirme modele dahil edildiğinde doğrudan etkinin azaldığı ancak anlamlılığını sürdürdüğü görülmektedir (b = 0,189; %95CI [0,089; 0,228]). Toplam etki ile doğrudan etki arasındaki farkı ifade eden dolaylı etkinin ise 0,261 olduğu ve %95 bootstrap güven aralığının [0,172; 0,353] sıfır değerini içermediği belirlenmiştir. Bu durum, test edilen aracılık modelinin istatistiksel olarak anlamlı olduğunu göstermektedir. Ayrıca tam standardize etki büyüklüğü K^2 = 0,33 olarak hesaplanmıştır. Bu değerin 0,25 eşik değerinin üzerinde olması, işte kendini yetiştirmenin prososyal motivasyon ile işe adanmışlık arasındaki ilişkide yüksek düzeyde ve güçlü bir aracılık rolü üstlendiğine işaret etmektedir.

Sonuç ve Tartışma

Bu çalışmada prososyal motivasyon ile işe adanmışlık arasındaki ilişkide işte kendini yetiştirmenin aracılık rolü incelenmiştir. Araştırma bulguları, prososyal motivasyonun hem işte kendini yetiştirme hem de işe adanmışlık üzerinde pozitif ve anlamlı bir etkiye sahip olduğunu ortaya koymuştur. Ayrıca işte kendini yetiştirmenin de işe adanmışlığı pozitif yönde etkilediği belirlenmiştir. Korelasyon analizi sonuçları, prososyal motivasyon ile işte kendini yetiştirme ve işe adanmışlık arasında orta düzeyde pozitif ilişkiler bulunduğunu göstermektedir. Benzer şekilde işte kendini yetiştirme ile işe adanmışlık arasında da pozitif yönlü ve orta düzeyde bir ilişki tespit edilmiştir. Bu bulgular, yardım etme ve başkalarına fayda sağlama isteği yüksek olan çalışanların işlerinde daha fazla gelişim, öğrenme ve canlılık deneyimi yaşadıklarını; bunun da onların işlerine daha güçlü biçimde bağlanmalarına katkı sağladığını göstermektedir. Araştırmada gerçekleştirilen aracılık analizi sonuçları ise, işte kendini yetiştirmenin prososyal motivasyon ile işe adanmışlık arasındaki ilişkide önemli bir mekanizma olduğunu ortaya koymuştur.
Elde edilen bulgular, prososyal motivasyon düzeyi yüksek sağlık çalışanlarının iş ortamında kendilerini geliştirme, öğrenme ve psikolojik canlılık yaşama eğilimlerinin arttığını; bunun da onların işe yönelik enerji, bağlılık ve yoğunlaşma düzeylerini güçlendirdiğini göstermektedir. Özellikle sağlık sektöründe çalışanların yalnızca teknik yeterliliklerinin değil, aynı zamanda psikolojik kaynaklarının da desteklenmesi gerektiği anlaşılmaktadır. Bu doğrultuda sağlık kurumlarında çalışanların prososyal motivasyonlarını artırabilecek örgütsel uygulamaların geliştirilmesi önem taşımaktadır. Çalışanlara anlamlı iş deneyimleri sunulması, öğrenme fırsatlarının desteklenmesi ve gelişim odaklı bir çalışma ortamının oluşturulması, çalışanların işte kendini yetiştirme deneyimlerini artırarak işe adanmışlık düzeylerini güçlendirebilir.
Çalışmanın yalnızca Gaziantep ilindeki sağlık çalışanları üzerinde yürütülmüş olması, elde edilen sonuçların genellenebilirliğini sınırlayabilir. Gelecek araştırmalarda farklı sektörlerde ve daha geniş örneklemler üzerinde benzer çalışmalar yürütülmesi önerilebilir. Bunun yanı sıra boylamsal araştırmalar aracılığıyla değişkenler arasındaki ilişkilerin zaman içerisindeki değişimi daha kapsamlı biçimde incelenebilir.

Kaynaklar

Ayyıldız, F., & Baran, H. (2024). Psikolojik Dayanıklılığın İş-İş Dışı Yaşam Dengesi Tatmini Üzerindeki Etkisinde İşte Kendini Yetiştirmenin Aracı Rolü. *Akademik Araştırmalar ve Çalışmalar Dergisi (AKAD)*, *16*(31), 309-330. https://doi.org/10.20990/kilisiibfakademik.1507881

Grant, A. M. (2008). Does intrinsic motivation fuel the prosocial fire? Motivational synergy in predicting persistence, performance, and productivity. *Journal of Applied Psychology*, 93(1), 48–58. https://doi.org/10.1037/0021-9010.93.1.48

Grant, A. M., Sumanth, J. J. (2009). Mission Possible? The Performance of Prosocially Motivated Employees Depends on Manager Trustworthiness, *Journal of Applied Psychology*, 94(4), 927-944.

Gül, A., & Güneş, E. (2024). Algılanan örgütsel destek ile işe adanmışlık arasındaki ilişkide işte kendini yetiştirmenin aracı rolü. *Tourism and Recreation*, *6*(1), 1-12. https://doi.org/10.53601/tourismandrecreation.1426052

Gürbüz, S., & Şahin, F. (2018). *Sosyal bilimlerde araştırma yöntemleri: Felsefe, yöntem, analiz* (5. baskı). Seçkin Yayıncılık.

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based perspective* (2nd ed.). The Guilford Press.

Kara, H., Uzunbacak, H. H., Akçakanat, T. ve Karagöz, Ş. (2025). Etik liderliğin işe adanmışlık ve örgütsel vatandaşlık üzerindeki etkisinde etik iklimin rolü. *Pamukkale Üniversitesi İşletme Araştırmaları Dergisi*, 12(2), 541-564. https://doi.org/10.47097/piar.1791308

Karadirek, G. (2023). Sosyal sorumluluk ve prososyal motivasyon ile işe bağlılık ve işkoliklik arasındaki ilişkide bir aracılık modeli. *Çankırı Karatekin Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 13 (1), 78-104. doi: 10.18074/ckuiibfd.1171036

Kavala, A, Şahin Tokatlıoğlu, T. (2025) Investıgatıon Of Prosocıal Motıvatıon Of Nursıng Students Who Wıll Practıce Clınıcal Practıce For The Fırst Tıme. Atljm. 5(13):116-123, https://doi.org/10.54270/atljm.2025.90

Kesen, M., & Akyüz, B. (2016). Duygusal Emek ve Prososyal Motivasyonun İşe Gömülmüşlüğe Etkisi: Sağlık Çalışanları Üzerine Bir Uygulama. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 25(2), 233-250. https://izlik.org/JA47GG77NA

Koçak, Ö. E. (2020). İşte Kendini Yetiştirme Ölçeğinin Meslek Grupları Arasında Ölçüm Değişmezliğinin Test Edilmesi. *Ekonomi İşletme ve Maliye Araştırmaları Dergisi*, 3(1), 73-84. https://doi.org/10.38009/ekimad.920473

Meydan, C. H., & Şeşen, H. (2011). *Yapısal eşitlik modellemesi AMOS uygulamaları.* Detay Yayıncılık.

Özkalp, P. E., & Meydan, P. B. (2015). Schaufeli ve Bakker Tarafından Geliştirilmiş Olan İşe Angaje Olma Ölçeğinin Türkçe'de Güvenilirlik ve Geçerliliğinin Analizi. *ISGUC The Journal of Industrial Relations and Human Resources*, 17(3), 1-19. https://izlik.org/JA75FT94MF

Porath, C., Spreitzer, G., Gibson, C., & Garnett, F. G. (2012). Thriving at work: Toward its measurement, construct validation, and theoretical refinement. *Journal of Organizational Behavior*, 33(2), 250-275.

Preacher, K. J.,& Hayes, A. F. (2004). SPSS and SAS Procedures for Estimating Indirect Effect in Simple Mediation Models, *Behavior Research Methods. Instruments, & Computers*, 36(4): 717-731. https://doi.org/10.3758/BF03206553

Preacher, K. J., & Kelley, K. (2011). Effect size measures for mediation models: quantitative strategies for communicating indirect effects. *Psychological methods*, 16(2), 93. https://doi.org/10.1037/a0022658

Schaufeli, W.B., & Bakker, A. B. (2003). Utrecht Work Engagement Scale (UWES): Test manual. *Unpublished manuscript*, Department of Psychology, Utrecht University, The Netherlands

Schaufeli, W.B., Salanova, M., González-romá, V. et al. (2002). The Measurement of Engagement and Burnout: A Two Sample Confirmatory Factor Analytic Approach. *Journal of Happiness Studies* 3, 71–92, https://doi.org/10.1023/A:1015630930326

Tabachnick, B. G. and Fidell, L. S. (2013). *Using Multivariate Statistics* (sixth ed.) Pearson, Boston.

Tarsuslu, S. (2024). Does corporate governance affect thriving at work? Employees' roles in knowledge sharing and prosocial motivation. *Anadolu Üniversitesi Sosyal Bilimler Dergisi, 24*(4), 1475-1498.

Tian X, Peng X and Peng X (2021) Influence of Prosocial Motivation on Employee Creativity: The Moderating Role of Regulatory Focus and the Mediating Role of Knowledge Sharing. Front. Psychol. 12:704630. doi: 10.3389/fpsyg.2021.704630

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

STATISTICAL EVALUATION OF THE PERFORMANCE OF THE DRACO LIZARD OPTIMIZER ON THE CEC-2019 (C06) BENCHMARK FUNCTIONS

Feyza ERDOĞAN
Research Assistant, Konya Technical University, Faculty of Computer and Information Sciences, Department of Software Engineering, Konya-Türkiye
Vahit TONGUR
Assist. Prof. Dr., Konya Technical University, Faculty of Computer and Information Sciences, Department of Software Engineering, Konya-Türkiye

Abstract

The Draco Lizard Optimizer (DLO) is a meta-heuristic optimization algorithm recently introduced to the literature. Draco Lizard Optimizer was developed by mathematically modeling the camouflage strategies, adaptive maneuverability, efficient gliding, and precise navigation capabilities of Draco lizards. Testing developed optimization algorithms on various problems is crucial for establishing the algorithm's recognition. In this study, the optimization performance of Draco Lizard Optimizer was evaluated using 10 test functions from the CEC-2019 (C06) benchmark set, which vary in terms of characteristics and difficulty levels. Draco Lizard Optimizer's results were compared—under equal conditions and based on 30 independent runs—with the Dragonfly Algorithm (DA), Grasshopper Optimization Algorithm (GOA), Grey Wolf Optimizer (GWO), Sine-Cosine Algorithm (SCA), Salp Swarm Algorithm (SSA), and Whale Optimization Algorithm (WOA). To assess algorithm performance, best, worst, and average fitness values, as well as standard deviation values, were utilized, thereby enabling an examination of the methods' overall consistency. The Wilcoxon rank-sum test was applied to determine the statistical significance of performance differences among the algorithms. Experimental results demonstrated that Draco Lizard Optimizer achieved lower average fitness values across all test functions compared to the other methods. Significant differences in favor of Draco Lizard Optimizer were observed in 50 out of the 60 pairwise statistical comparisons performed. The findings reveal that Draco Lizard Optimizer exhibits generally competitive and, in most cases, statistically superior performance compared to other methods on the CEC-2019 (C06) problems. In future studies, the Draco Lizard Optimizer could be applied to different problems to further test the algorithm's success. In this respect, the study contributes to the literature on the Draco Lizard Optimizer and sheds light on future research.

Keywords: Draco Lizard Optimizer, CEC-2019 (C06) Benchmark Functions, Optimization, Wilcoxon rank-sum test.

Introduction

Many optimization problems of varying structures arise in numerous fields today. Optimization algorithms are among the first solution techniques that come to mind for solving these problems. Optimization problems differ from each other due to their structure and characteristics. As the structure of the objective function, the number of dimensions, the number of local minima and the constraint characteristics of the problems change, the performance of algorithms on these problems can also differ significantly. Therefore, evaluating the generalizability and robustness of newly developed algorithms by testing them against different difficulty levels and problem structures is an important need in the literature.

The Draco Lizard Optimizer (DLO) is a recently proposed metaheuristic optimization algorithm (Wang, 2025). In the original study of DLO, performance evaluations were reported only on CEC-2017 test functions (Wang, 2025). In this study, the algorithm was evaluated on 10 functions within the scope of CEC-2019 (C06) to examine the adaptability of DLO to different problem structures (Price et al., 2018). Experiments were conducted over 30 independent runs for DLO and 6 different comparison algorithms under the same conditions. The results of DLO and the comparison algorithms were reported using best, worst and mean

fitness values and standard deviation metrics. Furthermore, a statistical comparison was performed using the Wilcoxon rank-sum test to examine the significance of performance differences between the algorithms.

CEC-2019 (C06) consists of 10 problems with different difficulty levels and function characteristics and is preferred in many studies in the literature for performance comparison purposes (Braik et al., 2022). Table 1 presents a representative literature review of studies using CEC-2019 (C06) test functions.

Table 1. Representative studies evaluating metaheuristic algorithms on the CEC-2019 (C06) benchmark functions

Year	Algorithm
2022	Ali Baba and the forty thieves algorithm (AFT) (Braik et al., 2022)
2022	Aphid–Ant Mutualism (AAM) (Eslami et al., 2022)
2023	Alligator Optimisation Algorithm (AgtrO) (Tan & Mohamad-Saleh, 2023)
2023	Group Learning Algorithm (GLA) (Rahman, 2023)
2023	Humboldt Squid Optimization Algorithm (HSOA) (Anaraki & Farzin, 2023)
2024	GOOSE algorithm (Hamad & Rashid, 2024)
2024	Horned Lizard Optimization Algorithm (HLOA) (Peraza-Vázquez et al., 2024)
2025	Cultural History Optimization Algorithm (CHOA) (Sharifi et al., 2025)
2025	Gaussian Combined Arms Algorithm (GCA) (Etesami et al., 2025)
2025	LEO: Lagrange elementary optimization (Aladdin & Rashid, 2025)

The remainder of this paper is organized as follows: Section 2 summarizes the basic structure of the DLO algorithm. Section 3 introduces the CEC-2019 (C06) test functions. Section 4 presents the experimental results and statistical analyses of the DLO and comparison algorithms. Finally, Section 5 provides the results and discussion.

Materials and Methods

Draco Lizard Optimizer (DLO)

Draco Lizard Optimizer (DLO) is a population-based metaheuristic optimization algorithm introduced to the literature by Xiaowei Wang in 2025 (Wang, 2025). DLO was developed by mathematically simulating the camouflage strategies, adaptive maneuvering, efficient gliding and precise navigation of Draco lizards. The DLO algorithm executes these adaptive behaviors in two phases ($exploration \rightarrow t < \frac{T_{max}}{2}$ and $exploitation \rightarrow t \geq \frac{T_{max}}{2}$) and performs the optimization process.

DLO is initialized with a population of N Draco lizards. Each individual in the population is represented by a vector determined by the problem size (D) and the upper and lower bounds of the search space. The initial population of the algorithm is created using Equation (1) and the optimization process of the algorithm is initiated.

$$X_{i,j} = lb_j + r \cdot \left(ub_j - lb_j\right) \qquad i = 1,2,\cdots,N \text{ and } j = 1,2,\cdots,D \tag{1}$$

where $X_{i,j}$ represents the j-th dimension value of the i-th individual, lb_j and ub_j represent the lower and upper limit values for the j-th dimension respectively and r is a randomly determined number in the interval [0,1].

The first phase of DLO represents the exploration phase of optimization. In this phase, the efficient gliding and precise navigation behaviors of the draco lizard are mathematically modeled. In the exploration phase, the position update operation of the individuals is performed with Equation (2).

$$\overrightarrow{x_i(t+1)} = \begin{cases} \overrightarrow{xbest_i} + r \cdot \left(\overrightarrow{x_m(t)} - A \cdot \overrightarrow{xbest_i}\right) + \overrightarrow{DL} \cdot r \cdot \left(\overrightarrow{x_m(t)} - \overrightarrow{x_n(t)}\right), if\ f\left(\overrightarrow{xbest_i}\right) > f\left(\overrightarrow{xbest_m}\right) \\ \overrightarrow{xbest_i} + r \cdot \left(\overrightarrow{x_{best}(t)} - \overrightarrow{x_m(t)}\right) + \overrightarrow{DL} \cdot r \cdot \left(\overrightarrow{x_m(t)} - \overrightarrow{x_n(t)}\right), otherwise \end{cases} \quad (2)$$

where t is the current iteration, $\overrightarrow{x_i}$ is the i-th individual's current position, $\overrightarrow{xbest_i}$ i-th represents the personal best position of the individual, $\overrightarrow{x_m(t)}$ and $\overrightarrow{x_n(t)}$ represent the positions of two randomly selected different individuals, r represents the D-dimensional random vector in the range [0,1] and $f(\cdot)$ represents the objective (fitness) function of the problem. A is a coefficient with a value of 1 or 2 and is calculated by Equation (3).

$$A = round\left(1 + rand(0,1)\right) \quad (3)$$

The turning vector ($\overrightarrow{DL}$), which is one of the basic components in this stage, is modeled with Equation (4) in order to provide efficient gliding with flexible directional control.

$$\overrightarrow{DL} = \left[DL_{(1)}, DL_{(2)}, DL_{(3)}, \cdots, DL_{(D)}\right]$$

$$DL_{(j)} = \begin{cases} 1, & if \quad t < \varphi_1 \cdot T_{max} \\ P_1(k), & else \quad t < \varphi_2 \cdot T_{max} \\ P_2(k), & else \quad t < \varphi_3 \cdot T_{max} \\ P_3(k), & else \quad t < \varphi_4 \cdot T_{max} \\ 0, & else \quad t < \varphi_5 \cdot T_{max} \end{cases}, \qquad j = 1,2,3,\cdots,D \quad (4)$$

where T_{max}represents the maximum number of iterations. k is randomly determined in the range [1,4]. ($\overrightarrow{DL}$) is a D -dimensional vector consisting of 0s and 1s.

In the other half of the iterations, DLO moves to the second phase, the exploitation phase and the search is concentrated around the global best solution. In this phase, the camouflage strategies and adaptive maneuvers of the draco lizard are mathematically modeled. In the exploitation phase, the position update of individuals is performed with Equation (5).

$$\overrightarrow{x_i(t+1)} = \begin{cases} \overrightarrow{gbest} + levy(D) \cdot \left(\overrightarrow{gbest} - \overrightarrow{x_i(t)}\right), & if\ rand(0,1) < p \\ \overrightarrow{gbest} + g \cdot \left(1 - \frac{t}{T_{max}}\right) \cdot \left(\overrightarrow{xbest_i} - \overrightarrow{x_i(t)}\right), & otherwise \end{cases}$$

$$levy = 0.05 \cdot \frac{u \cdot \rho}{|v|^{\frac{1}{\beta}}}, \qquad \rho = \left(\frac{\Gamma(1+\beta) \cdot \sin\left(\frac{\pi \cdot \beta}{2}\right)}{\Gamma\left(\frac{1+\beta}{2}\right) \cdot \beta \cdot 2^{\left(\frac{\beta-1}{2}\right)}}\right)^{\frac{1}{\beta}} \quad (5)$$

where $\overrightarrow{gbest}$ represents the vector of individuals with the best fitness value in the population, p is the probability of strategy transition, g is a random number following a normal distribution with a mathematical expected value of 0 and variance of 10, u and v are random variables belonging to the Lévy distribution and β is the Lévy distribution parameter.

In the DLO algorithm, individual and global best solutions are updated at the end of each iteration using a greedy selection mechanism. These updates are performed using Equations (6) and (7). This strategy guarantees a monotonic improvement in solution quality throughout the iterations.

$$\overrightarrow{xbest_i} = \begin{cases} \overrightarrow{x_i(t+1)}, & if\ f(\overrightarrow{x_i(t+1)}) < f(\overrightarrow{xbest_i}) \\ \overrightarrow{xbest_i}, & otherwise \end{cases} \quad (6)$$

$$\overrightarrow{gbest} = \begin{cases} \overrightarrow{x_i(t+1)}, & if\ f(\overrightarrow{x_i(t+1)}) < f(\overrightarrow{gbest}) \\ \overrightarrow{gbest_i}, & otherwise \end{cases} \quad (7)$$

The DLO algorithm offers a two-stage adaptive search process consisting of population initialization, exploration phase, exploitation phase and a greedy selection mechanism. Through this structure, DLO aims to deliver balanced, stable and effective performance in complex and multimodal optimization problems (Wang, 2025).

CEC-2019 (C06) Benchmark Functions

In the literature, standard benchmark test functions are widely used to objectively and comparably evaluate the performance of optimization algorithms. They serve as a reference, particularly in evaluating the accuracy, stability and convergence to the global optimum of metaheuristic algorithms (Baş, 2023; Braik et al., 2022; Wang, 2025).

In this study, the performance of the Draco Lizard Optimizer (DLO) algorithm was investigated using IEEE CEC-2019 (C06) benchmark test functions, developed for single-objective continuous optimization problems. CEC-2019 (C06) test functions provide an evaluation framework that aims to measure not only the rapid convergence of algorithms but also their ability to reach the global optimum with high precision (Price et al., 2018; Wang, 2025).

The CEC-2019 (C06) test functions consist of a total of 10 minimization problems and the global optimum value is defined as 1.0 for all functions. The test functions have different dimensions and search intervals and are problems of medium and high difficulty (Price et al., 2018).

Functions are considered in two main groups according to their structural properties. (CEC2019-1) – (CEC2019-3) functions consist of problems that do not involve shifting and rotation but contain strong dependencies between variables. (CEC2019-4) – (CEC2019-10) functions are shifted and rotated versions of classical test functions. These operations transform the functions into complex problems that are non-separable, multimodal and contain many local minima (Braik et al., 2022; Price et al., 2018).

CEC-2019 (C06) test functions are widely used in the literature to evaluate the performance of different metaheuristic algorithms and provide a suitable test environment for analyzing the local minima avoidance, global search capability and stable result generation properties of algorithms (Price et al., 2018). Therefore, the CEC-2019 (C06) benchmark set was preferred for evaluating the overall performance of the proposed DLO algorithm.

Basic information about the CEC-2019 (C06) benchmark test functions is presented in Table 2 (Braik et al., 2022; Price et al., 2018).

Table 2. CEC-2019 (C06) Benchmark Test Functions

Function ID	Function Name	Dimension	Search Range	F_{min}
CEC2019-1	Storn's Chebyshev Polynomial Fitting Problem	9	[-8192,8192]	1.0
CEC2019-2	Inverse Hilbert Matrix Problem	16	[-16384,16384]	1.0
CEC2019-3	Lennard-Jones Minimum Energy Cluster	18	[-4,4]	1.0
CEC2019-4	Rastrigin's Function	10	[-100,100]	1.0
CEC2019-5	Griewangk's Function	10	[-100,100]	1.0
CEC2019-6	Weierstrass Function	10	[-100,100]	1.0
CEC2019-7	Modified Schwefel's Function	10	[-100,100]	1.0
CEC2019-8	Expanded Schaffer's F6 Function	10	[-100,100]	1.0
CEC2019-9	Happy Cat Function	10	[-100,100]	1.0
CEC2019-10	Ackley Function	10	[-100,100]	1.0

Findings and Discussion

The performance of the Draco Lizard Optimizer (DLO) algorithm was evaluated on CEC-2019 (C06) benchmark test functions and compared with commonly used meta-heuristic optimization algorithms in the literature. Comparative analyses were performed considering the solution quality, stability and statistical significance of the algorithms.

In the experiments, a total of 10 single-objective minimization problems included in CEC-2019 (C06) were used. For comparison purposes, in addition to the proposed DLO algorithm, 6 different optimization algorithms were included in the experimental studies. These algorithms are: Dragonfly Algorithm (DA) (Mirjalili, 2016a), Grasshopper Optimisation Algorithm (GOA) (Saremi et al., 2017), Grey Wolf Optimizer (GWO) (Mirjalili et al., 2014), Sine Cosine Algorithm (SCA) (Mirjalili, 2016b), Salp Swarm Algorithm (SSA) (Mirjalili et al., 2017) and Whale Optimization Algorithm (WOA) (Mirjalili & Lewis, 2016). Common experimental parameters were used to ensure a fair comparison for all algorithms. In this context, for each algorithm the population size was set to 30, the maximum number of function evaluations (MaxFEs) to be 30.000 and the number of independent runs to be 30. All experiments were conducted by performing 30 independent runs for each function. Initial populations were randomly generated for each run to minimize the effects stemming from the stochastic nature of the algorithms.

Experimental studies were run under the same hardware and software conditions for all algorithms. This aimed to prevent potential performance differences arising from the computational environment.

The optimization algorithms used in the comparison were selected from methods widely used in the literature and possessing different search strategies. All algorithms were used with parameter settings suggested in their original studies or widely accepted in the literature. Keeping parameter settings constant for all algorithms ensures the impartiality and repeatability of the experimental comparison.

The performance of the algorithms was evaluated based on the best, worst, mean and standard deviation (std) values of the fitness values obtained from 30 independent runs for each test function. These metrics were used

to reveal both the solution quality and stability of the algorithms. The relevant numerical results are given in Table 3.

Table 3. Experimental results of DLO and other comparative algorithms on CEC-2019 (C06)

Function	Metrics	Algorithms						
		DLO	DA	GOA	GWO	SCA	SSA	WOA
CEC2019-1	*Best*	**1.00E+00**	5.61E+04	1.34E+05	**1.00E+00**	2.43E+00	2.23E+04	1.56E+02
	Worst	**6.01E+01**	5.65E+07	5.73E+06	2.33E+04	7.25E+06	2.77E+06	2.43E+07
	Mean	**3.34E+00**	1.56E+07	1.48E+06	4.59E+03	1.18E+06	6.81E+05	5.92E+06
	Std.	**1.08E+01**	1.64E+07	1.36E+06	7.48E+03	1.96E+06	7.64E+05	6.20E+06
CEC2019-2	*Best*	**1.18E+01**	6.02E+02	1.97E+02	4.20E+01	3.98E+02	1.58E+02	4.90E+01
	Worst	**9.26E+01**	7.88E+03	4.02E+03	7.06E+02	5.68E+03	2.58E+03	1.70E+04
	Mean	**4.78E+01**	3.28E+03	8.29E+02	3.05E+02	2.58E+03	8.04E+02	7.50E+03
	Std.	**2.25E+01**	2.11E+03	7.70E+02	1.83E+02	1.44E+03	7.12E+02	3.69E+03
CEC2019-3	*Best*	**1.00E+00**	5.49E+00	4.58E+00	**1.00E+00**	5.74E+00	**1.00E+00**	1.45E+00
	Worst	**1.41E+00**	1.17E+01	1.17E+01	7.71E+00	1.10E+01	7.02E+00	7.50E+00
	Mean	**1.37E+00**	9.37E+00	8.15E+00	2.38E+00	8.31E+00	2.98E+00	3.27E+00
	Std.	**1.25E-01**	1.29E+00	2.11E+00	1.94E+00	1.78E+00	1.73E+00	1.43E+00
CEC2019-4	*Best*	3.98E+00	1.44E+01	9.95E+00	**3.13E+00**	2.56E+01	1.09E+01	7.17E+00
	Worst	3.50E+01	9.35E+01	4.20E+01	**2.89E+01**	6.10E+01	4.88E+01	8.56E+01
	Mean	**1.12E+01**	4.95E+01	2.20E+01	1.32E+01	4.36E+01	2.41E+01	4.18E+01
	Std.	**6.38E+00**	1.89E+01	8.08E+00	5.54E+00	7.91E+00	9.89E+00	2.31E+01
CEC2019-5	*Best*	**1.00E+00**	1.26E+00	1.07E+00	1.12E+00	4.76E+00	1.10E+00	1.40E+00
	Worst	**1.23E+00**	9.98E+00	1.60E+00	3.80E+00	1.57E+01	1.78E+00	3.34E+00
	Mean	**1.03E+00**	2.48E+00	1.29E+00	1.65E+00	7.23E+00	1.30E+00	2.00E+00
	Std.	**4.68E-02**	1.90E+00	1.44E-01	6.33E-01	2.10E+00	2.03E-01	4.23E-01
CEC2019-6	*Best*	**1.00E+00**	1.90E+00	1.33E+00	1.15E+00	4.44E+00	1.07E+00	5.36E+00
	Worst	**1.16E+00**	1.02E+01	9.56E+00	3.89E+00	8.58E+00	7.71E+00	1.10E+01
	Mean	**1.01E+00**	7.10E+00	4.68E+00	2.18E+00	6.79E+00	3.87E+00	8.09E+00
	Std.	**2.87E-02**	2.23E+00	2.01E+00	7.38E-01	9.93E-01	1.70E+00	1.86E+00
CEC2019-7	*Best*	3.37E+02	7.79E+02	2.95E+02	**2.42E+02**	9.94E+02	2.85E+02	7.28E+02
	Worst	**1.11E+03**	1.80E+03	1.73E+03	1.27E+03	1.75E+03	1.47E+03	2.00E+03
	Mean	**6.84E+02**	1.23E+03	9.89E+02	7.12E+02	1.46E+03	8.01E+02	1.31E+03
	Std.	2.33E+02	2.72E+02	3.17E+02	2.82E+02	**1.87E+02**	3.12E+02	3.21E+02
CEC2019-8	*Best*	**2.65E+00**	3.85E+00	3.25E+00	2.82E+00	3.84E+00	3.15E+00	4.03E+00
	Worst	**4.42E+00**	5.04E+00	4.99E+00	4.98E+00	4.74E+00	4.58E+00	5.03E+00
	Mean	**3.62E+00**	4.55E+00	3.96E+00	3.87E+00	4.28E+00	3.91E+00	4.56E+00
	Std.	4.78E-01	2.96E-01	4.40E-01	5.51E-01	**2.34E-01**	3.70E-01	3.20E-01
CEC2019-9	*Best*	**1.03E+00**	1.11E+00	1.07E+00	1.06E+00	1.30E+00	1.11E+00	1.14E+00
	Worst	**1.26E+00**	1.59E+00	1.39E+00	1.32E+00	1.65E+00	1.63E+00	1.52E+00

	Mean	**1.15E+00**	1.32E+00	1.19E+00	1.16E+00	1.51E+00	1.30E+00	1.36E+00
	Std.	8.05E-02	1.11E-01	8.67E-02	**5.92E-02**	8.19E-02	1.42E-01	1.06E-01
CEC2019-10	***Best***	**1.00E+00**	2.10E+01	2.10E+01	2.11E+01	2.11E+01	2.10E+01	2.10E+01
	Worst	2.15E+01	2.16E+01	**2.13E+01**	2.15E+01	2.16E+01	2.14E+01	2.14E+01
	Mean	**1.95E+01**	2.13E+01	2.11E+01	2.14E+01	2.14E+01	2.10E+01	2.12E+01
	Std.	5.70E+00	1.44E-01	8.19E-02	8.16E-02	8.75E-02	**7.78E-02**	1.19E-01

In Table 3, each algorithm was evaluated over 30 independent runs and the best result for the respective metric is highlighted in bold. A general assessment reveals that the proposed DLO algorithm demonstrates vastly superior performance compared to the competing algorithms: DA, GOA, GWO, SCA, SSA and WOA. DLO achieves the best results across multiple metrics simultaneously for the vast majority of the 10 functions examined. These results indicate that the algorithm possesses a distinct advantage in terms of both solution quality and stability.

The CEC2019-1 function yields particularly noteworthy results. Regarding the "Best" metric, both DLO and GWO achieved a value of 1.00E+00, thereby attaining the optimum value. An analysis of the "Mean" value shows that DLO achieved the lowest average among all algorithms, at 3.34E+00. For the "Worst" value, DLO performed significantly better than the other algorithms, recording 6.01E+01. It also ranked among the most consistent algorithms—a crucial factor for algorithmic reliability—with a "Std" value of 1.08E+01.

For the CEC2019-2 function, DLO achieved the best results across all metrics. This indicates that DLO is capable of establishing a consistent balance between exploration and exploitation when compared to the competing algorithms.

In the case of the CEC2019-3 function, DLO, GWO and SSA all reached the optimum value of 1.00E+00 for the "Best" metric. However, an examination of the "Mean" and "Worst" metrics reveals that DLO produced the lowest values among all algorithms, recording 1.37E+00 and 1.41E+00, respectively. Regarding the Std metric, DLO achieved the lowest standard deviation at 1.25E-01, demonstrating the algorithm's high consistency.

For the CEC2019-4 function, GWO outperformed the others in the Best metric with a value of 3.13E+00. However, DLO delivered the best average performance with a Mean value of 1.12E+01. This indicates that DLO exhibited stable performance across independent runs.

DLO achieved the best results across all metrics for the CEC2019-5 and CEC2019-6 functions. In both functions, the Best value was 1.00E+00, representing the optimum result. Furthermore, the Mean and Std metrics indicate that DLO minimized variance across independent runs and produced reliable results.

For the CEC2019-7 function, while GWO stood out in the Best metric with a value of 2.42E+02, DLO achieved the best Mean value at 6.84E+02. DLO also recorded the lowest value among the algorithms in the Worst metric, at 1.11E+03. These results demonstrate that the algorithm produces superior outcomes compared to its competitors, even in worst-case scenarios.

DLO achieved the best values for the Best, Worst and Mean metrics in the CEC2019-8 and CEC2019-9 functions. Regarding the Std metric, however, SCA (2.34E-01) and GWO (5.92E-02) achieved the lowest standard deviations for CEC2019-8 and CEC2019-9, respectively. DLO ranked second in terms of consistency for these functions, yet it maintained its success regarding solution quality.

While DLO achieved the optimal value of 1.00E+00 for the CEC2019-10 function according to the "Best" metric, all other algorithms remained stuck within a specific range. The fact that only DLO reached the optimal

point suggests that the competing algorithms may have become trapped in local minima. Regarding the "Mean" metric, DLO's value of 1.95E+01 represents the lowest average. DLO also outperformed the other algorithms in the "Std" metric, achieving a value of 5.70E+00. This indicates that DLO effectively maintained the balance between exploration and exploitation across 30 independent runs.

An overall analysis of Table 3 reveals that DLO generally demonstrated superior performance compared to the other algorithms tested on the CEC-2019 (C06) functions. DLO consistently achieved the best results—particularly in terms of the "Best" and "Mean" metrics—and exhibited a competitive profile regarding the balance between solution quality and consistency.

The Wilcoxon rank-sum test was employed to assess whether the performance differences between the proposed DLO algorithm and the algorithms used for comparison were statistically significant. This test is widely preferred for comparing optimization results due to its non-parametric nature. The test utilized the final best fitness values obtained from 30 independent runs of the algorithms for each CEC-2019 (C06) function. DLO was compared individually against each of the comparison algorithms. The tests were conducted as two-way tests. The level of statistical significance was set at (α=0.05). ($p<0.05$) indicates that the performance difference between the two compared algorithms is statistically significant. The obtained p-values and the symbols (+), (=) and (-) indicating the status of the difference relative to DLO are presented in Table 4. Here, (+) indicates that DLO performed statistically significantly better than the comparison algorithm, (-) indicates statistically significantly worse performance and (=) indicates that there was no statistically significant difference between the algorithms. The W/T/L values in the bottom row of the table summarize the number of functions won, drawn and lost by DLO, respectively.

Table 4. Wilcoxon rank-sum test results of DLO against the comparison algorithms (α=0.05)

Function	DA	GOA	GWO	SCA	SSA	WOA
CEC2019-1	2.95E−11 (+)	2.95E−11 (+)	3.29E−06 (+)	4.87E−11 (+)	2.95E−11 (+)	2.95E−11 (+)
CEC2019-2	3.02E−11 (+)	3.02E−11 (+)	5.00E−09 (+)	3.02E−11 (+)	3.02E−11 (+)	1.09E−10 (+)
CEC2019-3	2.74E−11 (+)	2.74E−11 (+)	4.77E−08 (+)	2.74E−11 (+)	3.86E−10 (+)	2.74E−11 (+)
CEC2019-4	1.20E−10 (+)	2.78E−07 (+)	3.51E−02 (+)	4.06E−11 (+)	8.33E−08 (+)	1.01E−08 (+)
CEC2019-5	2.80E−11 (+)	1.36E−10 (+)	5.63E−11 (+)	2.80E−11 (+)	1.82E−10 (+)	2.80E−11 (+)
CEC2019-6	3.02E−11 (+)	3.02E−11 (+)	3.34E−11 (+)	3.02E−11 (+)	3.34E−11 (+)	3.02E−11 (+)
CEC2019-7	1.10E−08 (+)	1.32E−04 (+)	6.95E−01 (=)	4.50E−11 (+)	1.67E−01 (=)	4.18E−09 (+)
CEC2019-8	2.03E−09 (+)	1.03E−02 (+)	8.50E−02 (=)	3.81E−07 (+)	1.27E−02 (+)	2.67E−09 (+)
CEC2019-9	1.73E−07 (+)	1.33E−01 (=)	9.00E−01 (=)	3.02E−11 (+)	1.64E−05 (+)	9.26E−09 (+)
CEC2019-10	4.68E−02 (−)	5.97E−05 (−)	3.478E−01 (=)	4.68E−02 (+)	6.77E−05 (−)	7.30E−04 (−)
W/T/L	9/0/1	8/1/1	6/4/0	10/0/0	8/1/1	9/0/1

An overall assessment of Table 4 reveals that DLO demonstrates a statistically significant superiority over all six algorithms with which it was compared. DLO outperformed SCA across all functions. This statistical result indicates that DLO consistently produces better solutions than SCA in all test scenarios. DLO achieved statistical superiority over the DA and WOA algorithms on nine functions. Its failure on function F10 is directly linked to the high standard deviation value observed in Table 3. This statistically confirms that DLO exhibits inconsistency across runs for this specific function. DLO demonstrated statistical superiority over the SSA and

GOA algorithms on eight functions. There is no statistically significant difference regarding function F7 when compared to SSA, nor regarding function F9 when compared to GOA. However, it was outperformed by both algorithms on function F10. This further reinforces the observation of DLO's limited stability on F10. When examining the overall performance across algorithms, GWO emerges as DLO's closest competitor. Yet, the fact that DLO was never outperformed by GWO indicates that it generally surpasses GWO without falling significantly behind in any test problem.

In conclusion, the Wilcoxon rank-sum test findings confirm that DLO exhibits a statistically significant and consistent superiority over competing algorithms on the CEC-2019 (C06) test suite. Except for the limited inconsistencies observed in the F10 function and the ties with GWO, DLO's performance advantage is strongly supported at a statistical level. The obtained W/T/L ratios serve as an objective indicator of the proposed algorithm's overall optimization capability and competitive superiority.

Conclusion and Recommendations

Results from 30 independent runs on CEC-2019 (C06) benchmark functions show that DLO has strong overall performance against the compared DA, GOA, GWO, SCA, SSA and WOA algorithms. Considering the average fitness values, DLO achieved the lowest average value in all F1–F10 functions. Best and Worst results also largely support this trend. Especially in the F5 and F6 functions, DLO showed a clear superiority in terms of both solution quality and inter-run stability. On the other hand, the increase in standard deviation in F8 and especially F10 shows that DLO can produce more variable results between runs in these problems.

To evaluate the statistical significance of the differences between the algorithms, a two-way Wilcoxon rank-sum test was applied on the final best fitness values obtained from 30 independent runs. DLO statistically significantly outperformed all six compared algorithms in functions F1–F6. Additionally, 10/0/0 Win/Tie/Loss results were obtained against SCA, 9/0/1 against DA and WOA, 8/1/1 against GOA and SSA and 6/4/0 against GWO. With the Wilcoxon rank-sum test results, it is statistically seen that the overall success of DLO is superior to other methods.

The fact that all the significant results against DLO occur in the F10 function shows that this function is more challenging in terms of the algorithm. In F10, although DLO could reach the global optimum under some conditions, it showed a higher standard deviation. Therefore, the results show that DLO offers overall competitive and statistically strong performance in most functions on CEC-2019 (C06), but has room for improvement in terms of stability, especially on F10.

References

Aladdin, A. M., & Rashid, T. A. (2025). LEO: Lagrange elementary optimization. *Neural Computing and Applications*, *37*(19), 14365-14397. https://doi.org/10.1007/s00521-025-11225-2.

Anaraki, M. V., & Farzin, S. (2023). Humboldt Squid Optimization Algorithm (HSOA): A novel nature-inspired technique for solving optimization problems. *IEEe Access*, *11*, 122069-122115. DOI: 10.1109/ACCESS.2023.3328248.

Baş, E. (2023). Performance of Snake Optimizer on Cec-C06 2019 Test Functions.

Braik, M., Ryalat, M. H., & Al-Zoubi, H. (2022). A novel meta-heuristic algorithm for solving numerical optimization problems: Ali Baba and the forty thieves. *Neural Computing and Applications*, *34*(1), 409-455. https://doi.org/10.1007/s00521-021-06392-x.

Eslami, N., Yazdani, S., Mirzaei, M., & Hadavandi, E. (2022). Aphid–ant mutualism: A novel nature-inspired metaheuristic algorithm for solving optimization problems. *Mathematics and Computers in Simulation*, *201*, 362-395. https://doi.org/10.1016/j.matcom.2022.05.015.

Etesami, R., Madadi, M., Keynia, F., & Arabpour, A. (2025). Gaussian combined arms algorithm: a novel meta-heuristic approach for solving engineering problems. *Evolutionary Intelligence*, *18*(2), 43. https://doi.org/10.1007/s12065-025-01026-w.

Hamad, R. K., & Rashid, T. A. (2024). GOOSE algorithm: A powerful optimization tool for real-world engineering challenges and beyond. *Evolving Systems*, *15*(4), 1249-1274. https://doi.org/10.1007/s12530-023-09553-6.

Mirjalili, S. (2016). Dragonfly algorithm: a new meta-heuristic optimization technique for solving single-objective, discrete, and multi-objective problems. *Neural computing and applications*, *27*(4), 1053-1073. https://doi.org/10.1007/s00521-015-1920-1.

Mirjalili, S. (2016). SCA: a sine cosine algorithm for solving optimization problems. *Knowledge-based systems*, *96*, 120-133. http://dx.doi.org/10.1016/j.knosys.2015.12.022.

Mirjalili, S., Gandomi, A. H., Mirjalili, S. Z., Saremi, S., Faris, H., & Mirjalili, S. M. (2017). Salp Swarm Algorithm: A bio-inspired optimizer for engineering design problems. *Advances in engineering software*, *114*, 163-191. http://dx.doi.org/10.1016/j.advengsoft.2017.07.002.

Mirjalili, S., & Lewis, A. (2016). The whale optimization algorithm. *Advances in engineering software*, *95*, 51-67. http://dx.doi.org/10.1016/j.advengsoft.2016.01.008.

Mirjalili, S., Mirjalili, S. M., & Lewis, A. (2014). Grey wolf optimizer. *Advances in engineering software*, *69*, 46-61. http://dx.doi.org/10.1016/j.advengsoft.2013.12.007.

Peraza-Vázquez, H., Peña-Delgado, A., Merino-Treviño, M., Morales-Cepeda, A. B., & Sinha, N. (2024). A novel metaheuristic inspired by horned lizard defense tactics. *Artificial Intelligence Review*, *57*(3), 59. https://doi.org/10.1007/s10462-023-10653-7.

Price, K. V., Awad, N. H., Ali, M. Z., & Suganthan, P. N. (2018). Problem definitions and evaluation criteria for the 100-digit challenge special session and competition on single objective numerical optimization. In *Technical report*. Singapore: Nanyang Technological University.

Rahman, C. M. (2023). Group learning algorithm: a new metaheuristic algorithm. *Neural Computing and Applications*, *35*(19), 14013-14028. https://doi.org/10.1007/s00521-023-08465-5.

Saremi, S., Mirjalili, S., & Lewis, A. (2017). Grasshopper optimisation algorithm: theory and application. *Advances in engineering software*, *105*, 30-47. http://dx.doi.org/10.1016/j.advengsoft.2017.01.004.

Sharifi, T., Mirsalim, M., Soleimanian Gharehchopogh, F., & Mirjalili, S. (2025). Cultural history optimization algorithm: a new human-inspired metaheuristic algorithm for engineering optimization problems. *Neural Computing and Applications*, *37*(25), 21009-21068. https://doi.org/10.1007/s00521-025-11379-z.

Tan, W. H., & Mohamad-Saleh, J. (2023). Alligator optimisation algorithm for solving unconstrainted optimisation problems. *International Journal of Bio-Inspired Computation*, *21*(1), 11-25. https://doi.org/10.1504/IJBIC.2023.130025.

Wang, X. (2025). Draco lizard optimizer: a novel metaheuristic algorithm for global optimization problems. *Evolutionary Intelligence*, *18*(1), 10. https://doi.org/10.1007/s12065-024-00998-5.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

STOCK MARKET REACTIONS TO THE 2025 IRAN–ISRAEL CONFLICT AND THE 2026 IRAN WAR: COMPARATIVE EVIDENCE FROM GCC COUNTRIES

Zekeriya Gül
0000-0002-4241-117X, Gaziantep University, Faculty of Business Administration, Department of Business Administration, Gaziantep, Turkiye

Abstract

This paper examines Gulf stock markets' responses to two waves of military escalation involving Iran: the Twelve-Day War between Israel and Iran (13–24 June 2025) and the US–Israeli war against Iran, which began on 28 February 2026 with repercussions through October 2026. A descriptive event study compares major indices within specified windows around escalation and ceasefire dates, linking them to shock-transmission channels: oil prices, the Strait of Hormuz, foreign investor flows, and war-risk insurance premiums.
Three patterns emerge. First, the 2025 shock was short-lived and followed by a rebound: markets fell on the first day but recovered their losses after the ceasefire announcement, while Dubai's index reached a 17-year high within days. Second, the 2026 war differed qualitatively: strikes reached Gulf territories and infrastructure, and the strait was closed, prompting regulators in the UAE and Kuwait to suspend trading for the first time during war. Third, disparities widened: Qatar and Dubai suffered more because of their exposure to the strait, real estate, and tourism, whereas Saudi Arabia remained resilient thanks to its ability to redirect exports to the Red Sea, and Oman outperformed because it lies outside the strait.
Figures show divergence. From the war's beginning to 7 October 2026, Qatar's index fell 16%, Dubai's 9%, and Abu Dhabi's 5%, compared with a limited decline in Saudi Arabia, while Muscat's index rose 9.3% in the first month. Foreign investors withdrew a net $415 million from Gulf equities in July 2026 after US–Iranian understandings collapsed. It concludes the conflict's impact depends on strikes reaching Gulf territories, dependence on Hormuz, and crisis duration; the positive oil–equity relationship depends on actual export capacity.

Keywords: Geopolitical Risk; GCC Stock Markets; Event Study; Strait of Hormuz.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ANALYSIS OF THE RELATIONSHIP BETWEEN INFORMATION SECURITY MANAGEMENT PROCESSES AND PERSONAL DATA PROTECTION COMPLIANCE MATURITY IN THE ELECTRONIC COMMUNICATIONS SECTOR

Şeyma AKBULUT
Bilgi Teknolojileri ve İletişim Kurumu, Ankara, Türkiye
ORCID: 0009-0003-1212-7826
Çelebi ULUYOL
Prof. Dr., Gazi Üniversitesi, Ankara, Türkiye ORCID: 0000-0001-9774-0547

Abstract

This study examines the relationship between Information Security Management System (ISMS) control practices and personal data protection compliance maturity among operators in Turkey's electronic communications sector. The data comprise 175 valid responses to a researcher-developed, 93-item, five-point Likert questionnaire organized around the organisational, human, physical, and technological control themes of ISO/IEC 27002:2022. Internal consistency was assessed using Cronbach's alpha; the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test were used to assess whether the correlation matrix was suitable for factor analysis. Spearman's rank correlation and ordinal logistic regression were used to examine associations. Respondents reported high levels of practice across all four control dimensions, and all dimensions were positively associated with personal data protection compliance maturity. The associations were strongest for organisational and technological controls. Higher overall ISMS scores were also associated with being in a higher compliance-maturity category. Operators reporting ISO/IEC 27001 certification had higher compliance-maturity scores than uncertified operators and those undergoing certification. Item-level responses identified sectoral information sharing, segregation of duties, supplier security, pre-employment screening, physical access, data loss prevention, and secure software development as areas with relatively more room for improvement. These findings describe self-reported responses; they do not constitute independently verified evidence of implementation or regulatory compliance.

Keywords: Information Security Management System, Electronic Communications, Personal Data Protection, ISO/IEC 27001, Regulatory Compliance.

ELEKTRONİK HABERLEŞME SEKTÖRÜNDE BİLGİ GÜVENLİĞİ YÖNETİM SÜREÇLERİ İLE KİŞİSEL VERİ KORUMA UYUM OLGUNLUĞU ARASINDAKİ İLİŞKİNİN ANALİZİ

Özet

Bu çalışma, Türkiye'deki elektronik haberleşme işletmecilerinin bilgi güvenliği kontrollerini ne ölçüde uyguladıkları ile kişisel verileri koruma çalışmalarının hangi aşamada olduğu arasındaki ilişkiyi incelemektedir. Araştırmacı, ISO/IEC 27002:2022'de yer alan organizasyonel, insan kaynaklı, fiziksel ve teknolojik kontrol alanlarını temel alarak 93 maddelik bir anket hazırlamıştır. Ankette her soru için 1'den 5'e uzanan Likert tipi yanıt seçenekleri sunulmuş ve 175 geçerli yanıt alınmıştır. Anket sorularına verilen yanıtların tutarlılığı Cronbach alfa katsayısıyla değerlendirilmiştir. Yanıtların faktör analizine uygunluğu KMO göstergesi ve Bartlett küresellik testiyle incelenmiştir. Değişkenler arasındaki ilişkiler Spearman sıra korelasyonu ve sıralı lojistik regresyon kullanılarak değerlendirilmiştir. Katılımcılar dört kontrol alanında da uygulama düzeyinin yüksek olduğunu bildirmiştir. Dört alanın tamamı, kişisel verileri koruma çalışmalarının ulaştığı aşamayla pozitif ilişkilidir. Bu ilişkiler organizasyonel ve teknolojik kontrollerde daha belirgindir. Genel BGYS puanı yüksek olan katılımcıların daha ileri bir uyum aşamasında bulunma olasılığı da daha yüksektir. ISO/IEC 27001 sertifikalı olduğunu bildiren işletmecilerin uyum puanları, sertifikasız olanlardan

ve sertifika alma sürecinde olanlardan yüksektir. Madde yanıtları; sektör içinde bilgi paylaşımı, görevlerin ayrılması, tedarikçi güvenliği, işe alım öncesi güvenilirlik araştırması, fiziksel erişim, veri kaybını önleme ve güvenli yazılım geliştirme konularının daha fazla geliştirilebileceğini göstermektedir. Bulgular katılımcıların kendi bildirimlerine dayanır; uygulamaların gerçekten yapıldığını veya mevzuata uyulduğunu bağımsız olarak kanıtlamaz.

Anahtar Kelimeler: Bilgi Güvenliği Yönetim Sistemi, Elektronik Haberleşme, Kişisel Veri Koruma, ISO/IEC 27001, Düzenleyici Uyum.

Giriş

Elektronik haberleşme işletmecileri abone kimlik ve iletişim bilgileri, trafik kayıtları, konum bilgileri ve hizmet kullanım verileri gibi çok sayıda veriyi işlemektedir. Ayrıca kritik şebekeleri ve bilgi sistemlerini işletmektedir. Bu nedenle bilgi güvenliği yalnızca teknik önlemlerle sağlanamaz; yönetim, çalışanlar, fiziksel güvenlik, tedarik zinciri, olay yönetimi ve mevzuata uyum da önemlidir.

Türkiye'de elektronik haberleşme sektörüne özgü yükümlülüklerin temelini 5809 sayılı Elektronik Haberleşme Kanunu (EHK) oluşturur. 6698 sayılı Kişisel Verilerin Korunması Kanunu (KVKK) ise kişisel verilerin korunmasına ilişkin genel kuralları belirler (10/11/2008 tarihli ve 27050 sayılı Resmî Gazete; 07/04/2016 tarihli ve 29677 sayılı Resmî Gazete). BTK'nın 2014 tarihli Şebeke ve Bilgi Güvenliği Yönetmeliği, işletmecilerin bu alandaki yükümlülüklerini düzenler. BTK'nın 2020 tarihli yönetmeliği de elektronik haberleşme sektöründe kişisel verilerin işlenmesi ve gizliliğin korunmasına ilişkin kuralları belirler (13/07/2014 tarihli ve 29059 sayılı Resmî Gazete; 04/12/2020 tarihli ve 31324 sayılı Resmî Gazete).

BTK, 10.03.2026 tarihli ve 2026/DK-YED/71 sayılı Kurul Kararıyla Şebeke ve Bilgi Güvenliği Yönetmeliğinin dördüncü bölümündeki ek tedbirleri tüm yetkilendirilmiş işletmecileri kapsayacak şekilde genişletmiştir. Bu değişiklikle tedbirler işletmecilerin yıllık net satış tutarına bağlı olmaktan çıkarılmıştır. Söz konusu bölüm, ISO/IEC 27001 standardına göre belgelendirme yükümlülüğünü de içermektedir. Ayrıca 7545 sayılı Siber Güvenlik Kanunu, ülke genelindeki siber güvenlik yönetiminin çerçevesini yeniden düzenlemiştir (19/03/2025 tarihli ve 32846 sayılı Resmî Gazete).

ISO/IEC 27001:2022, Bilgi Güvenliği Yönetim Sisteminin (BGYS) kurulması, işletilmesi ve sürekli geliştirilmesi için gereken şartları açıklar. ISO/IEC 27002:2022 ise bilgi güvenliği kontrollerinin nasıl uygulanabileceği konusunda rehberlik sağlar. Bu standartta toplam 93 kontrol vardır. Kontroller dört alanda toplanır: 37'si Organizasyonel, 8'i İnsan Kaynaklı, 14'ü Fiziksel ve 34'ü Teknolojik Kontroldür (ISO/IEC, 2022a; ISO/IEC, 2022b). Bu sınıflandırma, bilgi güvenliğinde teknoloji kadar kurum süreçlerinin ve çalışanların da önemli olduğunu gösterir.

Önceki çalışmalar, ISO/IEC 27001'in risk yönetimi, kurumsal öğrenme, süreçlerin düzenli yürütülmesi ve sürekli gelişimle ilişkili olduğunu göstermektedir (Culot et al., 2021; Mirtsch et al., 2021). Güvenlik teknolojilerinin etkisi de çalışan davranışları ve kurum içi kontroller birlikte ele alındığında daha iyi anlaşılmaktadır (Onumo et al., 2021). Türkiye'de elektronik haberleşme sektöründe, ISO/IEC 27002:2022'nin dört kontrol alanını ayrı ayrı inceleyip bunların kişisel veri koruma düzeyiyle ilişkisini sayısal verilerle değerlendiren çalışma sayısı ise sınırlıdır.

Bu çalışmada dört konu incelenmiştir. İlk olarak, işletmecilerin dört bilgi güvenliği kontrol alanını ne düzeyde uyguladığı belirlenmiştir. İkinci olarak, bu alanların kişisel veri koruma düzeyiyle ilişkisi araştırılmıştır. Üçüncü olarak, ISO/IEC 27001 sertifika durumuna göre uyum düzeylerinin farklılaşıp farklılaşmadığı incelenmiştir. Son olarak, BTK açısından daha fazla geliştirilmesi gereken alanlar belirlenmiştir. Araştırmada veriler tek bir dönemde ve katılımcıların kendi bildirimleriyle toplandığından, sonuçlar neden-sonuç ilişkisi olarak değil, değişkenler arasındaki ilişki olarak değerlendirilmiştir.

Materyal ve Yöntem

Araştırma Tasarımı, Veri ve Hipotezler

Araştırma, tek bir dönemde toplanan sayısal anket verilerine dayanmaktadır. Analizlerde elektronik haberleşme sektöründeki işletmecilerden alınan 175 geçerli yanıt kullanılmıştır. Veriler 21 Temmuz-6 Eylül 2026 tarihleri arasında çevrim içi form aracılığıyla toplanmıştır. Araştırmacı, anketin bilgi güvenliği kontrollerine ilişkin bölümünü ISO/IEC 27002:2022'deki dört kontrol alanını temel alarak hazırlamıştır. Bu bölümde 93 madde vardır. Katılımcılar her maddeyi 1 (Kesinlikle Katılmıyorum) ile 5 (Kesinlikle Katılıyorum) arasında puanlamıştır. Organizasyonel Kontroller 37, İnsan Kaynaklı Kontroller 8, Fiziksel Kontroller 14 ve Teknolojik Kontroller 34 maddeden oluşmaktadır.

Bu çalışmada kişisel veri koruma uyum olgunluğu (kısaca uyum düzeyi), anketteki altı sıralı aşamayla ölçülmüştür. İlk aşama "Uyum çalışması başlatılmadı", son aşama ise "Sürekli iyileştirme mekanizmaları kuruldu" şeklindedir. ISO/IEC 27001 yanıtları üç gruba ayrılmıştır: sertifikasız, sertifika alma sürecinde ve sertifikalı. ISO/IEC 27001 dışında başka bir yönetim sistemi belgesi olduğunu bildiren tek yanıt, sertifikasız gruba eklenmiştir. Son iki yılda ihlal girişimi veya ihlal bildiren yanıtlar "olay var"; doğrudan "Hayır" diyenler "olay yok" olarak sınıflandırılmıştır. "Bilgim yok/Açıklanamaz" yanıtı bu karşılaştırmada kullanılmamıştır.

Hipotezler beş başlıkta toplanmıştır. H1a-H1d, dört kontrol alanındaki puanların nötr değer olan 3'ten yüksek olup olmadığını sınamaktadır. H2a-H2d, her kontrol alanı ile kişisel veri koruma düzeyi arasında pozitif ilişki olup olmadığını sınamaktadır. H3, genel BGYS puanı yükseldikçe kişisel veri koruma düzeyinin de yükselip yükselmediğini incelemektedir. H4, ISO/IEC 27001 sertifika gruplarının uyum düzeylerinin farklı olup olmadığını sınamaktadır. H5 ise son iki yılda ihlal veya ihlal girişimi bildiren işletmecilerin BGYS puanlarının olay bildirmeyenlerden düşük olup olmadığını incelemektedir.

Puanların Hesaplanması ve Anket Yanıtlarının Tutarlılığı

Her katılımcının ilgili kontrol alanındaki puanı, o alandaki maddelerin eşit ağırlıklı ortalaması alınarak hesaplanmıştır:

$$\overline{X}_{id} = \frac{1}{k_d}\sum_{j=1}^{k_d} x_{ijd} \tag{1}$$

Formülde i katılımcıyı, d kontrol alanını, j ise o alandaki maddeyi gösterir. $\bar{X}$, katılımcının ilgili alandaki ortalama puanıdır. k o alandaki madde sayısını, x ise tek bir maddeye verilen puanı ifade eder. Genel BGYS puanı da 93 maddenin eşit ağırlıklı ortalaması alınarak hesaplanmıştır.

Anketteki maddelerin birbiriyle ne kadar tutarlı olduğu Cronbach alfa katsayısıyla değerlendirilmiştir (Cronbach, 1951):

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{j=1}^{k}\sigma_j^2}{\sigma_T^2}\right) \tag{2}$$

Formülde k madde sayısıdır. Paydaki terimler tek tek maddelerin puanlarındaki değişimi; paydadaki terim ise tüm maddelerin toplam puanındaki değişimi gösterir.

Maddelerin birbiriyle ilişkilerinin faktör analizi için uygun olup olmadığı KMO ölçüsü ve Bartlett küresellik testiyle incelenmiştir (Kaiser, 1970; Kaiser & Rice, 1974; Bartlett, 1954):

$$KMO = \frac{\sum_{i\neq j} r_{ij}^2}{\sum_{i\neq j} r_{ij}^2 + \sum_{i\neq j} a_{ij}^2} \tag{3}$$

$$\chi_B^2 = -\left[n - 1 - \frac{2p+5}{6}\right]\ln|\mathbf{R}| \tag{4}$$

KMO formülünde i ve j maddeleri gösterir. r, iki madde arasındaki basit ilişkiyi; a ise diğer maddelerin etkisi hesaba katıldıktan sonra kalan kısmi ilişkiyi ifade eder. Bartlett formülünde n yanıt sayısı, p madde sayısı, |R| ise korelasyon matrisinin determinantıdır. Bartlett testinin sonucu, p(p−1)/2 serbestlik dereceli ki-kare dağılımına göre değerlendirilmiştir. KMO ve Bartlett sonuçları, verilerin faktör analizine uygun olup olmadığı hakkında bilgi verir. Ancak bu sonuçlar tek başına anket sorularının geçerli olduğunu kanıtlamaz; bu çalışmada faktör analizi yapılmamıştır.

İstatistiksel Analiz Yöntemleri

Boyut puanlarının normal dağılıma uygunluğu Shapiro-Wilk testiyle incelenmiştir (Shapiro & Wilk, 1965):

$$W = \frac{\left(\sum_{i=1}^{n} a_i \, x_{(i)}\right)^2}{\sum_{i=1}^{n}(x_i - \overline{x})^2} \tag{5}$$

Formülde x_i, puanlar küçükten büyüğe sıralandığında i'inci sıradaki puanı; a_i ise standart normal dağılımın sıra değerlerinden elde edilen katsayıyı gösterir. Testler, dört kontrol alanının hiçbirinde puanların normal dağılıma uymadığını göstermiştir. Bu nedenle temel karşılaştırmalarda normal dağılım varsayımı gerektirmeyen testler kullanılmıştır. Dört kontrol alanındaki puanların nötr değer olan 3'ten yüksek olup olmadığı tek yönlü Wilcoxon işaretli sıralar testiyle incelenmiştir (Wilcoxon, 1945):

$$\Delta_{id} = \overline{X}_{id} - 3, \qquad W_{\text{pos},d} = \sum_{i:\Delta_{id}>0} R_{id} \tag{6}$$

Burada i katılımcıyı, d kontrol alanını gösterir. Δ, alan puanı ile nötr değer 3 arasındaki farktır. R ise sıfır olmayan mutlak farkların sıralamadaki yerini gösterir.

Kontrol alanları ile kişisel veri koruma düzeyi arasındaki ilişkiler, puanların sıralarını karşılaştıran Spearman korelasyonuyla hesaplanmıştır (Spearman, 1904):

$$\rho_s = \frac{\mathrm{Cov}(R_X, R_Y)}{\sigma_{R_X}\sigma_{R_Y}} \tag{7}$$

Dört ilişki testi yapıldığı için tesadüfen anlamlı sonuç bulma olasılığını azaltmak amacıyla Holm düzeltmesi uygulanmıştır (Holm, 1979):

$$p_{(i)}^{\text{Holm}} = \min\left\{1, \max_{j \le i}\left[(m - j + 1)p_{(j)}\right]\right\} \tag{8}$$

Kişisel veri koruma düzeyi sıralı kategorilerden oluşmaktadır. Bu nedenle doğrusal regresyon yerine sıralı lojistik regresyon kullanılmıştır. Bu yöntem, bir puandaki artışın daha yüksek uyum kategorilerinde yer alma lehindeki oranla nasıl ilişkili olduğunu değerlendirir (McCullagh, 1980):

$$\log\left[\frac{P(Y_i \le c)}{P(Y_i > c)}\right] = \theta_c - \beta Z_i, \qquad c = 1, \ldots, 5 \tag{9}$$

Modelde incelenen puanlar karşılaştırılabilir olsun diye standartlaştırılmış ve her kontrol alanı ayrı bir modelde değerlendirilmiştir. Sonuçları yorumlamak için OR (olasılık oranı) ve %95 güven aralığı hesaplanmıştır. Tablodaki her OR, ilgili puan bir standart sapma arttığında daha yüksek uyum kategorisinde yer alma lehindeki oranın nasıl değiştiğini gösterir. Standart sapma, puanların ortalamadan ne kadar yayıldığını özetler. Beş modelin p değerlerine çoklu test düzeltmesi uygulanmamıştır; bu değerler her model için ayrı ayrı değerlendirilmelidir.

$$OR = e^{\beta}, \qquad CI_{95\%} = \left[e^{\beta - 1.96\,SE(\beta)}, e^{\beta + 1.96\,SE(\beta)}\right] \tag{10}$$

Sıralı lojistik regresyonda önemli varsayımlardan biri, kontrol puanıyla uyum düzeyi arasındaki ilişkinin bütün kategori eşiklerinde aynı olmasıdır (orantılılık varsayımı). Bu varsayım Brant (1990) yaklaşımıyla sınanmıştır.

Test sonuçları Organizasyonel Kontroller için $\chi^2(4)=3,35$ ($p=0,500$), İnsan Kaynaklı Kontroller için $\chi^2(4)=11,02$ ($p=0,026$), Fiziksel Kontroller için $\chi^2(4)=2,69$ ($p=0,611$), Teknolojik Kontroller için $\chi^2(4)=1,25$ ($p=0,870$) ve Genel BGYS modeli için $\chi^2(4)=2,65$ ($p=0,619$) bulunmuştur. İnsan Kaynaklı Kontroller modelinde bu varsayımın sağlanmadığına dair kanıt vardır. Bu nedenle bu boyut için OR=1,28 sonucu dikkatle yorumlanmalıdır. Diğer dört modelde varsayımın sağlanmadığını gösteren istatistiksel kanıt bulunmamıştır.

Dört kontrol alanının birbiriyle fazla örtüşüp örtüşmediğini görmek için varyans şişirme faktörü (VIF) hesaplanmıştır. VIF, bir değişkenin diğer değişkenlerle ne ölçüde benzer bilgi taşıdığını gösterir (O'Brien, 2007):

$$VIF_k = \frac{1}{1 - R_k^2} \tag{11}$$

ISO/IEC 27001 sertifika gruplarının uyum puanları Kruskal-Wallis testiyle karşılaştırılmıştır. Genel test gruplar arasında fark gösterdiğinde, hangi grupların farklı olduğunu bulmak için Holm düzeltmeli Mann-Whitney U testleri yapılmıştır (Kruskal & Wallis, 1952; Mann & Whitney, 1947):

$$H = \frac{1}{C_H}\left[\frac{12}{N(N+1)}\sum_{g=1}^{G}\frac{R_g^2}{n_g} - 3(N+1)\right] \tag{12}$$

$$\varepsilon^2 = (H - G + 1)/(N - G) \tag{13}$$

$$U_1 = R_1 - n_1(n_1 + 1)/2; \quad U_2 = n_1 n_2 - U_1 \tag{14}$$

Eşitlik (12)'de N toplam yanıt sayısını, G grup sayısını gösterir. Grup alt indisleri, her gruptaki yanıt sayısını ve sıra puanları toplamını belirtir. C_H, eşit puanlar bulunduğunda Kruskal-Wallis testinde kullanılan düzeltme katsayısıdır. Eşitlik (13)'teki ε^2, Kruskal-Wallis testi için etki büyüklüğünü gösterir ve Tomczak ve Tomczak'ın (2014) önerdiği biçimde hesaplanmıştır. Eşitlik (14)'te n_1 ve n_2 karşılaştırılan iki grubun büyüklükleri, R_1 birinci grubun sıra puanları toplamı, U_1 Mann-Whitney test istatistiğidir. U_2 ise U_1'in tamamlayıcı değeridir ve $n_1n_2 - U_1$ olarak hesaplanır. Aynı katılımcıların dört kontrol alanındaki puanları Friedman testiyle karşılaştırılmıştır. Farkın büyüklüğü Kendall W ile verilmiştir (Friedman, 1937; Kendall & Babington Smith, 1939). Friedman testi anlamlı olduğunda, hangi alanların farklı olduğunu görmek için Holm düzeltmeli ikili Wilcoxon testleri yapılmıştır:

$$\chi_F^2 = \frac{1}{C_F}\left[\frac{12}{Nk(k+1)}\sum_{j=1}^{k}R_j^2 - 3N(k+1)\right] \tag{15}$$

$$W_K = \frac{\chi_F^2}{N(k-1)} \tag{16}$$

Eşitlik (15)'te k kontrol alanı sayısını, R_j j'inci alanın sıra puanları toplamını, C_F ise eşit puanlar için kullanılan düzeltme katsayısını gösterir. Eşitlik (16)'da N katılımcı sayısıdır. Tüm testlerde anlamlılık sınırı $\alpha=0,05$ olarak belirlenmiştir. Hesaplamalar Python ortamında NumPy, SciPy ve statsmodels kullanılarak yeniden kontrol edilmiştir.

Eşit puan alan gözlemlere aynı sıra değerinin verilmesi durumunda kullanılan düzeltme katsayıları şöyledir: Kruskal-Wallis için $C_H = 1 - [\Sigma_{\ell=1}^{L}(t_\ell^3 - t_\ell)]/(N^3 - N)$. Burada N toplam gözlem sayısıdır; L tüm gruplarda eşit puan alan değer gruplarının sayısı, t_ℓ ise ℓ'inci gruptaki gözlem sayısıdır. Friedman testi için $C_F = 1 - [\Sigma_{i=1}^{N}\Sigma_\ell(t_{i\ell}^3 - t_{i\ell})]/[N(k^3 - k)]$ kullanılır. Burada i katılımcıyı, ℓ ise o katılımcının k kontrol alanı içindeki eşit sıra gruplarını gösterir; $t_{i\ell}$ i'inci katılımcının ℓ'inci gruptaki gözlem sayısıdır. Bu katsayılar, eşit sıraların test sonuçlarını bozmasını önlemek için kullanılır (Kruskal & Wallis, 1952; Friedman, 1937).

Veri Kalitesi ve Ek Kontroller

Kontrol maddelerinin hiçbirinde eksik yanıt yoktur. Ancak 39 katılımcı (%22,3) 93 maddenin tamamında aynı seçeneği işaretlemiştir: 30 kişi tüm maddelere 5, sekiz kişi 4, bir kişi ise 1 vermiştir. Aynı seçeneğin tekrarlanması tek başına yanıtın hatalı olduğunu göstermez; bu nedenle bu yanıtlar ana analizde tutulmuştur. Sonuçların bu yanıtlara bağlı olup olmadığını görmek için analizler bu 39 kayıt çıkarılarak yeniden yapılmıştır (N=136).

Aynı işletme adıyla kaydedilmiş, birbirine çok benzeyen iki yanıt da belirlenmiştir. Ana analizde konferans özetinde bildirilen N=175 örneklem korunmuştur. Ek kontrolde ise 93 maddeden yalnızca birinde farklı yanıt veren bu iki kayıttan biri çıkarılmış ve analiz N=174 ile tekrarlanmıştır. Bu kontrolde dört kontrol alanının ve Genel BGYS puanının uyum düzeyiyle ilişkisi anlamlı kalmıştır (ρ=0,163-0,248). ISO/IEC 27001 grupları arasındaki fark da anlamlılığını korumuştur ($H(2)=17,774$; $p<0,001$).

Bulgular ve Tartışma

Örneklemin Genel Yapısı

Örneklem ağırlıklı olarak mikro ve küçük işletmecilerden oluşmaktadır. ISO/IEC 27001 durumuna göre yanıtların %20,0'ı sertifikasız, %37,1'i sertifikasyon sürecinde ve %42,9'u sertifikalı gruptadır. Kişisel veri koruma uyum aşamalarının tamamı örneklemde temsil edilmektedir. Son iki yılda ihlal veya ihlal girişimi bildirmeyen yanıtların oranı %88,6'dır.

Tablo 1. Örneklemin temel kurumsal profili (N=175)

Değişken / Kategori	n	%
Kurum büyüklüğü: Mikro (1 ile 9)	92	52,6
Kurum büyüklüğü: Küçük (10 ile 49)	65	37,1
Kurum büyüklüğü: Orta (50 ile 249)	10	5,7
Kurum büyüklüğü: Büyük (250 ile 999)	2	1,1
Kurum büyüklüğü: Çok büyük (1000+)	6	3,4
ISO/IEC 27001: Sertifikasız	35	20,0
ISO/IEC 27001: Süreçte	65	37,1
ISO/IEC 27001: Sertifikalı	75	42,9
Uyum: Başlatılmadı	8	4,6
Uyum: Veri envanteri	25	14,3
Uyum: Aydınlatma/gizlilik metni	51	29,1
Uyum: VERBİS tamamlandı	32	18,3
Uyum: Tedbirler bütünüyle uygulandı	34	19,4
Uyum: Sürekli iyileştirme	25	14,3
Son 2 yıl: İhlal yok	155	88,6
Son 2 yıl: İhlal girişimi	15	8,6
Son 2 yıl: Küçük/raporlanabilir ihlal	4	2,3
Son 2 yıl: Bilinmiyor	1	0,6

Anket Yanıtlarının Tutarlılığı ve Dağılımı

Dört kontrol alanında Cronbach alfa katsayıları 0,952-0,989 arasındadır. 93 maddenin tamamı için katsayı 0,995'tir. KMO değerlerinin tüm alanlarda 0,90'ın üzerinde olması ve Bartlett testlerinin anlamlı çıkması, maddeler arasındaki ilişkilerin faktör analizi yapmaya uygun olduğunu göstermektedir (Kaiser & Rice, 1974). Tüm 93 madde birlikte incelendiğinde KMO=0,933 ve Bartlett $\chi^2(4278)=28224,3$ ($p<0,001$) bulunmuştur.

Bununla birlikte, çok yüksek alfa değerleri ve kontrol alanları arasındaki güçlü ilişkiler bazı maddelerin benzer konuları ölçüyor olabileceğini düşündürmektedir. Ayrıca tüm maddelerin aynı anketle ölçülmesinden kaynaklanan ortak bir etki bulunması da mümkündür (Podsakoff et al., 2003).

Tablo 2. Güvenilirlik ve faktör analizine uygunluk sonuçları

Boyut	Madde	Cronbach α	KMO	Bartlett χ^2	p
Organizasyonel	37	0,987	0,966	8675,0	<0,001
İnsan Kaynaklı	8	0,952	0,904	1450,8	<0,001
Fiziksel	14	0,978	0,950	3293,5	<0,001
Teknolojik	34	0,989	0,961	8984,1	<0,001
Genel	93	0,995	0,933	28224,3	<0,001

Shapiro-Wilk testleri, Organizasyonel (W=0,795), İnsan Kaynaklı (W=0,758), Fiziksel (W=0,737) ve Teknolojik Kontrol (W=0,794) puanlarının normal dağılıma uymadığını göstermiştir (tüm p<0,001). Puanların çoğunun yüksek değerlerde toplanması da bu sonuçla uyumludur.

Kontrol Uygulama Düzeyleri ve H1

Dört kontrol alanının ortalama puanları 5 üzerinden 4,35-4,46 arasındadır. "Katılıyorum" ve "Kesinlikle Katılıyorum" yanıtlarının toplam oranı %89,5-%93,0 arasında değişmektedir. Her alanda uygulama puanları nötr değer olan 3'ten anlamlı biçimde yüksektir (Wilcoxon testlerinin tümünde p<0,001). Bu nedenle H1a-H1d desteklenmiştir. Katılımcı yanıtlarına göre dört alandaki uygulama düzeyi yüksektir; bu uygulamalar bağımsız bir denetimle doğrulanmamıştır.

Tablo 3. Kontrol boyutlarının betimsel sonuçları ve nötr nokta karşılaştırmaları

Boyut	Ort.	SS	Medyan	Olumlu %	Wilcoxon p
Organizasyonel	4,348	0,687	4,378	89,5	<0,001
İnsan Kaynaklı	4,410	0,713	4,625	91,2	<0,001
Fiziksel	4,456	0,699	4,714	93,0	<0,001
Teknolojik	4,353	0,710	4,441	90,1	<0,001

Friedman testi, dört kontrol alanının puanları arasında istatistiksel olarak anlamlı fark bulunduğunu göstermiştir ($\chi^2(3)=32,612$; p<0,001). Ancak Kendall W=0,062'dir; yani alanlar arasındaki farkın büyüklüğü küçüktür. İkili karşılaştırmalarda Fiziksel Kontrol puanları Organizasyonel ve Teknolojik Kontrol puanlarından; İnsan Kaynaklı Kontrol puanları ise Organizasyonel Kontrol puanlarından yüksek bulunmuştur. Bu karşılaştırmaların Holm düzeltmeli p değerleri sırasıyla <0,001, <0,001 ve 0,048'dir. Diğer üç alan çifti arasında anlamlı fark bulunmamıştır. Genel olarak katılımcılar dört alanda da uygulama düzeyini yüksek bildirmiştir.

Kişisel Veri Koruma Düzeyiyle İlişkiler: H2 ve H3

Spearman korelasyonu, dört kontrol alanının tamamının kişisel veri koruma düzeyiyle pozitif ilişkili olduğunu göstermiştir. Holm düzeltmesi uygulandıktan sonra da bu ilişkiler anlamlı kalmıştır. İlişki Organizasyonel Kontrollerde en yüksek (ρ=0,251), Fiziksel Kontrollerde en düşüktür (ρ=0,166). Teknolojik Kontroller için ρ=0,210, İnsan Kaynaklı Kontroller için ρ=0,187'dir. Bu nedenle H2a-H2d desteklenmiştir. Ancak ilişkiler küçüktür. Kişisel veri koruma düzeyinin bilgi güvenliğinin yanı sıra hukuk, yönetim ve iş süreçleri gibi başka etkenlerle de ilişkili olabileceği düşünülmektedir.

Tablo 4. Kişisel Veri Koruma Düzeyiyle İlişkiler ve Sıralı Lojistik Regresyon Sonuçları

Boyut	Spearman ρ	p*	OR / 1 SS artış	%95 GA	p (sıralı model)
Organizasyonel	0,251	0,0033	1,44	1,06-1,94	0,018
İnsan Kaynaklı	0,187	0,0262	1,28	0,97-1,70	0,082

Boyut	Spearman ρ	p*	OR / 1 SS artış	%95 GA	p (sıralı model)
Fiziksel	0,166	0,0280	1,18	0,89-1,55	0,242
Teknolojik	0,210	0,0158	1,34	1,01-1,79	0,044
Genel BGYS	0,225	0,0028	1,36	1,02-1,83	0,039

Not: Dört kontrol alanı için hesaplanan p değerlerine Holm düzeltmesi uygulanmıştır. Genel BGYS satırındaki p=0,0028 ise tamamlayıcı Spearman analizinin düzeltilmemiş p değeridir.

Sıralı lojistik regresyon sonuçlarına göre Organizasyonel Kontroller (OR=1,44; p=0,018) ve Teknolojik Kontroller (OR=1,34; p=0,044), daha yüksek bir uyum kategorisinde yer almayla anlamlı ilişki göstermiştir. İnsan Kaynaklı Kontroller (OR=1,28; p=0,082) ve Fiziksel Kontroller (OR=1,18; p=0,242) için bulunan ilişkiler anlamlı değildir. İnsan Kaynaklı Kontroller modelinde temel varsayımlardan biri sağlanmadığı için bu sonuca özellikle dikkatle yaklaşılmalıdır. Genel BGYS modeli de anlamlıdır (OR=1,36; %95 GA 1,02-1,83; p=0,039). Genel BGYS puanının bir standart sapma artması, daha yüksek bir uyum kategorisinde yer alma lehindeki oranın %36 artmasıyla ilişkilidir. Bu, uyum düzeyinin yüksek olma olasılığının %36 arttığı anlamına gelmez. Ayrıca bu sonuç neden-sonuç ilişkisi göstermez. H3 desteklenmiştir.

Kontrol alanlarının puanları birbiriyle güçlü ilişkilidir (Spearman ρ=0,769-0,857). VIF değerleri Organizasyonel Kontroller için 10,57, İnsan Kaynaklı Kontroller için 6,88, Fiziksel Kontroller için 8,14 ve Teknolojik Kontroller için 8,61'dir. Bu nedenle dört alan aynı modele birlikte konmamıştır. Her alan ayrı bir modelde incelenmiş, tüm alanları temsil eden ortak puan ise Genel BGYS puanı üzerinden değerlendirilmiştir.

ISO/IEC 27001 Sertifika Durumu, İhlal Bildirimi ve H4-H5

ISO/IEC 27001 sertifika gruplarının kişisel veri koruma puanları arasında anlamlı fark vardır (H(2)=18,135; p<0,001; etki büyüklüğü=0,094). Bu değer orta düzeyde bir farkı göstermektedir (Tomczak & Tomczak, 2014). Ortalama puan sertifikasız grupta 3,20, sertifika alma sürecindeki grupta 3,49 ve sertifikalı grupta 4,27'dir. Holm düzeltmeli karşılaştırmalarda sertifikalı işletmecilerin puanları hem sertifikasız gruptan (p=0,00075) hem de sertifika alma sürecindeki gruptan (p=0,00156) yüksektir. Sertifikasız grup ile sertifika alma sürecindeki grup arasındaki fark anlamlı değildir (p=0,318). Bu nedenle H4 desteklenmiştir. Sonuç, BTK'nın ISO/IEC 27001 belgelendirmesine verdiği önemle uyumludur. Anket, 2026/DK-YED/71 sayılı Kurul Kararıyla ek tedbirlerin tüm yetkilendirilmiş işletmecilere uygulanmaya başlamasından yaklaşık dört ay sonra yapılmıştır. Yanıtların %37,1'inin sertifika alma sürecindeki işletmecilerden gelmesi bu dönemdeki geçişi yansıtmaktadır. Bu grubun ortalaması sertifikasız gruptan yüksek olsa da (3,49 ve 3,20) aradaki fark anlamlı değildir. Grubun zamanla sertifikalı işletmecilere yaklaşıp yaklaşmadığı, ancak aynı işletmecilerden zaman içinde tekrar veri toplanarak anlaşılabilir.

Tablo 5. ISO/IEC 27001 sertifika durumuna göre kişisel veri koruma puanı

ISO/IEC 27001 durumu	n	Uyum Ort.	Medyan
Sertifikasız	35	3,20	3
Sertifikasyon sürecinde	65	3,49	3
Sertifikalı	75	4,27	5

Son iki yılda ihlal veya ihlal girişimi bildirmeyen grubun Genel BGYS ortalaması 4,372, olay bildiren grubun ortalaması ise 4,333'tür. Mann-Whitney testinde olay bildirmeyen grup için U_1=1683, tamamlayıcı değer için U_2=1262 bulunmuştur (iki yönlü p=0,310; hipotezin öngördüğü yöndeki tek yönlü p=0,155). Fark beklenen yönde olsa da istatistiksel olarak anlamlı değildir. Olay bildiren yalnızca 19 yanıt bulunduğu için testin farkı saptama gücü sınırlı olabilir. Ayrıca olay bildirilmesi yalnızca güvenlik açığına değil, olayları fark etme ve bildirme kapasitesine de bağlıdır. Bu nedenle olay bildirimi tek başına işletmenin performansını göstermez. H5 desteklenmemiştir.

Anket Maddelerinin Ayrı Ayrı Değerlendirilmesi

Organizasyonel Kontrollerde en yüksek ortalama puanlar; işten ayrılan personelin varlıklarının geri alınması ve erişiminin kapatılması (4,560), hassas verilerin sınıflandırılması (4,543) ve kimlik doğrulama bilgilerinin güvenli yönetimi (4,543) maddelerinde görülmüştür. Bu alandaki daha düşük puanlar sektör paydaşlarıyla bilgi güvenliği paylaşımı (4,069), görevlerin ayrılması (4,183) ve tedarikçilerin güvenlik düzeyinin izlenmesi (4,189) maddelerindedir.

İnsan Kaynaklı Kontrollerde en yüksek puan, işten ayrılan personelin erişiminin aynı gün kapatılması maddesindedir (4,617). İşe alım öncesi güvenilirlik araştırması (4,251) ve düzenli farkındalık eğitimi (4,320) bu alandaki diğer maddelere göre daha düşük puan almıştır. Fiziksel Kontrollerde veri merkezlerinin fiziksel olarak korunması (4,560) ve kişisel veri içeren cihazlarla sunucuların korunması (4,543) öne çıkmıştır. Kartlı veya biyometrik sistemlerle fiziksel erişimin denetlenmesi ise bu alandaki en düşük ortalamaya sahiptir (4,274).

Teknolojik Kontrollerde sistem kapasitesi ve sürekliliği (4,480) ile zaman eşitleme ve kayıtların (logların) bütünlüğü (4,474) en yüksek puan alan konulardandır. Çekirdek sistemlerden kişisel veri sızıntısının Veri Kaybını Önleme (DLP) araçlarıyla engellenmesi (4,120), uç nokta cihazlarının merkezi olarak yönetilip korunması (4,171) ve yazılımların güvenli geliştirme süreci (4,229) daha fazla geliştirmeye açık alanlardır. Genel puanlar yüksek olsa da bu maddeler denetim ve iyileştirme çalışmalarında önceliklendirilebilir.

Tüm maddelerde aynı yanıtı verenler çıkarıldığında sonuçların kontrolü

Tablo 6. Tüm maddelerde aynı yanıtı verenler çıkarıldığında elde edilen sonuçlar

Boyut	Ort. (N=136)	Cronbach α	ρ	p
Organizasyonel	4,250	0,982	0,274	0,0012
İnsan Kaynaklı	4,329	0,935	0,190	0,0264
Fiziksel	4,389	0,970	0,166	0,0527
Teknolojik	4,256	0,985	0,220	0,0100
Genel BGYS	4,280	0,992	0,237	0,0054

Not: Tablodaki p değerlerine düzeltme uygulanmamıştır. Dört kontrol alanı için Holm düzeltmesi yapıldığında Organizasyonel (p=0,0049) ve Teknolojik Kontroller (p=0,0299) anlamlı kalmıştır. İnsan Kaynaklı (p=0,0529) ve Fiziksel Kontroller (p=0,0527) için p değerleri 0,05'in üzerinde kalmış ve sonuçlar anlamlı bulunmamıştır.

93 maddenin tamamında aynı seçeneği işaretleyen 39 yanıt çıkarıldığında da dört kontrol alanının ortalama puanı 4,24'ün üzerindedir. Cronbach alfa katsayıları 0,935 veya daha yüksektir. Düzeltme uygulanmamış p değerlerine göre Organizasyonel, İnsan Kaynaklı ve Teknolojik Kontroller ile Genel BGYS puanının ilişkileri anlamlı kalmıştır. Fiziksel Kontrollerin ilişki katsayısı neredeyse değişmemiştir; ancak yanıt sayısının azalması nedeniyle p değeri 0,053'e çıkmıştır. Genel olarak ana sonuçlar bu 39 yanıtın dahil edilmesine bağlı görünmemektedir. Bu yanıtlar çıkarıldığında ilişki katsayısı Organizasyonel Kontrollerde 0,251'den 0,274'e, Teknolojik Kontrollerde 0,210'dan 0,220'ye çıkmıştır.

BTK Açısından Bulguların Değerlendirilmesi

Katılımcıların anket yanıtları, sektörde bilgi güvenliği uygulamalarının genel olarak olumlu olduğunu düşündürmektedir. Ancak bu değerlendirme BTK'nın bağımsız denetim sonuçlarıyla karşılaştırılmamıştır. Yetkili makamlarla iletişim kurallarının yazılı olmasına ilişkin maddenin ortalaması 4,326; bu ifadeye olumlu yanıt verenlerin oranı %88,6'dır. Dijital delillerin ve sistem kayıtlarının (logların) BTK incelemelerinde kullanılabilecek biçimde saklanmasına ilişkin maddenin ortalaması 4,469, olumlu yanıt oranı ise %94,3'tür. BTK düzenlemeleri ile kişisel verilerin korunması yükümlülüklerinin yerine getirildiği ifadesinin ortalaması 4,371'dir; olumlu yanıt oranı %90,9'dur. Katılımcıların %88,6'sı son iki yılda ihlal veya ihlal girişimi olmadığını bildirmiştir. Bildirim gerektiren kişisel veri ihlali ise yalnızca iki yanıtta (%1,1) belirtilmiştir.

Katılımcıların kendi bildirimlerine dayanan bu sonuçlar, BTK'nın 2014 tarihli Şebeke ve Bilgi Güvenliği Yönetmeliği ile 2020 tarihli sektörel kişisel veri düzenlemesinin oluşturduğu çerçeveyle uyumludur (BTK, 2014; BTK, 2020). 2026 yılında ek şebeke ve bilgi güvenliği tedbirlerinin işletme büyüklüğünden bağımsız olarak tüm yetkilendirilmiş işletmecilere uygulanması bu çerçeveyi güçlendirmiştir (BTK, 2026). Ancak ankette BTK denetimlerinin ne sıklıkta yapıldığı, son denetimin ne zaman gerçekleştiği, hangi bulguların elde edildiği veya yaptırım uygulanıp uygulanmadığı sorulmamıştır. Bu nedenle yüksek kontrol puanlarının BTK denetimlerinden kaynaklandığı söylenemez. Anket yanıtları, işletmecilerin mevzuata uyduğunu tek başına kanıtlamaz.

BTK, denetimlerde riskin daha yüksek olabileceği alanlara ağırlık verebilir. Bunlar arasında sektör içinde bilgi paylaşımı, görevlerin ayrılması, tedarikçi güvenliği, işe alım öncesi güvenilirlik araştırması, fiziksel erişim, veri kaybını önleme ve güvenli yazılım geliştirme yer almaktadır. ISO/IEC 27001 sertifika durumu, düzenleyici denetimin yerine kullanılmamak koşuluyla riskleri sınıflandırmaya yardımcı olabilir. Mikro ve küçük işletmecilere örnek politika ve prosedürler, asgari kayıt ve delil saklama gereklilikleri ile öz değerlendirme listeleri sunulması uygulama birliğini destekleyebilir.

Çalışmanın Sınırlılıkları

Araştırma tek bir dönemde yürütüldüğü için değişkenler arasındaki ilişkiler gösterilebilir; ancak birinin diğerine neden olduğu sonucuna varılamaz. Katılımcıların aynı ankette verdiği yanıtlar, ölçülen ilişkileri olduğundan güçlü gösterebilir (Podsakoff et al., 2003).

Kişisel veri koruma uyum olgunluğu tek bir soruyla ve altı aşama üzerinden ölçülmüştür. Verilen materyalde örneklemin nasıl seçildiği, kaç işletmeciye veya katılımcıya davet gönderildiği ve yanıt oranı yer almamaktadır. Bu bilgiler olmadığı için yanıt verenlerin tüm sektörü ne ölçüde temsil ettiği değerlendirilememektedir.

Anket maddeleri dört kontrol alanına göre araştırmacı tarafından hazırlanmıştır. Ancak verilen materyalde her maddenin ISO/IEC 27002'deki kontrol numarasıyla nasıl eşleştirildiği, uzman görüşü alınıp alınmadığı veya anketin önceden denenip denenmediği açıklanmamıştır. KMO ve Bartlett sonuçları faktör analizinin yapılabileceğini gösterse de bu çalışmada faktör analizi yapılmamıştır. Bu nedenle puanlar, standarda tam uyulduğunu doğrulayan ölçümler olarak görülmemelidir.

Örneklemde mikro ve küçük işletmeciler ağırlıktadır; bu nedenle sonuçları büyük işletmecilere aktarırken dikkatli olmak gerekir. Aynı seçeneği tüm maddelerde işaretleyen yanıtlar çıkarıldığında ana bulguların çoğu korunmuştur. Gelecek araştırmalarda örnekleme yöntemi ve yanıt oranı açıkça belirtilmeli; daha büyük ve işletme büyüklüğüne göre dengeli örneklemler kullanılmalıdır. Ayrıca uyum düzeyi birden fazla soruyla ölçülebilir, anketin geçerliği incelenebilir, aynı işletmecilerden farklı zamanlarda veri toplanabilir ve sonuçlar kimlik bilgileri kaldırılmış BTK denetim verileriyle karşılaştırılabilir.

Sonuç ve Öneriler

Bu çalışmada dört bilgi güvenliği kontrol alanı, ISO/IEC 27002:2022'deki sınıflandırmaya göre incelenmiş ve bu alanlarla kişisel veri koruma düzeyi arasındaki ilişki değerlendirilmiştir. Katılımcılar dört alandaki uygulama puanlarını yüksek bildirmiştir. Dört alanın tamamı kişisel veri koruma düzeyiyle pozitif ilişkilidir. Bu ilişki Organizasyonel ve Teknolojik Kontrollerde daha belirgindir. Genel BGYS puanındaki artış da daha ileri bir uyum aşamasında bulunmayla ilişkili bulunmuştur. Ancak bu sonucun p değerine çoklu test düzeltmesi uygulanmamıştır; bu nedenle temkinli değerlendirilmelidir. Bulgular katılımcıların kendi yanıtlarına dayanır ve bağımsız olarak doğrulanmış mevzuat uyumu şeklinde yorumlanmamalıdır.

ISO/IEC 27001 sertifikalı olduğunu bildiren işletmecilerin kişisel veri koruma puanları diğer iki gruptan yüksektir. Bu bulgu, bilgi güvenliği süreçleri düzenli hale geldikçe kişisel veri koruma çalışmalarının da ilerleyebileceğini düşündürmektedir. Ancak veriler tek bir dönemde toplandığı için sertifikanın bu farka neden olduğu söylenemez. İhlal deneyimine göre anlamlı bir fark bulunmaması da olay sayısının azlığı ve işletmelerin olayları fark etme kapasitesi dikkate alınarak değerlendirilmelidir.

BTK için temel öneri, ankette bildirilen uygulama düzeyini korurken denetimleri daha fazla geliştirmeye ihtiyaç duyulan alanlara yöneltmektir. Sektör içi bilgi paylaşımı, görevlerin ayrılması, tedarikçi riskleri, çalışanların güvenilirliği, fiziksel erişim, veri kaybını önleme ve güvenli yazılım geliştirme düzenli ve ölçülebilir göstergelerle izlenebilir. Böylece denetimler yalnızca belgelerin varlığını değil, bilgi güvenliği uygulamalarının zaman içindeki gelişimini de takip edebilir.

Kaynaklar

Bartlett, M. S. (1954). A note on the multiplying factors for various chi-square approximations. Journal of the Royal Statistical Society: Series B, 16(2), 296-298.

Bilgi Teknolojileri ve İletişim Kurumu (BTK), (2014), Elektronik Haberleşme Sektöründe Şebeke ve Bilgi Güvenliği Yönetmeliği. Resmî Gazete, 13 Temmuz 2014, Sayı: 29059.

Bilgi Teknolojileri ve İletişim Kurumu (BTK), (2020), Elektronik Haberleşme Sektöründe Kişisel Verilerin İşlenmesi ve Gizliliğin Korunmasına İlişkin Yönetmelik. Resmî Gazete, 4 Aralık 2020, Sayı: 31324.

Bilgi Teknolojileri ve İletişim Kurumu (BTK), (2026), Yetkilendirme Mevzuatı ve Şebeke ve Bilgi Güvenliğine İlişkin Düzenlemeler Hakkında Kurul Kararı. Karar tarihi: 10.03.2026; karar sayısı: 2026/DK-YED/71. BTK karar sayfasında yayımlanma tarihi: 24.03.2026.

Brant, R. (1990). Assessing proportionality in the proportional odds model for ordinal logistic regression. Biometrics, 46(4), 1171-1178.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16(3), 297-334.

Culot, G., Nassimbeni, G., Podrecca, M., & Sartor, M. (2021). The ISO/IEC 27001 information security management standard: Literature review and theory-based research agenda. The TQM Journal, 33(7), 76-105.

Friedman, M. (1937). The use of ranks to avoid the assumption of normality implicit in the analysis of variance. Journal of the American Statistical Association, 32(200), 675-701.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics, 6(2), 65-70.

ISO/IEC. (2022a). ISO/IEC 27001:2022 Information security, cybersecurity and privacy protection - Information security management systems - Requirements. Geneva: International Organization for Standardization.

ISO/IEC. (2022b). ISO/IEC 27002:2022 Information security, cybersecurity and privacy protection - Information security controls. Geneva: International Organization for Standardization.

Kaiser, H. F. (1970). A second generation little jiffy. Psychometrika, 35(4), 401-415.

Kaiser, H. F., & Rice, J. (1974). Little jiffy, mark IV. Educational and Psychological Measurement, 34(1), 111-117.

Kendall, M. G., & Babington Smith, B. (1939). The problem of m rankings. The Annals of Mathematical Statistics, 10(3), 275-287.

Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. Journal of the American Statistical Association, 47(260), 583-621.

Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. The Annals of Mathematical Statistics, 18(1), 50-60.

McCullagh, P. (1980). Regression models for ordinal data. Journal of the Royal Statistical Society: Series B, 42(2), 109-142.

Mirtsch, M., Blind, K., Koch, C., & Dudek, G. (2021). Information security management in ICT and non-ICT sector companies: A preventive innovation perspective. Computers & Security, 109, 102383.

O'Brien, R. M. (2007). A caution regarding rules of thumb for variance inflation factors. Quality & Quantity, 41(5), 673-690.

Onumo, A., Ullah-Awan, I., & Cullen, A. J. (2021). Assessing the moderating effect of security technologies on employees compliance with cybersecurity control procedures. ACM Transactions on Management Information Systems, 12(2), Article 11, 1-29.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. Journal of Applied Psychology, 88(5), 879-903.

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). Biometrika, 52(3-4), 591-611.

Spearman, C. (1904). The proof and measurement of association between two things. The American Journal of Psychology, 15(1), 72-101.

Tomczak, M., & Tomczak, E. (2014). The need to report effect size estimates revisited. An overview of some recommended measures of effect size. Trends in Sport Sciences, 21(1), 19-25.

Wilcoxon, F. (1945). Individual comparisons by ranking methods. Biometrics Bulletin, 1(6), 80-83.

5809 sayılı Elektronik Haberleşme Kanunu. Resmî Gazete, 10 Kasım 2008, Sayı: 27050.

6698 sayılı Kişisel Verilerin Korunması Kanunu. Resmî Gazete, 7 Nisan 2016, Sayı: 29677. 7545 sayılı Siber Güvenlik Kanunu. Resmî Gazete, 19 Mart 2025, Sayı: 32846.

FINITE TIME PERFORMANCE OF A CARNOT ENGINE WITH RELATIVISTIC ELECTRON POSITRON PHOTON PLASMA UNDER LOW DISSIPATION REGIME.

T. Aarthi
K. Nilavarasi
M. Ponmurugan
Research Scholar, School of Basic and Applied Sciences, Department of Physics, Central University of Tamil Nadu, Thiruvarur - 610 005, Tamil Nadu - India.
Independent Researcher, PNV academy, Thiruvarur, Tamil Nadu-India.
Assistant Professor, School of Basic and Applied Sciences, Department of Physics, Central University of Tamil Nadu, Thiruvarur - 610 005, Tamil Nadu- India.

Abstract

We investigate the finite-time thermodynamic operation of a Carnot engine using Relativistic Electron Positron Photon Plasma (REPPP) as the working substance within the low dissipation framework. Using the relativistic equation of state we calculate the work produced by the cycle and optimize the power output with respect to the time, from which the efficiency at maximum power is obtained. The resulting performance is then examined under different conditions. For Symmetric dissipation, the efficiency at maximum power recovers the well-known Curzon Ahlborn efficiency, $\boldsymbol{\eta_{CA} = 1 - \sqrt{T_c/T_h}}$. In contrast, Asymmetric dissipation between hot and cold isothermal process, we obtained the upper bounds and lower bounds for the efficiency at maximum power as $\frac{\eta_c}{2-\eta_c}$ and $\frac{\eta_c}{2}$ respectively.

Keywords: REPPP, low dissipation, curzon ahlborn efficiency.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE CREATION OF A NECKLACE - THE CIRCLE OF LIFE: MOLECULES AWAKEN LIFE, LIFE BREATHES INTO ART, ART SCULPTS THE NECKLACE AND THE NECKLACE CAPTURES THE VERY SHAPE OF WATER MOLECULES

Florina Ravariu
Cristian Ravariu
0009-0008-6168-3315, Union of Professional Visual Artists of Romania Association UAPR, 021042, sect. 1, Bucharest, Romania
0000-0002-1483-2583, Education Science Art SRL, str. Iovita no. 2, sect. 5, Bucharest, Romania

Abstract

The artistic piece described in this paper belongs to the visual arts, specifically metalwork, and more particularly, art jewelry, consisting of a necklace entitled 'The Circle of Life'. It was created over the last few months, inspired by the idea that art is as essential to humanity, as the water molecules are indispensable to life.

This article presents the design and fabrication of a statement necklace composed of nine artistic representations of the water molecule (H_2O). The work explores the relationship between scientific knowledge and contemporary jewelry through the material interpretation of atomic and molecular structure. Each of the nine units represents a water molecule, using shaped silver-plated copper wire, fine golden textile thread, and faceted semi-precious aquamarine beads.

The oxygen atom is represented by a large circular structure made from silver-plated copper wire, while two smaller wire spirals symbolize the hydrogen atoms. The copper-wire framework provides mechanical support for an interior textile structure produced using crochet techniques. Six cubic aquamarine beads, each measuring 4 mm, are incorporated into the crocheted structure to represent the six valence electrons of oxygen. Aquamarine was selected primarily for its blue-green colour, which evokes the visual appearance of water.

Keywords: Jewerly Art, New Product, contemporary jewellery, crochet wires, silver-plated copper, aquamarine, art and science.

INTRODUCTION

The water molecule is a suitable subject for an artistic investigation of this relationship. Its chemical formula, H_2O, indicates that each molecule contains two hydrogen atoms and one oxygen atom. Despite its simple composition, water has important physical and chemical properties arising from its molecular geometry, polarity and intermolecular interactions.

A neutral oxygen atom has atomic number 8 and the ground-state electron configuration $1s^2\ 2s^2\ 2p^4$. Its six electrons in the second principal energy level are conventionally identified as valence electrons (Finney, 2001). In a water molecule, oxygen forms two covalent bonds with two hydrogen atoms. The molecule has a bent geometry, with an H–O–H bond angle of approximately 104.5° (Powles, 1981).

These scientific characteristics provide the conceptual basis for the necklace described in this article, Fig. 1. Its design translates the atomic and molecular structure of water into a composition of wire, textile thread and gemstones. Each molecular unit combines a circular form, two spiral elements, a crocheted interior and six cubic aquamarine beads, Fig. 1.

MATERIALS AND TOOLS

Three principal materials were used to fabricate the nine molecular units: 1 mm diameter silver-plated copper wire, fine golden textile thread and faceted cubic semi-precious aquamarine beads.

The silver-plated copper wire served as the rigid structural framework. Its metallic core provided the malleability required for shaping and sufficient mechanical support to maintain the intended geometry of each component. The silver-coloured surface established a consistent metallic appearance throughout the framework and connecting elements.

Figure 1. Artistic piece in metal, as front view of the entire product.

The fine golden textile thread was used to produce the internal network by crochet. Its contrasting colour distinguished the textile structure from the silver-plated wire. The thread also allowed the incorporation of the gemstones into the interior of each unit.

The third material consisted of semi-precious aquamarine beads, micro-faceted and cubic in shape, with a side length of 4 mm. Aquamarine was selected primarily for aesthetic reasons, particularly its blue-green colour, which recalls the visual appearance commonly associated with water. The beads also provided a regular geometric form and a consistent unit of size within the crocheted structure.

Additional silver-plated copper-wire components were used to connect the nine molecular units. A silver-coloured ring clasp completed the necklace. Among the tools used, notable examples include pliers of various shapes and purposes, hooks, and needles for securing aquamarines, Fig. 2.

DESIGN AND SCIENTIFIC CORRESPONDENCE

Firstly, the design was based on a simplified symbolic representation of the water molecule, as a black pencil drawing on paper, with colour decorations, Fig. 3. In each unit, a larger circular wire element represents the oxygen atom, while two smaller spirals represent the two hydrogen atoms. These forms establish a visual distinction between the central oxygen component and the two hydrogen components. The oxygen representation contains six aquamarine beads. Their number corresponds to the six valence electrons of a neutral oxygen atom. The beads are positioned within the crocheted textile structure, which is supported by the circular wire framework.

This correspondence is numerical and symbolic rather than spatially literal. The beads do not reproduce the physical dimensions or shapes of electrons, and the wire spirals do not represent actual electron trajectories. Similarly, the circular framework is a design element rather than a depiction of an electron orbit.

In chemical terms, water has a bent molecular geometry, with an H–O–H bond angle of approximately 104.5°. The arrangement of the wire components in the necklace should therefore be understood as an artistic interpretation rather than a geometrically exact molecular model.

Figure 2. Tools and materials used to create the circle of life.

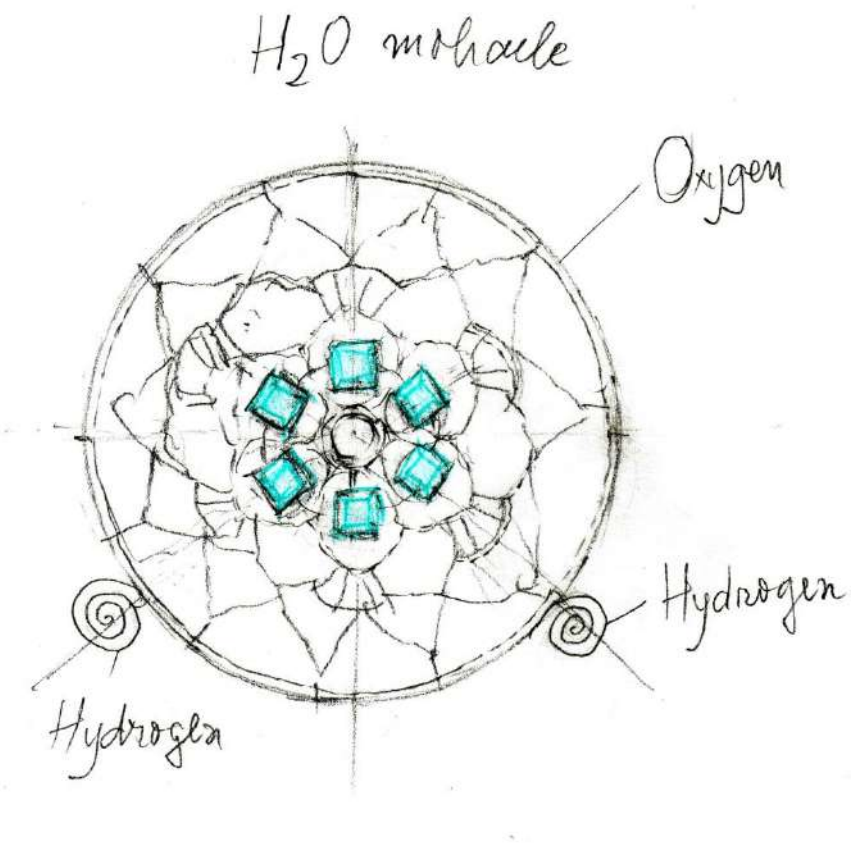


Figure. 3. The initial design, black pencil drawing on paper, with colour decorations.

FABRICATION PROCEDURE

The fabrication process consisted of four principal stages: wire shaping, crochet construction, insertion of the aquamarine beads, and assembly of the structural components.

Stage 1: Shaping the silver-plated copper wire

The 1 mm diameter wire was manually shaped to produce the circular framework representing oxygen and the two spiral elements representing hydrogen. The wire was manipulated to establish the required contours and to create a rigid structure capable of supporting the textile component.

The circular element provided the main structural boundary of each molecular unit. The smaller spirals were formed as distinct components within the same design concept. The wire framework was intended to preserve the overall shape during subsequent assembly and handling.

Stage 2: Producing the crocheted textile structure

A fine golden textile thread was worked using crochet techniques to create the internal network. The crocheted structure was designed to fit within the circular wire framework.

The use of crochet allowed the thread to form a connected textile surface while retaining an open, delicate appearance. This stage introduced a flexible component into the design, contrasting with the rigidity of the shaped wire.

Stage 3: Inserting the aquamarine beads

The six cubic aquamarine beads, each measuring 4 mm on a side, were incorporated into the crocheted textile structure. Their insertion was carried out as part of the construction process, allowing the beads to become

integrated into the thread network rather than being applied solely as external decoration. The six-bead arrangement was maintained for each oxygen representation, preserving the intended numerical correspondence with oxygen's six valence electrons.

Stage 4: Assembling the molecular units

The crocheted structure was assembled with the shaped silver-plated copper wire. The circular wire component provided a rigid frame for the textile network and helped maintain the geometry of the completed unit. This procedure was repeated to produce nine molecular units. The units were subsequently connected using four additional linking elements made from silver-plated copper wire. A silver-coloured ring clasp was attached to complete the necklace.

The finished object therefore comprises nine principal molecular units, four connecting elements and one clasp. The repeated construction method established material and formal consistency across the necklace.

RESULTS

The fabrication process produced a statement necklace composed of nine interconnected units representing water molecules. Each unit combines a shaped metallic framework, a crocheted golden textile structure and six cubic aquamarine beads, (see details in Fig. 4).

The silver-plated copper wire provides the principal structural support. Its circular and spiral forms establish the visual framework of each unit, while the crocheted thread creates an internal network. The contrast between the metallic wire and the golden textile thread differentiates the structural and textile components. The aquamarine beads introduce a third material and colour, providing visual contrast and a repeated geometric element.

Each principal unit contains six aquamarine beads measuring 4 mm on a side. Across the nine units, this results in a total of 54 aquamarine beads. This total follows directly from the design specification of six beads per molecular unit. The completed necklace comprises 13 principal assembled elements when the nine molecular units and four connecting elements are counted separately, together with the ring clasp. The four linking elements connect the main units into a wearable composition.

Figure 4. Different details of the a necklace - the circle of life.

From the fabrication perspective, the process combines wire forming, crochet, bead integration and metallic assembly. These techniques serve different functions: wire forming establishes the framework, crochet creates the interior textile structure, bead insertion introduces the gemstone components, and final assembly produces the continuous necklace.

The resulting object is a wearable artistic interpretation of molecular structure. Its visual organization is based on repetition, material contrast and the relationship between rigid and flexible components. Final result is an unique necklace, art piece, - presented in Fig. 5.

Figure 5. Final artistic piece, the circle of life, on an artistic support.

DISCUSSION

The necklace translates selected characteristics of the water molecule into a material composition. Its scientific relevance lies in the correspondence between the design and the chemical concepts that informed it, rather than in the literal reproduction of molecular geometry.

The first correspondence concerns the oxygen atom. Oxygen has six valence electrons, represented in the necklace by six aquamarine beads [1]. This numerical relationship provides a clear connection between the scientific description and the artistic design. However, electrons are quantum-mechanical entities described by states and probability distributions, not rigid cubic objects. The beads therefore function as visual symbols rather than physical representations of electrons.

The second correspondence concerns the hydrogen atoms. The two wire spirals represent the two hydrogen atoms in H_2O. Their form is a deliberate design choice and should not be interpreted as the physical shape of hydrogen atoms or as a representation of electron motion.

The circular wire framework represents the oxygen component within the artistic composition. It also performs a practical function by supporting the crocheted textile structure. This dual role is important because the material choices are not exclusively symbolic: they also respond to the requirements of constructing a durable and coherent piece of jewellery.

The golden textile thread establishes the internal network. Although it may evoke connectivity and atomic structure, it does not reproduce an actual atomic force field or the electron distribution within oxygen. Its function is to provide a visual and material interpretation of the invisible structures described by science. Aquamarine contributes both colour and geometry. Its blue-green appearance evokes water, while its cubic shape establishes a consistent visual unit. The choice was based on aesthetic considerations rather than on a claim that the gemstone has a chemical or physical equivalence to water or electrons.

The use of crochet is also relevant to the interdisciplinary character of the work. A textile technique traditionally associated with handmade objects is employed to interpret a scientific subject. The combination of crochet and wire forming creates a relationship between flexible and rigid materials, while the insertion of gemstones integrates a repeated decorative element into the structure.

This distinction is essential to an accurate presentation of the necklace. The object is not a scientific instrument or a molecular model intended for quantitative analysis. It is a piece of contemporary jewellery informed by chemistry and designed to communicate that the life essence is the water melocule.

CONCLUSION

This article presented the design and fabrication of a statement necklace composed of nine artistic representations of the water molecules. The construction combined 1 mm diameter silver-plated copper wire, fine golden textile thread and 4 mm cubic faceted semi-precious aquamarine beads.

The fabrication process involved shaping the wire framework, producing the internal crochet structure, inserting the aquamarine beads, assembling the textile and metallic components, and connecting the nine units using four additional wire elements. A silver-coloured ring clasp completed the necklace. The design draws on the chemical composition of water and the electronic configuration of oxygen. Six aquamarine beads represent the six valence electrons of oxygen, while the circular wire form and two spirals symbolically represent oxygen and hydrogen, respectively.

The work demonstrates how wire forming, crochet and gemstone setting can be combined to create an artistic interpretation of scientific structure. The principal contribution of the work is its integration of chemical concepts with traditional craft techniques in contemporary jewellery. Through this approach, molecular structure becomes the subject of material interpretation while retaining a clear distinction between scientific description and artistic representation.

ACKNOWLEDGEMENTS

This work was not sponsored or financially supported. However, Florina Ravariu expresses her gratitude to her professors from the National University of Arts in Bucharest for their guidance during her Master's studies.

REFERENCES

John L. Finney, The water molecule and its interactions: the interaction between theory, modelling, and experiment, Elsevier Journal of Molecular Liquids, Volume 90, Issues 1–3, 2001, Pages 303-312, https://doi.org/10.1016/S0167-7322(01)00134-9.

Powles, J. G. (1981). The structure of the water molecule in liquid water. Molecular Physics, 42(4), 757–765, https://doi.org/10.1080/00268978100100611.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

TWO-TIER AI TRIAGE FOR VIRAL GENE ANNOTATION WITHOUT RUNTIME SEQUENCE DATABASE QUERIES: A FIVE-PATHOGEN PROOF OF CONCEPT FOUNDED ON JAPANESE ENCEPHALITIS VIRUS

Arli Aditya Parikesit
ORCID: 0000-0001-8716-3926, i3L University (formerly Indonesia International Institute for Life Sciences), Department of Biotechnology, Field of study: Bioinformatics, Jakarta, Indonesia.

Abstract

Annotation of viral gene sequences normally depends on remote database searches such as NCBI BLAST, or on a local nucleotide database of tens of gigabytes. Neither option sits well with laboratories that work under limited bandwidth, limited storage, or outbreak field conditions. We present the General Viral Gene Annotator, an open pipeline that assigns a query FASTA sequence to one of five human viral pathogens: Japanese encephalitis virus (gp2), SARS-CoV-2 (ORF1ab), influenza A H5N1 (NA), poliovirus (PVgp1), and HIV-1 (gag-pol). Reference genes were retrieved once from NCBI Datasets and stored locally, so no database query is issued at run time. The pipeline joins a deterministic step to a probabilistic one. A dependency-free Python k-mer engine (k = 15) computes the fraction of unique query k-mers shared with each reference gene, which gives an inspectable similarity profile. That profile, together with sequence length and a sequence preview, is passed to a constrained-choice probabilistic model (Tier 1) returning a class probability and a decision confidence of $2|p - 0.5|$. Samples above a confidence of 0.85 are reported directly. Ambiguous samples escalate to a large language model (Tier 2) that reports homology, candidate recombination, and sequencing artefacts as narrative text, falling back to the Tier 1 call when that service is unreachable. Records run concurrently under asyncio. Two behaviours are demonstrated. A 4,307 bp HIV-1 gag-pol gene carrying a nonsense FASTA header was classified from sequence content alone, and synthetic tandem-repeat controls were rejected at roughly 94% confidence. Thresholds remain computational heuristics, the panel is small, and no wet-laboratory calibration has been performed, so every call is a hypothesis for confirmation by BLAST, RT-qPCR, or Sanger sequencing. The source code is available at https://github.com/Johnkecops/General-Viral-Gene-Annotator.

Keywords: viral genomics; sequence annotation; k-mer similarity; large language models; low-resource bioinformatics.

INTRODUCTION

Annotation of a new viral sequence usually starts with a similarity search against a public archive. BLAST remains the default tool for this step, because its seed-and-extend heuristic returns alignments with E-values that most virologists know how to read (Altschul et al., 1990; Camacho et al., 2009). The search is either sent to the NCBI servers or run against a local copy of the nucleotide collection, and each route has a cost. Remote queries need a stable connection and wait in a shared queue, while a local database occupies tens of gigabytes and must be refreshed. Portable sequencing during the West African Ebola outbreak showed that sequencing itself can now be done in the field, and that analysis close to the sample becomes the limiting step (Quick et al., 2016). The same constraint applies to arbovirus surveillance in Indonesia, where routine and standardized diagnosis of Japanese encephalitis is still missing in most provinces (Garjito et al., 2018).

Alignment-free methods lower this cost by comparing sequences through the words they contain, usually k-mers, instead of computing alignments (Zielezinski et al., 2017). Kraken 2 assigns reads to taxa through exact k-mer matches against a precomputed library (Wood et al., 2019), and Mash estimates mutation distance from MinHash sketches of k-mer sets (Ondov et al., 2016). The containment index, the fraction of one set's words found in another, was defined for comparing documents (Broder, 1997) and suits the case where a short query

is compared with a longer reference. These tools still need a reference library, although the library can be small when the panel of target pathogens is fixed in advance.

Language models have also entered sequence analysis. DNABERT and the Nucleotide Transformer learn representations of genomic sequence through pre-training (Ji et al., 2021; Dalla-Torre et al., 2025), and general-purpose large language models (LLMs) have been tested on annotation tasks such as naming cell types from marker genes (Hou and Ji, 2024). Their outputs are probabilistic, and their explanations can be fluent and wrong, a failure mode known as hallucination (Ji et al., 2023). A pipeline that uses such models for annotation therefore needs a deterministic anchor that a person can check, plus a rule that decides when a model's call is accepted. The classical form of that rule is the reject option, in which a classifier abstains when its confidence falls below a threshold (Chow, 1970).

Japanese encephalitis virus (JEV) is a mosquito-borne flavivirus with a positive-sense RNA genome of about 11 kb that encodes a single polyprotein (Sumiyoshi et al., 1987). An estimated 67,900 cases of Japanese encephalitis occur each year in 24 endemic countries of Asia and the Western Pacific, and only about 10% are reported to the World Health Organization (Campbell et al., 2011). Ardeid birds maintain the virus, pigs amplify it, and *Culex* mosquitoes carry it to people (Mulvey et al., 2021). Phylogeographic work places the origin of JEV in the Indonesia-Malaysia region, where all genotypes have circulated (Solomon et al., 2003; Schuh et al., 2013). Recent Indonesian surveillance detected the virus in mosquito pools and bats from 11 provinces (Diptyanusa et al., 2022) and genotype III in sentinel pigs in Bali (Kardena et al., 2024). Elsewhere, genotype I has replaced genotype III as the dominant lineage in much of Asia (Pan et al., 2011), and the virus reached south-eastern Australia in 2022 (van den Hurk et al., 2022).

These traits make JEV a demanding founding case for a general annotator. Its genotypes differ from one another by up to about 20% at the nucleotide level (Solomon et al., 2003), which is a hard test for exact-match methods. Its polyprotein gene organisation is shared with poliovirus and, through the ORF1ab polyprotein, with SARS-CoV-2, so a design that handles JEV should carry over to those genes (Kitamura et al., 1981; Wu et al., 2020). This paper describes the General Viral Gene Annotator, a Python pipeline that began as a JEV triage script and now assigns a query FASTA sequence to one of five human viral pathogens without querying a sequence database at run time. The study reverse-engineers the published codebase to document its design, recomputes its deterministic layer on the bundled data, and measures how that layer behaves as a JEV query diverges from its reference, following the benchmarking logic proposed for alignment-free tools (Zielezinski et al., 2019).

MATERIALS AND METHODS

Reference panel and query sets

Reference genes for the five pathogens were downloaded once from NCBI Datasets as gene data packages (O'Leary et al., 2024) and stored with the code (Table 1). Each package holds the coding sequence in FASTA format, a JSON Lines data report and an MD5 checksum file. The panel contains the JEVgp2 gene of strain JaOArS982, annotated by NCBI as a truncated polyprotein (Sumiyoshi et al., 1987), SARS-CoV-2 ORF1ab from Wuhan-Hu-1 (Wu et al., 2020), the neuraminidase gene of A/goose/Guangdong/1/1996 (H5N1) (Xu et al., 1999), the poliovirus type 1 Mahoney polyprotein gene PVgp1 (Kitamura et al., 1981) and HIV-1 gag-pol from HXB2 (Ratner et al., 1985). The whole panel is 37,233 nt long.

Table 1. Local reference panel retrieved from NCBI Datasets and used at run time.

Pathogen (family)	Gene	RefSeq accession: range	NCBI GeneID	TaxID	Length (nt)
JEV (Flaviviridae)	JEVgp2	NC_001437.1: 96-3691	12978160	11072	3,596
SARS-CoV-2 (Coronaviridae)	ORF1ab	NC_045512.2: 266-21555	43740578	2697049	21,290
Influenza A H5N1 (Orthomyxoviridae)	NA	NC_007361.1: 21-1430	3654619	93838	1,410
Poliovirus 1 (Picornaviridae)	PVgp1	NC_002058.3: 743-7372	919920	138950	6,630
HIV-1 (Retroviridae)	gag-pol	NC_001802.1: 336-4642	155348	11676	4,307

Three query sets from the repository, all in FASTA format (Pearson and Lipman, 1988), were analysed. The five reference files were run as self-queries. The file gene.fasta carries the 4,307 nt HIV-1 gag-pol sequence under the meaningless header ">tralalalalalaallaalal", which tests whether a call depends on the header. The file jev_samples.fasta holds two 112 nt synthetic controls built from the tandem repeats (CGTA)n and (GGGAAA)n, with headers that falsely label them as a JEV genotype III sample and an ambiguous recombinant.

FASTA parsing and k-mer containment

The parser reads FASTA files line by line in plain Python, so the pipeline needs no Biopython or other sequence library (Cock et al., 2009). A header line starting with ">" opens a new record, the following lines are concatenated, blank lines are skipped, and undecodable bytes are replaced instead of stopping the run. Only the first record of each reference file is kept, and it is converted to upper case. Pseudocode 1 gives the procedure together with the scoring step, which follows the word-based framework reviewed by Zielezinski et al. (2017). For a sequence S of length $|S|$, the set of distinct k-mers is given by Eq. (1).

$$\mathcal{K}_k(S) = \{S[i \ldots i+k-1] : 1 \le i \le |S|-k+1\} \quad (1)$$

The similarity of a query Q to a reference R is the containment of the query's k-mer set in the reference's set (Broder, 1997), as written in Eq. (2); C is set to 0 when either sequence is shorter than k. The pipeline uses k = 15. There are $4^{15} \approx 1.07 \times 10^9$ possible 15-mers, so chance matches between unrelated viral genes of a few kilobases are rare, which is the same reasoning behind the k-mer lengths used by Mash and Kraken (Ondov et al., 2016; Wood et al., 2019). The best-matching reference is selected by Eq. (3), where V is the set of five panel viruses.

$$C(Q,R) = \frac{|\mathcal{K}_k(Q) \cap \mathcal{K}_k(R)|}{|\mathcal{K}_k(Q)|} \quad (2)$$

$$\hat{v} = \underset{v \in V}{\operatorname{argmax}}\, C(Q, R_v) \quad (3)$$

Because every k-mer that contains a substituted base is lost, the expected containment of a query that differs from its reference by uniform point substitutions at rate r follows Eq. (4) when spurious matches are ignored (Blanca et al., 2022). To test this behaviour, the JEVgp2 reference was mutated at rates from 0% to 30% with 50 replicates per rate and random seed 42, each substituted base changing to one of the other three with equal probability. Random fragments of 50 to 3,000 nt were also drawn at 0% and 5% substitution. Every simulated query was scored against all five references with the pipeline's own compute_kmer_alignment function, imported unchanged from the script.

$$E[C] \approx (1-r)^k \quad (4)$$

Pseudocode 1. FASTA parsing and k-mer containment scoring (native Python, no external libraries).

```
PROCEDURE PARSE_FASTA(file)
  records ← [ ];  id ← NULL;  seq ← [ ]
  FOR each line IN file DO
    line ← STRIP(line);  IF line = "" THEN CONTINUE
```

```
  IF line starts with ">" THEN
    IF id ≠ NULL THEN APPEND (id, JOIN(seq)) TO records
    id ← line[2..];  seq ← [ ]
  ELSE APPEND line TO seq
 IF id ≠ NULL THEN APPEND (id, JOIN(seq)) TO records
 RETURN records

PROCEDURE KMER_CONTAINMENT(Q, R, k = 15)
 Q ← UPPER(Q);  R ← UPPER(R)
 IF |Q| < k OR |R| < k THEN RETURN 0
 KQ ← { Q[i .. i+k−1] : i = 1 … |Q|−k+1 }        ▷ Eq. (1)
 KR ← { R[i .. i+k−1] : i = 1 … |R|−k+1 }
 RETURN |KQ ∩ KR| / |KQ|                          ▷ Eq. (2)
```

Tier 1: constrained-choice classification

The FASTA header, the containment profile, the sequence length and the first 300 nt of the sequence are assembled into a text block (bio_state) and sent to TypeSafe System One, a constrained-choice decision model reached through the typesafe-sdk client (TypeSafe AI, 2026). The model must choose one of six labels: jev, sars_cov_2, influenza_h5n1, poliovirus, hiv, or none (non-viral or synthetic). It returns the chosen label, a probability distribution over the six labels and a decision confidence. The project documentation defines confidence from the probability p of a call as in Eq. (5), so $p = 0.5$ gives $\gamma = 0$ and $p = 0$ or 1 gives $\gamma = 1$; in the code the value is read directly from the SDK response. A call is accepted when γ reaches the threshold $\tau = 0.85$ (Eq. 6), which is a reject option in the sense of Chow (1970). Solving Eq. (5) for p shows that a record escalates whenever $0.075 < p < 0.925$.

$$\gamma = 2|p - 0.5| \tag{5}$$

$$\text{call} = \begin{cases} \text{Auto-Processed}, & \gamma \geq \tau \\ \text{Escalate to Tier 2}, & \gamma < \tau \end{cases}, \quad \tau = 0.85 \tag{6}$$

Tier 2: language model escalation, fallback and concurrency

Records below the threshold go to a large language model through the google-genai client, using the model identifier gemini-3.8-flash set in the script (Gemini Team, 2023). The system instruction frames the model as a viral genomics expert covering flaviviruses, coronaviruses, orthomyxoviruses, picornaviruses and retroviruses, and the prompt asks for homology, candidate recombination and anomalies given the bio_state block, with output capped at 1,500 tokens. The answer is free text stored beside the Tier 1 label, which stays the reported top hit. If the call fails, the record is marked "Tier 1 Fallback (Gemini Unreachable)" and the Tier 1 label stands. Because LLM text can contain confident errors (Ji et al., 2023), Tier 2 output is meant for a human reviewer. Pseudocode 2 summarises the triage of one record.

Pseudocode 2. Two-tier triage of a FASTA record and concurrent execution.

```
PROCEDURE TRIAGE(record, panel, τ = 0.85)
 FOR each virus v IN panel DO  C[v] ← KMER_CONTAINMENT(record.seq, panel[v])
 v_top ← argmax_v C[v]                            ▷ Eq. (3)
 state ← (record.id, v_top, C, |record.seq|, record.seq[1..300])
 TRY
  (label, P, γ) ← TIER1_CHOICE(state, {jev, sars_cov_2, influenza_h5n1,
                               poliovirus, hiv, none})
```

```
  IF γ ≥ τ THEN RETURN (label, γ, P, C, "Auto-Processed")   ▷ Eq. (6)
  TRY   text ← TIER2_LLM(state);  status ← "Escalated to Gemini"
  CATCH err:  text ← err;  status ← "Tier 1 Fallback"
  RETURN (label, γ, P, C, status, text)
CATCH err:  RETURN ("Error", err)

MAIN:  results ← AWAIT GATHER( TRIAGE(r, panel) FOR r IN PARSE_FASTA(query) )
```

Each record runs as an asynchronous coroutine, and all records are awaited together with asyncio.gather, so network latency for one record does not hold up the others (Python Software Foundation, 2026). Figure 1 shows the complete workflow. The pipeline needs Python 3.10 or later with the packages google-genai, typesafe-sdk and httpx, and it reads its API keys from the TYPESAFE_API_KEY and GEMINI_API_KEY environment variables. The codebase is deposited on GitHub and is being released as a Streamlit web application, so that users can upload FASTA files through a browser (Streamlit, 2026). The robustness simulation and figures in this paper were produced with Python 3.11.5, NumPy 1.26.4 and Matplotlib 3.8.2 (scripts/robustness_kmer.py and scripts/fig1_workflow.py in the project folder).

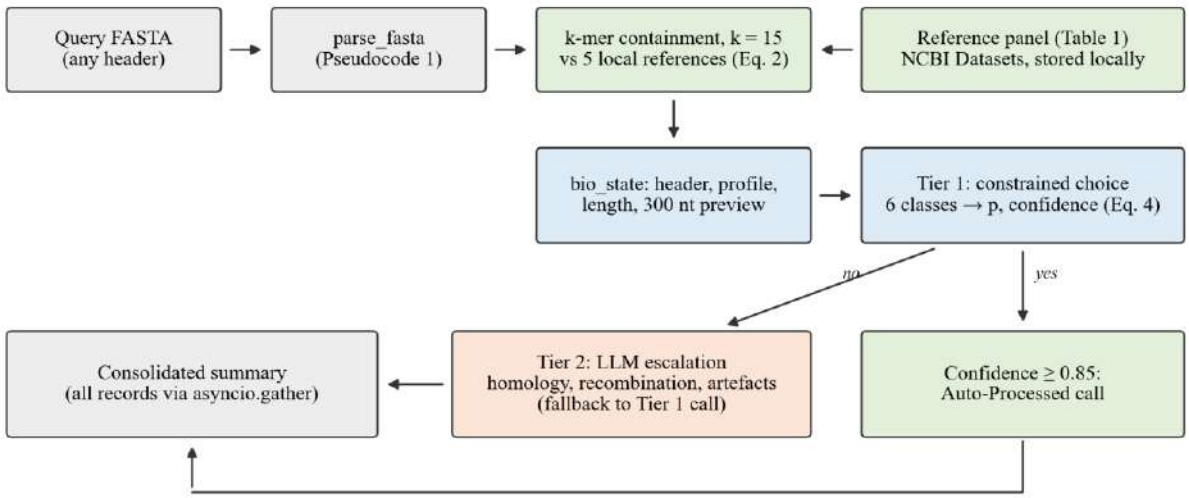


Figure 1. Workflow of the General Viral Gene Annotator. Green boxes are deterministic and run offline; blue boxes form Tier 1; the orange box is the Tier 2 language model path with its fallback.

RESULTS

Table 2 lists the containment scores recomputed from the repository files. Each reference gene scored C = 1.000 against itself and 0.000 against the other four, so the five panel genes share no 15-mer. This is expected for genes from five virus families that are unrelated at the nucleotide level (Zielezinski et al., 2017). The header-blind file gene.fasta gave the same profile as the HIV-1 reference because its sequence is identical to it. Both tandem-repeat controls scored 0.000 against every reference; out of 98 overlapping positions they contain only 23 and 22 distinct 15-mers, and none occurs in a panel gene (Broder, 1997). An example output in the repository documentation shows off-target scores of 0.9% to 2.1% and an HIV-1 score of 68.4% for the same file, whereas the recomputation gives exactly 0% and 100%, so that example is illustrative only.

Table 2. k-mer containment C (k = 15) of each query against the five references, recomputed from the repository files.

Query	Length (nt)	HIV-1	SARS-CoV-2	H5N1	PV	JEV
JEVgp2 reference	3,596	0.000	0.000	0.000	0.000	1.000
SARS-CoV-2 ORF1ab reference	21,290	0.000	1.000	0.000	0.000	0.000
H5N1 NA reference	1,410	0.000	0.000	1.000	0.000	0.000
PVgp1 reference	6,630	0.000	0.000	0.000	1.000	0.000
HIV-1 gag-pol reference	4,307	1.000	0.000	0.000	0.000	0.000
gene.fasta (nonsense header)	4,307	1.000	0.000	0.000	0.000	0.000
Control (CGTA)n	112	0.000	0.000	0.000	0.000	0.000
Control (GGGAAA)n	112	0.000	0.000	0.000	0.000	0.000

For the Tier 1 layer, the project's recorded runs assigned the header-blind gene to HIV-1 and rejected both synthetic controls as non-JEV with $p \approx 0.03$. Under Eq. (5) this gives $\gamma = 2|0.03 - 0.5| = 0.94$, above the 0.85 threshold, so neither control reached Tier 2 (Chow, 1970). These Tier 1 values come from the project's run records and were not re-executed for this paper, because the proprietary services require paid API keys (TypeSafe AI, 2026).

Figure 2a shows the mean JEV containment of mutated full-length JEVgp2 queries. The simulated means followed Eq. (4) closely: 0.860 at 1% substitution (expected 0.860), 0.462 at 5% (0.463), 0.206 at 10% (0.206) and 0.034 at 20% (0.035), in line with the k-mer survival model of Blanca et al. (2022). At 30% substitution the mean fell to 0.0045, and 1 of 50 replicates shared no 15-mer with the reference. The highest off-target score among all 500 mutated queries was 0.0008, about 3 of roughly 3,580 query k-mers, so JEV stayed the top hit whenever any JEV k-mer survived. Figure 2b shows that error-free fragments scored 1.000 at every length from 50 to 3,000 nt. At 5% substitution the mean stayed near the expected 0.463 at all lengths, but the spread widened as fragments shortened, from a standard deviation of 0.037 at 3,000 nt to 0.321 at 50 nt, and 5 of the 50 fragments of 50 nt shared no 15-mer with the reference.

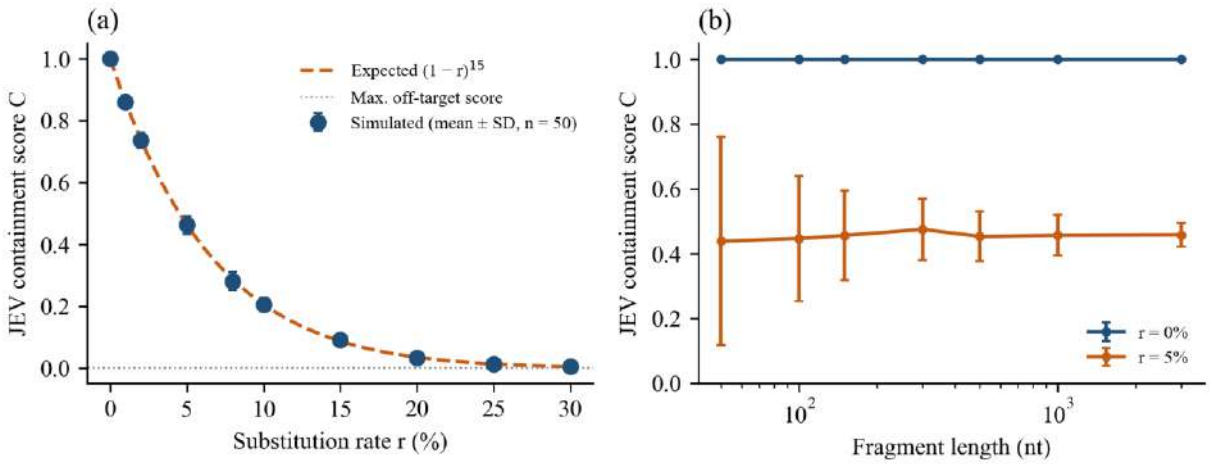


Figure 2. Behaviour of the k = 15 containment score for simulated JEV queries (50 replicates per condition, seed 42). (a) Full-length JEVgp2 with uniform substitutions; the dashed line is Eq. (4). (b) Random fragments of the JEVgp2 reference at 0% and 5% substitution. Error bars are one standard deviation.

DISCUSSION

The annotator replaces a database search with a local panel of 37 kb, several orders of magnitude smaller than the multi-gigabyte collections used for local BLAST searches (Camacho et al., 2009). For a fixed surveillance

question, such as whether a sample from a pig farm in Bali carries JEV, a small panel is enough, and the k-mer step runs on a laptop without a network connection, which matters for sequencing done in the field (Quick et al., 2016). Table 3 compares the approach with a standard BLAST pipeline. The deterministic layer can be audited: anyone can recompute Table 2 from the files, whereas the reasoning inside a language model cannot be reproduced in the same way (Zielezinski et al., 2017).

Table 3. Comparison of a standard BLASTn pipeline with the General Viral Gene Annotator.

Feature	Standard pipeline (BLASTn)	General Viral Gene Annotator
Detection method	Local alignment, seed-and-extend heuristic	Exact 15-mer containment plus constrained-choice model
Reference data	NCBI nt or RefSeq viral collections	Five genes, 37,233 nt, stored with the code
Network at run time	Remote search needs it; local search needs large database updates	None for the k-mer step; API calls for Tiers 1 and 2
Reported metrics	E-value, bit score, % identity, alignment coordinates	Containment C, class probabilities, confidence γ, free text
Divergent query	Alignment extends through mismatches	C decays as $(1 - r)^{15}$ (Figure 2)
Scope	Any sequence in the database	Five pathogens plus a none class
Auditability	Base-level alignment	k-mer profile recomputable; model reasoning not

The simulation measures the main weakness of exact k-mer matching, and JEV is the panel member most exposed to it. Genotype IV differs from genotypes I to III by 17.4% to 19.6% at the nucleotide level (Solomon et al., 2003), and at that divergence Eq. (4) predicts a containment of only 0.04 to 0.06 against a single genotype III reference. Such a query would still be called JEV here, because the other panel genes share almost nothing with it, but the margin is thin, and a short or noisy read could lose every k-mer and fall into the none class. Genotype I, now dominant across Asia (Pan et al., 2011), and the genotype III strains found in Bali (Kardena et al., 2024) would each need their own reference, or a shorter k, before the score could separate a divergent JEV from a sequence that is simply new. BLAST copes better with this case because it extends alignments through mismatches and attaches an E-value to the result (Altschul et al., 1990).

The Tier 1 model adds a label for inputs outside the panel, and the threshold decides how often a person must read an LLM report (Chow, 1970). The model receives the containment profile together with the 300 nt preview, which on its own is too short for most homology judgements. General-purpose LLMs were not trained for viral typing, and their annotation quality varies by task (Hou and Ji, 2024), so Tier 2 text is best read as a list of hypotheses. DNA foundation models trained on nucleotide sequence could replace the general model in a later version and would be easier to benchmark (Ji et al., 2021; Dalla-Torre et al., 2025).

The evaluation has clear limits. The test queries are the reference sequences themselves, so Table 2 confirms that the scoring works as coded; it does not estimate accuracy on new isolates. The threshold of 0.85 was set by hand and has not been calibrated against laboratory results. Eq. (5) maps a binary probability to confidence, while the panel has six classes, and the SDK does not document how it computes the value it returns. The repository documentation also gives the escalation band as $0.425 < p < 0.575$, whereas Eq. (5) implies $0.075 < p < 0.925$. Tiers 1 and 2 depend on proprietary services whose model versions can change, which limits reproducibility (Gemini Team, 2023; TypeSafe AI, 2026).

Every call from the annotator should therefore be treated as a hypothesis. A positive JEV call on a clinical, veterinary or mosquito sample should be confirmed by BLAST against RefSeq, by a JEV-specific TaqMan RT-PCR (Pyke et al., 2004) and by Sanger sequencing. Typing and recombination claims from Tier 2 should be checked with Genome Detective (Vilsker et al., 2019) and RDP5 (Martin et al., 2021) after reads are mapped with minimap2 (Li, 2018). A fair benchmark would use held-out JEV genomes of all genotypes, with related flaviviruses as near-neighbour negatives, scored under the protocols proposed for alignment-free methods (Zielezinski et al., 2019).

CONCLUSION AND RECOMMENDATIONS

The General Viral Gene Annotator assigns viral gene sequences to five pathogens using a 37 kb local reference panel, a 15-mer containment score and a two-tier AI decision layer, and it never queries a sequence database at run time. On the bundled data the deterministic layer separated the five genes completely, recognised an HIV-1 gene under a nonsense header, and gave zero similarity to two synthetic repeats. Simulation showed that containment falls as $(1 - r)^{15}$, so a JEV query 20% divergent from its reference keeps only about 3% of its 15-mers. Before field use, the panel should gain references for each JEV genotype and for related flaviviruses, the 0.85 threshold should be calibrated on labelled sequences with laboratory confirmation, and every positive call should be reported next to a BLAST check. The Streamlit release should show the k-mer profile to users, since it is the part of the output they can verify for themselves.

ACKNOWLEDGEMENTS

The source code, reference data packages and example FASTA files of the General Viral Gene Annotator are available in the GitHub repository https://github.com/Johnkecops/General-Viral-Gene-Annotator. The author thanks i3L University for institutional support. Claude Pro from Anthropic ® was used for ideation, brainstorming, and outlining the manuscript. However, the author is solely responsible for the validity of the content.

REFERENCES

Altschul SF, Gish W, Miller W, Myers EW, Lipman DJ 1990. Basic local alignment search tool. Journal of Molecular Biology, 215(3): 403-410. https://doi.org/10.1016/S0022-2836(05)80360-2 (PMID: 2231712)

Blanca A, Harris RS, Koslicki D, Medvedev P 2022. The statistics of k-mers from a sequence undergoing a simple mutation process without spurious matches. Journal of Computational Biology, 29(2): 155-168. https://doi.org/10.1089/cmb.2021.0431 (PMID: 35108101)

Broder AZ 1997. On the resemblance and containment of documents. In: Proceedings of Compression and Complexity of SEQUENCES 1997. Salerno: IEEE, pp. 21-29. https://doi.org/10.1109/SEQUEN.1997.666900

Camacho C, Coulouris G, Avagyan V, Ma N, Papadopoulos J, Bealer K, Madden TL 2009. BLAST+: architecture and applications. BMC Bioinformatics, 10: 421. https://doi.org/10.1186/1471-2105-10-421 (PMID: 20003500)

Campbell GL, Hills SL, Fischer M, Jacobson JA, Hoke CH, Hombach JM, Marfin AA, Solomon T, Tsai TF, Tsu VD, Ginsburg AS 2011. Estimated global incidence of Japanese encephalitis: a systematic review. Bulletin of the World Health Organization, 89(10): 766-774. https://doi.org/10.2471/BLT.10.085233 (PMID: 22084515)

Chow CK 1970. On optimum recognition error and reject tradeoff. IEEE Transactions on Information Theory, 16(1): 41-46. https://doi.org/10.1109/TIT.1970.1054406

Cock PJ, Antao T, Chang JT, Chapman BA, Cox CJ, Dalke A, et al. 2009. Biopython: freely available Python tools for computational molecular biology and bioinformatics. Bioinformatics, 25(11): 1422-1423. https://doi.org/10.1093/bioinformatics/btp163 (PMID: 19304878)

Dalla-Torre H, Gonzalez L, Mendoza-Revilla J, Lopez Carranza N, Grzywaczewski AH, Oteri F, et al. 2025. Nucleotide Transformer: building and evaluating robust foundation models for human genomics. Nature Methods, 22(2): 287-297. https://doi.org/10.1038/s41592-024-02523-z (PMID: 39609566)

Diptyanusa A, Herini ES, Indarjulianto S, Satoto TBT 2022. Estimation of Japanese encephalitis virus infection prevalence in mosquitoes and bats through nationwide sentinel surveillance in Indonesia. PLoS ONE, 17(10): e0275647. https://doi.org/10.1371/journal.pone.0275647 (PMID: 36223381)

Garjito TA, Widiarti, Anggraeni YM, Alfiah S, Tunggul Satoto TB, Farchanny A, et al. 2018. Japanese encephalitis in Indonesia: an update on epidemiology and transmission ecology. Acta Tropica, 187: 240-247. https://doi.org/10.1016/j.actatropica.2018.08.017 (PMID: 30118700)

Gemini Team 2023. Gemini: a family of highly capable multimodal models. arXiv, 2312.11805. https://doi.org/10.48550/arXiv.2312.11805

Hou W, Ji Z 2024. Assessing GPT-4 for cell type annotation in single-cell RNA-seq analysis. Nature Methods, 21(8): 1462-1465. https://doi.org/10.1038/s41592-024-02235-4 (PMID: 38528186)

Ji Y, Zhou Z, Liu H, Davuluri RV 2021. DNABERT: pre-trained Bidirectional Encoder Representations from Transformers model for DNA-language in genome. Bioinformatics, 37(15): 2112-2120. https://doi.org/10.1093/bioinformatics/btab083 (PMID: 33538820)

Ji Z, Lee N, Frieske R, Yu T, Su D, Xu Y, et al. 2023. Survey of hallucination in natural language generation. ACM Computing Surveys, 55(12): 1-38. https://doi.org/10.1145/3571730

Kardena IM, Adi AAAM, Astawa INM, Oka IBM, Sahibzada S, Bruce M, O'Dea M 2024. Seroconversion, genotyping, and potential mosquito vector identification of Japanese encephalitis virus in pig sentinel settings in Bali, Indonesia. Veterinary World, 17(1): 89-98. https://doi.org/10.14202/vetworld.2024.89-98 (PMID: 38406355)

Kitamura N, Semler BL, Rothberg PG, Larsen GR, Adler CJ, Dorner AJ, et al. 1981. Primary structure, gene organization and polypeptide expression of poliovirus RNA. Nature, 291(5816): 547-553. https://doi.org/10.1038/291547a0 (PMID: 6264310)

Li H 2018. Minimap2: pairwise alignment for nucleotide sequences. Bioinformatics, 34(18): 3094-3100. https://doi.org/10.1093/bioinformatics/bty191 (PMID: 29750242)

Martin DP, Varsani A, Roumagnac P, Botha G, Maslamoney S, Schwab T, et al. 2021. RDP5: a computer program for analyzing recombination in, and removing signals of recombination from, nucleotide sequence datasets. Virus Evolution, 7(1): veaa087. https://doi.org/10.1093/ve/veaa087 (PMID: 33936774)

Mulvey P, Duong V, Boyer S, Burgess G, Williams DT, Dussart P, Horwood PF 2021. The ecology and evolution of Japanese encephalitis virus. Pathogens, 10(12): 1534. https://doi.org/10.3390/pathogens10121534 (PMID: 34959489)

O'Leary NA, Cox E, Holmes JB, Anderson WR, Falk R, Hem V, et al. 2024. Exploring and retrieving sequence and metadata for species across the tree of life with NCBI Datasets. Scientific Data, 11: 732. https://doi.org/10.1038/s41597-024-03571-y (PMID: 38969627)

Ondov BD, Treangen TJ, Melsted P, Mallonee AB, Bergman NH, Koren S, Phillippy AM 2016. Mash: fast genome and metagenome distance estimation using MinHash. Genome Biology, 17: 132. https://doi.org/10.1186/s13059-016-0997-x (PMID: 27323842)

Pan XL, Liu H, Wang HY, Fu SH, Liu HZ, Zhang HL, et al. 2011. Emergence of genotype I of Japanese encephalitis virus as the dominant genotype in Asia. Journal of Virology, 85(19): 9847-9853. https://doi.org/10.1128/JVI.00825-11 (PMID: 21697481)

Pearson WR, Lipman DJ 1988. Improved tools for biological sequence comparison. Proceedings of the National Academy of Sciences of the USA, 85(8): 2444-2448. https://doi.org/10.1073/pnas.85.8.2444 (PMID: 3162770)

Pyke AT, Smith IL, van den Hurk AF, Northill JA, Chuan TF, Westacott AJ, et al. 2004. Detection of Australasian Flavivirus encephalitic viruses using rapid fluorogenic TaqMan RT-PCR assays. Journal of Virological Methods, 117(2): 161-167. https://doi.org/10.1016/j.jviromet.2004.01.007 (PMID: 15041213)

Python Software Foundation 2026. asyncio: Asynchronous I/O. Python 3 documentation. Available at: https://docs.python.org/3/library/asyncio.html [29.09.2026]

Quick J, Loman NJ, Duraffour S, Simpson JT, Severi E, Cowley L, et al. 2016. Real-time, portable genome sequencing for Ebola surveillance. Nature, 530(7589): 228-232. https://doi.org/10.1038/nature16996 (PMID: 26840485)

Ratner L, Haseltine W, Patarca R, Livak KJ, Starcich B, Josephs SF, et al. 1985. Complete nucleotide sequence of the AIDS virus, HTLV-III. Nature, 313(6000): 277-284. https://doi.org/10.1038/313277a0 (PMID: 2578615)

Schuh AJ, Ward MJ, Brown AJ, Barrett AD 2013. Phylogeography of Japanese encephalitis virus: genotype is associated with climate. PLoS Neglected Tropical Diseases, 7(8): e2411. https://doi.org/10.1371/journal.pntd.0002411 (PMID: 24009790)

Solomon T, Ni H, Beasley DW, Ekkelenkamp M, Cardosa MJ, Barrett AD 2003. Origin and evolution of Japanese encephalitis virus in southeast Asia. Journal of Virology, 77(5): 3091-3098. https://doi.org/10.1128/JVI.77.5.3091-3098.2003 (PMID: 12584335)

Streamlit 2026. Streamlit: a faster way to build and share data apps. Available at: https://streamlit.io [29.09.2026]

Sumiyoshi H, Mori C, Fuke I, Morita K, Kuhara S, Kondou J, et al. 1987. Complete nucleotide sequence of the Japanese encephalitis virus genome RNA. Virology, 161(2): 497-510. https://doi.org/10.1016/0042-6822(87)90144-9 (PMID: 3686827)

TypeSafe AI 2026. System One decision models and typesafe-sdk. Available at: https://typesafe.ai [29.09.2026]

van den Hurk AF, Skinner E, Ritchie SA, Mackenzie JS 2022. The emergence of Japanese encephalitis virus in Australia in 2022: existing knowledge of mosquito vectors. Viruses, 14(6): 1208. https://doi.org/10.3390/v14061208 (PMID: 35746679)

Vilsker M, Moosa Y, Nooij S, Fonseca V, Ghysens Y, Dumon K, et al. 2019. Genome Detective: an automated system for virus identification from high-throughput sequencing data. Bioinformatics, 35(5): 871-873. https://doi.org/10.1093/bioinformatics/bty695 (PMID: 30124794)

Wood DE, Lu J, Langmead B 2019. Improved metagenomic analysis with Kraken 2. Genome Biology, 20: 257. https://doi.org/10.1186/s13059-019-1891-0 (PMID: 31779668)

Wu F, Zhao S, Yu B, Chen YM, Wang W, Song ZG, et al. 2020. A new coronavirus associated with human respiratory disease in China. Nature, 579(7798): 265-269. https://doi.org/10.1038/s41586-020-2008-3 (PMID: 32015508)

Xu X, Subbarao K, Cox NJ, Guo Y 1999. Genetic characterization of the pathogenic influenza A/Goose/Guangdong/1/96 (H5N1) virus: similarity of its hemagglutinin gene to those of H5N1 viruses from the 1997 outbreaks in Hong Kong. Virology, 261(1): 15-19. https://doi.org/10.1006/viro.1999.9820 (PMID: 10484749)

Zielezinski A, Girgis HZ, Bernard G, Leimeister CA, Tang K, Dencker T, et al. 2019. Benchmarking of alignment-free sequence comparison methods. Genome Biology, 20: 144. https://doi.org/10.1186/s13059-019-1755-7 (PMID: 31345254)

Zielezinski A, Vinga S, Almeida J, Karlowski WM 2017. Alignment-free sequence comparison: benefits, applications, and tools. Genome Biology, 18: 186. https://doi.org/10.1186/s13059-017-1319-7 (PMID: 28974235)

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

GENETIC STRUCTURE AND INBREEDING IN THE POPULATION OF KORÇË, ALBANIA: AN ASSESSMENT THROUGH SURNAME FREQUENCIES

Desareda Mero
Rezana Pengu
Xhuljana Sula
ORCID ID: https://orcid.org/0009-0006-0045-5955,
Fan S. Noli University, Faculty of Natural and Human Science, Department of Biology and Chemistry, Korçë, Albania.,
ORCID ID: https://orcid.org/0009-0003-1924-5868
Fan S. Noli University, Faculty of Natural and Human Science, Department of Biology and Chemistry, Korçë, Albania.
ORCID ID: https://orcid.org/0009-0006-9696-6900
Fan S. Noli University, Faculty of Natural and Human Science, Department of Biology and Chemistry, Korçë, Albania.

Abstract

This study investigates the population structure and microevolutionary dynamics of Korçë, Albania, through surname-based analysis, using surnames as indirect bio-cultural markers of population diversity, migration, and marital patterns. Data obtained from civil registration records were analyzed across successive birth cohorts, considering the total population (Total) and two subpopulations based on birthplace: individuals born within (Within) and outside (Outside) the former district of Korçë.
The analysis included surname frequency distributions, regression coefficients, Fisher's alpha, the Karlin–McGregor parameter, Euclidean and Lasker distances, and matrimonial-demographic indicators such as age at marriage, endogamy, exogamy, and premarital migration distances. The findings indicate greater surname diversity among individuals born outside the former district, while distance analyses reveal patterns broadly consistent with random mating and demographic mixing. Temporal changes in marital patterns, particularly an increasing prevalence of endogamous unions, were also observed. An inverse association between surname diversity and estimated total inbreeding was identified.
Overall, the study highlights the value of surname-based methods as complementary tools in population genetics and historical demography, providing insights into the role of migration, marital patterns, and demographic processes in shaping the population structure and microevolutionary dynamics of Korçë.

Keywords: genetic structure, isonymy, surname diversity, endogamy, premarital migration, inbreeding coefficients.

INTRODUCTION

The investigation of human population structure and microevolutionary dynamics requires the integration of demographic, genealogical, and population-genetic approaches. Among indirect methods, surname analysis represents a valuable bio-cultural tool, as surname distribution and transmission across generations may provide information on population history, familial continuity, migration, and biological relatedness. The scientific relevance of this approach is associated with the predominantly patrilineal transmission of surnames in many societies, which follows a pattern broadly analogous to that of Y-chromosome inheritance. Although surnames cannot be considered direct genetic markers, their distribution may serve as an indirect indicator of paternal ancestry and population relationships, particularly in historical studies where molecular-genetic information is unavailable (Yasuda & Morton, 1967; King & Jobling, 2009).
The foundations of surname-based population analysis date back to Darwin (1875), who investigated marriages between individuals sharing identical surnames as an indicator of consanguinity. This approach was

subsequently formalized by Crow and Mange (1965), establishing the methodology known as isonymy analysis. The frequency of isonymous marriages provides an indirect basis for estimating population inbreeding and investigating patterns of shared paternal ancestry. Further methodological developments, including Lasker's coefficient of relationship and indicators such as Fisher's alpha, effective surname number, and the Karlin–McGregor parameter, have expanded the possibilities for assessing surname diversity, population relationships, and migration processes (Barrai *et al*., 1996; Rodríguez-Larralde *et al*., 1994, 1999). Applications of these methods in different geographical settings have demonstrated the influence of migration, geographical isolation, population subdivision, and historical demographic processes on surname distributions and population differentiation (Barrai *et al*., 1996; Rodríguez-Larralde *et al*., 1999, 2003; Carrieri *et al*., 2020). Furthermore, marital patterns, particularly endogamy and exogamy, contribute to the maintenance or introduction of familial lineages. While endogamy may reinforce population continuity and shared ancestry, exogamy and migration facilitate the introduction of new surnames and paternal lineages, influencing population diversity and gene flow.

Comparative analyses of surname distributions can also employ Euclidean and Lasker distances to evaluate similarities and differences between geographical groups and successive temporal cohorts. Combined with demographic indicators, these measures provide additional insight into population differentiation and historical changes. Nevertheless, surname-based methods have limitations, including independent surname origins, variations in spelling and transmission, adoption, and uncertain paternity. Therefore, their results should be interpreted as indirect indicators of population structure rather than substitutes for molecular-genetic evidence.

In Albania, surname analysis has contributed to understanding population structure and demographic history. Studies by Mikerezi *et al*. (2003) and Mikerezi *et al*. (2013) demonstrated the influence of geographical distance, isolation, genetic drift, and administrative subdivision on surname diversity and estimated inbreeding, establishing an important basis for further regional investigations.

Within this context, the present study examines the population structure and microevolutionary dynamics of Korçë, Albania, through surname distributions and demographic indicators derived from civil registration records. The population is analyzed as a whole and according to birthplace, distinguishing individuals born within the former district of Korçë from those born outside it. The study focuses on temporal variations in surname diversity, isonymic parameters, Euclidean and Lasker distances, as well as marital indicators, including endogamy, exogamy, age at marriage, and premarital migration distances. Through the combined analysis of these parameters across successive birth cohorts, the study aims to identify demographic changes, evaluate the contribution of migration and marital patterns to population differentiation, and provide insight into the microevolutionary processes shaping the population of Korçë.

MATERIALS AND METHODS

Study population and data collection

The present study is based on marriage records collected over a six-decade period from the official registers of the Civil Status Office of the Municipality of Korçë, Albania. The dataset comprises information on individuals whose marriages were registered in the city of Korçë. The collected data included the surnames of both spouses, their sex, dates of birth, places of birth, and dates of marriage. These variables provided the basis for investigating temporal changes in surname distribution, population structure, marriage patterns, and migration-related processes.

Data organization and processing

The collected information was organized into a structured database and processed using Microsoft Excel. Marriage records were initially classified into successive five-year intervals, beginning in 1946 and extending through 2006, to examine temporal changes in the characteristics of the study population. For analyses based on individuals' years of birth, the population was divided into nine temporal cohorts:

P1: up to 1910; P2: 1911–1920; P3: 1921–1930; P4: 1931–1940; P5: 1941–1950; P6: 1951–1960; P7: 1961–1970; P8: 1971–1980; P9: 1981–1990.

Three population categories were established according to birthplace:

Within: individuals born within the former district of Korçë;

Outside: individuals born outside the former district of Korçë, including those born abroad;
Total: the overall study population, comprising both locally and non-locally born individuals.This classification enabled the comparative assessment of population characteristics and their temporal variation according to geographical origin.

Assessment of surname diversity and microevolutionary parameters

The analysis of microevolutionary processes was based on the assessment of temporal changes in population structure using surname-based indicators. In particular, Fisher's alpha coefficient (α) and the Karlin–McGregor coefficient (ν) were employed to evaluate surname diversity and migration dynamics, respectively. Calculations were performed using relative surname-frequency matrices for each temporal cohort and population category.

Unexpected random isonymy

Unexpected random isonymy was calculated for each population cohort using the following expression:

$$I_{ii}=\sum_k p_{ik}^{2}-\frac{1}{N_i}\tag{1}$$

where p_{ik} represents the relative frequency of the k-th surname in cohort (i), and N_i is the corresponding sample size.

Fisher's alpha coefficient

Fisher's alpha coefficient (α) was used as an indicator of surname richness and diversity. It was calculated as the reciprocal of unexpected random isonymy:

$$\alpha=\frac{1}{I_{ii}}\tag{2}$$

In sufficiently large samples, this coefficient approaches the number of alleles at a genetic locus Barrai *et al.* (1999).

Karlin–McGregor coefficient

The Karlin–McGregor coefficient (ν) was used as an indicator of migration dynamics and surname diversity within the population. It was calculated according to the following expression:

$$\nu=\frac{1-B_{ii}}{B_{ii}(N_i-1)}\tag{3}$$

where:

$$B_{ii}=\sum_k p_{ik}^{2}$$

The coefficient ranges from zero, when all individuals share the same surname, to one, when all individuals have different surnames (Zei et al., 1983). Both coefficients were calculated separately for the Within, Outside, and Total population categories across the nine birth cohorts, allowing the investigation of temporal changes in surname diversity and migration-related population structure.

Analysis of surname-frequency distributions

The distribution of surnames was further investigated through the relationship between the logarithm of the number of distinct surnames ((s)) and the logarithm of their frequency of occurrence ((k)). The relationship between $\log_2 s$ and $\log_2 k$ was examined separately for the Within and Outside population groups. For each group, the number of surnames occurring a specified number of times was determined, and the corresponding regression lines were constructed and compared. The regression coefficient of $\log_2 s$ on $\log_2 k$ was used to characterize differences in surname-frequency distributions between the two population groups (Lasker, 1985; Chatterjee et al., 2000).

Surname-based distance measures

Relationships between different temporal cohorts were investigated through the construction of surname-based distance matrices. Three measures were considered: the Lasker coefficient, a distance based on surname-frequency similarity, and standardized isonymy.

Lasker coefficient

The Lasker coefficient was calculated as the sum of the products of the relative frequencies of corresponding surnames in two different cohorts:

$$I_{ij}=\sum_k p_{ik}q_{jk}\tag{4}$$

where p_{ik} and q_{jk} represent the relative frequencies of the k-th surname in cohorts (i) and (j), respectively.

This coefficient was used to assess surname similarity between temporal cohorts and to evaluate changes in population composition over time.

Distance based on cosine similarity

The degree of dissimilarity between surname distributions across temporal cohorts was assessed using:

$$D=\sqrt{1-\cos\theta} \tag{5}$$

where: $\cos\theta=\sum_k\sqrt{p_{ik}q_{jk}}$

This measure evaluates the similarity between the surname-frequency distributions of two cohorts, with higher distance values indicating greater dissimilarity.

Standardized isonymy

Standardized isonymy between two populations or temporal cohorts was calculated according to Chen and Cavalli-Sforza (1983):

$$R_{ij}=\frac{I_{ij}}{\sqrt{I_{ii}\times I_{jj}}} \tag{6}$$

where (I_{ii}) and (I_{jj}) represent unexpected random isonymy within the respective populations, while (I_{ij}) represents the Lasker coefficient between them.

Estimation of inbreeding coefficients

The genetic structure of the population was further investigated through the estimation of inbreeding coefficients, which provide information on population isolation and the extent of surname sharing. The analysis considered three components: random inbreeding, non-random inbreeding, and total inbreeding, following the approaches described by Crow and Mange (1965) and Crow (1980).

The random inbreeding coefficient (F_r) was calculated as:

$$F_r=\frac{\sum_k p_{ik}q_{jk}}{4} \tag{7}$$

The non-random inbreeding coefficient (F_n) was estimated using:

$$F_n=\frac{I_{ii}-\sum_k p_{ik}q_{jk}}{4\left(1-\sum_k p_{ik}q_{jk}\right)} \tag{8}$$

The total inbreeding coefficient (F_t) was subsequently calculated as:

$$F_t=F_r(1-F_n)+F_n \tag{9}$$

These coefficients were estimated across the nine birth cohorts to assess temporal variation in the inbreeding structure of the population.

Analysis of age at marriage

Age at marriage was examined separately for male and female individuals using the recorded birth dates and marriage dates. The corresponding age distributions were constructed using frequency distributions, allowing the assessment of differences between sexes and temporal changes in marriage age.

Analysis of marital structure and endogamy–exogamy patterns

The marital structure of the population was investigated according to the birthplaces of both spouses. For this purpose, marriages were classified into three categories:

Both spouses born within the former district of Korçë.

One spouse born within the district of Korçë and the other born outside the district or abroad.

Both spouses born outside the district of Korçë.

The first category represented endogamous marriages, whereas the second and third categories represented exogamous marriages. The relative frequencies and percentages of each category were calculated across successive marriage periods, beginning in 1946. The temporal distribution of these categories was subsequently examined through graphical comparisons to identify changes in marital structure and the relative contribution of endogamous and exogamous unions.

Premarital migration analysis

Premarital migration was assessed by measuring the geographical distance, in kilometres, between each spouse's birthplace and the city of Korçë, where the marriage was registered. Distances were determined using straight-line geographical measurements rather than road distances.

Two separate indicators were considered:

The distance between the husband's birthplace and Korçë;

The distance between the wife's birthplace and Korçë.

The analysis was conducted separately for male and female individuals and according to the respective marriage cohorts. Endogamous marriages were excluded from this analysis because both spouses were born within the district under investigation. For each temporal cohort, descriptive statistical measures, including the mean, median, and standard deviation, were calculated to characterize the distribution of premarital migration

distances. Separate descriptive tables were constructed for men and women to facilitate comparisons of migration patterns and their temporal variation.

Additionally, the seasonal distribution of marriages was examined by recording the frequency of marriages across the twelve calendar months. Monthly frequencies were used to describe seasonal patterns in marriage occurrence.

Statistical processing

All data organization, calculations of population parameters, construction of frequency distributions, descriptive statistical analyses, and graphical representations were performed using Microsoft Excel. The analyses were primarily descriptive and comparative, focusing on temporal changes in surname diversity, population structure, inbreeding, marital patterns, and premarital migration.

RESULTS

The analysis of surname distribution and demographic characteristics revealed important patterns in the population structure of Korçë. Of the individuals included in the study, 9,828 were born in Korçë, whereas 2,628 originated from other locations. The predominance of locally born individuals was observed in both sexes, although the number of female migrants exceeded that of male migrants. Surname frequency analysis also revealed differences between the two groups, with only one surname (Prifti) appearing among the ten most frequent surnames in both locally born and migrant individuals.

Mean age at marriage showed an overall increasing trend in both sexes. Among men, the mean age increased from 28.71 years in the earliest period to 30.47 years in the latest period, while among women it increased from 22.96 to 24.99 years. The lowest values for both sexes were recorded during 1961–1971. Throughout the study period, men consistently married at an older age than women.

Surname distribution and regression analysis revealed differences between locally born and migrant individuals. The regression coefficients of the $\log_2 S$–$\log_2 k$ relationship were −2.0897 for the local group and −2.5076 for the migrant group, indicating a greater representation of unique surnames among migrants.

Population diversity and migration indicators further highlighted temporal differences in population structure. Fisher's α values were generally higher among migrants than among locally born individuals, with some exceptions across the studied periods. For the combined population, the highest value (1,374.26) was recorded in 1921–1930, whereas the lowest (821.78) occurred before 1910. Similarly, the Karlin–McGregor ν coefficient was consistently higher among migrants. Its maximum value for the total population (0.8259) occurred before 1910, while its minimum (0.3098) was recorded during 1951–1960.

Lasker and Euclidean distance analyses showed that Euclidean distances generally approached 1, whereas Lasker distances tended towards zero across the local, migrant and combined population groups, indicating patterns broadly consistent with the expected theoretical distributions under random association.

Temporal patterns of marital structure revealed a predominance of endogamous marriages throughout the study period (1946–2006). Their proportion ranged from 52.9% in 1956–1966 to 72.7% in 1986–1996. Conversely, exogamous marriages showed an overall declining tendency, reaching their lowest proportion (27.3%) during 1986–1996.

Premarital migration distances varied across periods and between sexes. The highest mean distance among men was recorded during 1986–1996 (454.64 km), whereas among women it occurred during 1996–2006 (226.69 km). Women's mean migration distances were generally higher than men's during the first four periods. High standard deviations in several periods reflected substantial variability and the influence of individuals originating from geographically distant locations.

Marriage seasonality showed a non-uniform monthly distribution, with the highest number of marriages recorded in July (663) and the lowest in November (359), suggesting seasonal variation in marriage patterns. Finally, **inbreeding coefficients** demonstrated temporal variation in the population's genetic structure. Both random inbreeding (Fr) and total inbreeding (Ft) reached their highest values before 1910. The lowest Fr value occurred during 1921–1930, while the lowest Ft values were recorded during 1921–1930 and 1941–1950. An inverse relationship was observed between Fisher's α and total inbreeding, indicating an association between surname diversity and the level of population inbreeding.

DISCUSSION

The findings provide insight into the demographic and microevolutionary dynamics of the population of Korçë, highlighting the influence of migration, marital patterns and temporal changes in surname diversity. Surnames, as indirect bio-cultural markers predominantly transmitted through the paternal line, offer a useful framework for investigating population differentiation and historical demographic processes.

The predominance of locally born individuals indicates the importance of the native population in the demographic structure of Korçë. Nevertheless, the presence of a considerable migrant component reflects the contribution of population movements to its demographic composition. Differences in surname distribution between local and migrant individuals suggest distinct patterns of familial and geographical origin, while the greater representation of unique surnames among migrants is consistent with their heterogeneous backgrounds.

The increase in mean age at marriage in both sexes reflects broader changes in marital behaviour over time. These changes may be associated with socioeconomic development, cultural transformations and the gradual modification of traditional family structures. The persistent age difference between men and women may also reflect historically established marriage customs and social expectations regarding the age of spouses.

The regression analysis and Fisher's α estimates provide further evidence of differences in surname diversity between the two population groups. The higher diversity observed among migrants may be attributed to their varied geographical origins and the introduction of surnames from different populations. These findings suggest that migration contributed to the diversification of the surname pool in Korçë and influenced its changing demographic structure.

The temporal variation in the Karlin–McGregor ν coefficient complements these observations, indicating differences in surname distribution and population composition across successive birth cohorts. The comparatively higher values among migrants are consistent with their greater surname heterogeneity. The lower values observed in certain periods may reflect changes in population composition and the relative predominance of specific surnames. Nevertheless, these indicators should be interpreted as indirect measures of demographic processes rather than direct estimates of migration rates.

The Lasker and Euclidean distance patterns provide additional information on the relationships between surname structures across different periods. Their proximity to the expected theoretical values suggests broadly compatible patterns of random association. However, surname-based distances alone cannot establish the absence of non-random marital preferences or specific population subdivisions.

The predominance of endogamous marriages throughout the study period indicates the continued importance of local marital connections. The increase in endogamy until 1986–1996, accompanied by a corresponding decline in exogamy, may reflect changes in social relationships, residential patterns and partner selection. Such tendencies may have contributed to the maintenance of local familial connections and influenced the population's demographic and biological structure.

Premarital migration distances reveal an additional dimension of population mobility. The considerable distances recorded, particularly during the later periods, suggest an expansion of the geographical range of population movements. Differences between men and women may reflect variations in migration patterns and the social and familial circumstances associated with settlement in Korçë. The substantial standard deviations also demonstrate the influence of individuals originating from distant locations, emphasizing the importance of considering both mean and median values when interpreting migration distances.

The seasonal distribution of marriages, characterized by a peak in July and a minimum in November, may be associated with climatic conditions, cultural traditions and social practices influencing the timing of marriage ceremonies.
Finally, the temporal patterns of inbreeding provide further evidence of changes in population structure. The inverse relationship between Fisher's α and total inbreeding suggests that greater surname diversity is generally associated with lower levels of inbreeding. The comparatively higher inbreeding values observed in earlier periods may reflect a more restricted structure of familial and marital associations, whereas subsequent changes may be related to increased population heterogeneity and demographic interactions.
Overall, the findings indicate that the population structure of Korçë has been shaped by the combined influence of migration, marital behaviour and temporal demographic changes. The integration of surname distribution, migration indicators, marital patterns and inbreeding coefficients demonstrates the value of surname-based analysis as an indirect approach to investigating population history and microevolutionary dynamics.

CONCLUSION

The analysis revealed a higher proportion of individuals born in Korçë ("Within") than those born outside the region ("Outside"), with the number of local males exceeding that of local females.
Mean age at marriage was consistently higher among males than females and showed an overall increasing trend across the study period.

Surname distribution indicated greater surname diversity among non-local individuals, as reflected by the steeper regression slope and the higher values of Fisher's α. Similarly, Karlin–McGregor's ν was higher in the non-local group, suggesting a stronger contribution of migration to its surname structure. These findings highlight the role of population mobility in shaping surname diversity.

The Euclidean and Lasker distance matrices showed values generally approaching their expected theoretical limits, indicating relatively weak differentiation between temporal groups and patterns broadly consistent with random population movements. Nevertheless, these indicators should be interpreted as indirect evidence of population structure and migration dynamics.

Marriage patterns showed an increasing tendency towards endogamy and a corresponding decline in exogamous unions over much of the study period. Premarital migration distances were broadly comparable between males and females, although notable gender differences emerged in some periods.

Finally, the relationship between Fisher's α and the total inbreeding coefficient indicated an inverse association: higher surname diversity was generally accompanied by lower levels of estimated total inbreeding.
Overall, the findings demonstrate that surname-based analysis provides valuable insight into the demographic structure, migration patterns, marital relationships, and microevolutionary dynamics of the population of Korçë.

REFERENCES

- Barrai I, Scapoli C, Beretta M, Nesti C, Mamolini E, Rodriguez-Larralde A 1996. Isonymy and the genetic structure of Switzerland. I. The distribution of surnames. Annals of Human Biology, 23(6): 431–455.
- Barrai I, Rodriguez-Larralde A, Mamolini E, Scapoli C 1999. Isonymy and isolation by distance in Italy. Human Biology, 71(6): 947–961.
- Chatterjee S, Hadi AS, Price B 2000. Regression Analysis by Example. 3rd ed. New York: John Wiley & Sons.
- Chen KH, Cavalli-Sforza LL 1983. Surnames in Taiwan: interpretations based on geography and history. Human Biology, 55(2): 367–374.

- Crow JF 1980. The estimation of inbreeding from isonymy. Human Biology, 52(1): 1–14.
- Crow JF, Mange AP 1965. Measurement of inbreeding from the frequency of marriages between persons of the same surname. Eugenics Quarterly, 12(4): 199–203.
- Darwin GH 1875. Marriages between first cousins in England and their effects. Journal of the Statistical Society of London, 38(2): 153–184.
- King TE, Jobling MA 2009. What's in a name? Y chromosomes, surnames and the genetic genealogy revolution. Trends in Genetics, 25(8): 351–360.
- Lasker GW 1985. Surnames and Genetic Structure. Cambridge: Cambridge University Press.
- Mikerezi I, Pizzetti P, Lucchetti E, Ekonomi M 2003. Isonymy and the genetic structure of Albanian populations. Collegium Antropologicum, 27(2): 507–514.
- Mikerezi I, Xhina E, Scapoli C, Barbujani G, Mamolini E, Sandri M, Carrieri A, Rodriguez-Larralde A, Barrai I 2013. Surnames in Albania: A study of the population of Albania through isonymy. Annals of Human Genetics, 77(3): 232–243.
- Rodriguez-Larralde A, Barrai I, Alfonzo JC 1993. Isonymy structure of four Venezuelan states. Annals of Human Biology, 20(2): 131–145.
- Rodriguez-Larralde A, Pavesi A, Scapoli C, Conterio F, Siri G, Barrai I 1994. Isonymy and the genetic structure of Sicily. Journal of Biosocial Science, 26(1): 9–24.
- Rodriguez-Larralde A, Gonzales-Martin A, Scapoli C, Barrai I 2003. The names of Spain: A study of the isonymy structure of Spain. American Journal of Physical Anthropology, 121(3): 280–292.
- Yasuda N, Morton NE 1967. Studies on human population structure. In: Crow JF, Neel JV (eds), Proceedings of the Third International Congress of Human Genetics. Baltimore: Johns Hopkins University Press, pp. 249–265.
- Zei G, Guglielmino Matessi R, Siri E, Moroni A, Cavalli-Sforza LL 1983. Surnames in Sardinia. I. Fit of frequency distributions for neutral alleles and genetic population structure. Annals of Human Genetics, 47: 329–352.

ECOLOGICAL TECHNOLOGY FOR CONVERSION OF WASTE BIOMASS TO FUNCTIONAL CARBON MATERIALS

Boyko Tsyntsarski
Ivanka Stoycheva
Nartzislav Petrov
Bilyana Petrova
Angelina Kosateva
Izabela Ivanova
Institute of Organic Chemistry with Centre of Phytochemistry, Bulgarian Academy of Sciences,
Acad. G. Bonchev str., BL. 9, Sofia 1113, Bulgaria

Abstract

Nowadays the conversion of waste biomass from fruit processing into useful products is important environmental challenge. Fruit stones are biomass waste from canning industry, and they are often subjected to combustion, however they have low calorific value and the process is associated with release of hazardous matererials, such as CO_2, SO_2, soot, etc. A solution of this problem can be development of a waste-free technology for processing the waste biomass by-products (peach stones, apricot stones, etc.) into high-quality nanoporous carbon with wide environmental application - in various purification technologies of air and water, catalysis, medicine, electronics, etc.

The main aim is the development of a waste-free technology for the conversion of waste biomass -, remaining after food processing, to nanoporous carbon adsorbent with high adsorption capacity. Other important issue is the apllication of obtained carbon adsorbent in purification filters for purifying flue gases from CO_2 and other harmful emissions. The obtained nanoporous carbon will be also used for the purification of drinking and wastewater from toxic organic pollutants and heavy metals. Carbon composites with metal nanoparticles will be preapared and further apllied in medicine against bacteria and viruses.

Keywords: waste utilization, biomass, hydro-pyrolysis, nanoporous carbon, water purification, antibacterial effect.

Acknowledgements: The authors acknowledge financial support by the International Polish-Bulgarian Project IC-PL/06/2026-2027.

NOVEL BOROPHOSPHATE GLASSES: SYNTHESIS, STRUCTURAL, PHYSICOCHEMICAL CHARACTERIZATION AND IN VITRO BIOACTIVITY

Ibtissam Zriaa
Noureddine Sajai
Abdellah El Boukili
Rachid Fakhreddine
Saida Krimi
0009-0008-1347-4500, Hassan II University of Casablanca, Faculty of Sciences Ain Chock, Chemistry Department, Laboratory of Materials, Processes and Environment Engineering (GeMaPE), Casablanca, Morocco.
0000-0001-9161-4080, Hassan II University of Casablanca, Faculty of Sciences Ain Chock, Chemistry Department, Laboratory of Materials, Processes and Environment Engineering (GeMaPE), Casablanca, Morocco.
0000-0003-2236-8773, Mohammed V University in Rabat, Ecole Normale Supérieure (ENS), Center for Materials Science, Laboratory of Physicochemistry of Inorganic and Organic Materials (LPCMIO), Rabat, Morocco.
0000-0002-4741-9509, Hassan II University of Casablanca, Faculty of Sciences Ain Chock, Chemistry Department, Laboratory of Materials, Processes and Environment Engineering (GeMaPE), Casablanca, Morocco.
0000-0001-5528-7991, Hassan II University of Casablanca, Faculty of Sciences Ain Chock, Chemistry Department, Laboratory of Materials, Processes and Environment Engineering (GeMaPE), Casablanca, Morocco.

Abstract

Phosphate glasses have attracted considerable interest due to their unique physicochemical properties, compositional flexibility and wide range of applications in optics, catalysis, energy storage, inorganic solid electrolytes, and environmental technologies. One of the most attractive features of phosphate glasses is their potential use as biomaterials because of their controlled dissolution behavior in physiological environments, making them promising candidates for bone repair and regeneration. In this context, the present work investigates the structural, thermal, physicochemical and in vitro bioactivity of borophosphate glasses in the Na_2O-CaO-MgO-B_2O_3-P_2O_5 system. Accordingly, a series of seven borophosphate glass compositions was synthesized using the conventional melt-quenching technique. The obtained glasses were characterized by several techniques, including X-ray diffraction (XRD), differential scanning calorimetry (DSC), density measurements, chemical durability tests, infrared spectroscopy (IR) and Raman spectroscopy. XRD analysis confirmed the amorphous nature of all prepared samples, while DSC measurements evidenced their glassy state through the observation of a glass transition. Replacing Na_2O with MgO resulted in a significant increase in both the glass transition temperature (Tg) and density (ρ), while the molar volume (V_m) decreased, suggesting enhanced structural compactness and stronger network connectivity. IR and Raman studies revealed that the glass structure consists of PO_4 tetrahedra, PO_2 chains and P_2O_7 pyrophosphate groups, as well as BO_4 tetrahedra, interconnected through P-O-P, P-O-B and B-O-B linkages. The bioactivity of two representative compositions (x = 0 and 5 mol % MgO) was evaluated by immersion in simulated body fluid (SBF). After 10 and 30 days of immersion, the formation of a hydroxyapatite layer on the glass surfaces was observed and confirmed by X-ray diffraction, infrared spectroscopy and scanning electron microscopy. These results suggest that the studied borophosphate glasses are promising candidates for the repair and regeneration of bone tissue.

Keywords: Boro-phosphate glass; XRD; IR; Raman spectroscopy; SEM; In vitro bioactivity.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

BRAIN ACTIVITY CLASSIFICATION WITH DEEP LEARNING AND EEG CHANNEL SELECTION

Etibar Vazirov
ADA University, School of IT and Engineering, Baku, Azerbaijan
Ayan Bayramova
Dunya School, Baku, Azerbaijan

Abstract

Electroencephalography (EEG) provides a non-invasive means of investigating changes in brain activity associated with cognitive tasks. However, developing reliable EEG classification systems remains challenging due to individual differences in neural signals, limited training data, and the complexity of multichannel recordings. Although deep learning has introduced increasingly sophisticated architectures, it remains unclear whether greater model complexity consistently improves classification performance or whether comparable results can be achieved using fewer EEG channels. This study investigates these questions through a comparative evaluation of machine learning, deep learning, and electrode selection strategies. Using the publicly available PhysioNet EEG During Mental Arithmetic Tasks dataset, recordings from 36 participants were processed into 853 non-overlapping ten-second segments representing brain activity before and during mental arithmetic. Three classification approaches—XGBoost, EEGNet, and a compact EEG Transformer—were evaluated using five-fold subject-independent cross-validation. Additionally, anatomical, data-driven, and random channel selection strategies were examined using configurations of three, five, and ten electrodes, with the complete 19-channel EEGNet serving as a reference. EEGNet model achieved the highest mean balanced accuracy (0.7275), outperforming XGBoost (0.6473) and the Transformer (0.5818). Data-driven channel selection consistently produced higher average balanced accuracy than anatomical and random selection across the reduced-channel configurations. Notably, the five-channel data-driven model achieved a mean ROC-AUC of 0.7705, approaching the 19-channel reference performance of 0.7722, although its balanced accuracy remained lower. Channel importance analysis also identified Fp1, O1, and Pz as frequently selected electrodes across validation folds.

These findings suggest that EEG-specific architectures and informed electrode selection offer promising opportunities for reducing recording complexity while retaining useful discriminative information. The study highlights the importance of subject-independent evaluation and provides an experimental foundation for developing more accessible EEG-based cognitive state monitoring systems.

Keywords: Electroencephalography (EEG), Cognitive State Classification, Deep Learning, EEGNet, Channel Selection, Explainable Machine Learning, Subject-Independent Cross-Validation.

I. INTRODUCTION

Electroencephalography (EEG) provides a non-invasive way to record brain activity and examine its changes during cognitive tasks. Recent advances in machine learning and deep learning have expanded the possibilities of EEG-based classification, although differences between individuals remain a major challenge [1], [2]. In particular, models trained on one group of participants may not perform equally well on previously unseen subjects. This makes subject-independent evaluation essential when assessing the practical reliability of EEG classification systems. Several approaches have been developed to address these challenges. EEGNet, introduced by Lawhern et al. [3], uses a compact convolutional architecture to learn spatial and temporal patterns from EEG recordings. More recent research has explored alternative learning strategies to improve generalization across individuals [1], [2]. However, choosing an appropriate model is only part of the problem. The number of EEG electrodes also affects the complexity and practicality of a recording system. Using fewer EEG channels can reduce preparation time, equipment requirements, and computational costs. Earlier research established channel selection as a useful approach to simplifying EEG analysis [4], while more recent work has demonstrated that substantial reductions in electrode count may be possible without severely

compromising classification performance [5]. Nevertheless, the effectiveness of a selected channel subset depends on the task, the classification model, and the evaluation procedure. This study investigates brain activity classification using the publicly available EEG During Mental Arithmetic Tasks dataset [6]. We compare XGBoost [7], EEGNet [3], and a compact Transformer using five-fold subject-independent cross-validation. We also examine anatomical, data-driven, and random channel selection strategies with three, five, and ten electrodes, using the complete 19-channel configuration as a reference. The main contribution of this work is a systematic comparison of classification models and channel selection strategies under a common evaluation protocol. Rather than introducing a new architecture, we investigate whether carefully selected EEG channels can retain useful predictive information and how consistently these channels are identified across different training folds. The findings provide practical insights into balancing classification performance and recording complexity in EEG-based systems. The remainder of the paper is organized as follows: Section IV presents the experimental results, Section V discusses the findings and limitations, and Section VI concludes the paper.

II. RELATED WORK

Recent research on EEG classification has focused on improving predictive performance while addressing the practical challenges of signal variability and limited training data. Sun and Mou [8] reviewed advances in EEG preprocessing, feature extraction, and classification, identifying convolutional neural networks as a widely adopted deep learning approach. Their review also highlighted cross-subject generalization and model interpretability as continuing challenges. Several studies have examined EEG signals during cognitive tasks. Mikheev et al. [9] compared different machine learning pipelines for identifying cognitive traits using EEG recordings collected during arithmetic, logical, and verbal tasks. Their findings demonstrated the usefulness of spectral features and statistical representations in subject-independent classification. More closely related to the present dataset, Coman et al. [10] investigated EEG recordings during mental arithmetic using spectral peaks and signal correlations. Their analysis showed that selected frequency bands and electrode locations can provide useful information for distinguishing recording conditions. Another research direction concerns reducing the number of EEG channels without losing important information. Guttmann-Flury et al. [11] reviewed electrode selection approaches based on source localization, emphasizing the relationship between channel configuration and classification performance. Aljalal et al. [12] applied multi-objective optimization to select EEG channels and features for mild cognitive impairment detection. Their results demonstrated that carefully chosen electrode subsets can outperform larger configurations in certain experimental settings. Similarly, Dharia et al. [13] investigated dataset-independent channel selection for emotion recognition, highlighting the importance of evaluating whether selected electrodes remain useful beyond the data used to identify them. Channel selection has also been combined directly with deep learning. Mwata-Velu et al. [14] explored EEG channel selection alongside deep network architectures for multiclass visual EEG classification, illustrating how electrode configuration and model design can be considered together. Although these studies demonstrate the potential of EEG classification and channel reduction, their experimental tasks, selection methods, and evaluation protocols differ. The present work therefore examines these factors within a single experimental setting. Using mental arithmetic EEG recordings, we compare three classification models and evaluate anatomical, data-driven, and random electrode selection under subject-independent cross-validation. We also examine how frequently individual channels are selected across training folds, providing an additional perspective on the stability of data-driven channel selection.

III. METHODOLOGY

A. Dataset and EEG Preprocessing. This study uses the publicly available EEG During Mental Arithmetic Tasks dataset from PhysioNet, which contains EEG recordings from 36 participants [6]. The classification task aims to distinguish baseline brain activity from activity recorded during mental arithmetic. Recent research has also examined EEG-based approaches for identifying cognitive activity associated with mental arithmetic [15]. The original recordings were sampled at 500 Hz and included 19 EEG channels. A band-pass filter between 1 and 40 Hz was applied to reduce low-frequency drift and high-frequency noise. The recordings were divided into non-overlapping 10-second epochs. For the deep learning models, the filtered signals were

downsampled to 128 Hz, producing an input representation of 19 channels and 1,280-time samples per epoch. After preprocessing, the dataset contained 853 epochs, including 637 baseline epochs and 216 mental arithmetic epochs. This class imbalance was considered during training and evaluation. The main dataset characteristics and experimental settings are summarized in Table I.

Parameter	Description
Dataset	PhysioNet EEG During Mental Arithmetic Tasks
Participants	36
EEG channels	19
Sampling frequency	500 Hz (original); 128 Hz (deep learning)
Band-pass filter	1–40 Hz
Epoch duration	10 s (non-overlapping)
Total epochs	853
Class distribution	Baseline: 637; mental arithmetic: 216
Spectral features	76 (19 channels × 4 frequency bands)
Classification models	XGBoost, EEGNet, Transformer
Evaluation protocol	5-fold subject-independent GroupKFold
Channel configurations	3, 5, 10, and 19

TABLE I. Dataset Characteristics and Experimental Setup.

B. Feature Extraction and Classification Models. Two complementary EEG representations were considered. XGBoost operated on frequency-domain features, while EEGNet and the compact Transformer learned directly from EEG time-series signals. For XGBoost, power spectral density (PSD) was estimated using Welch's method. Spectral power was extracted from four frequency bands: delta (1–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), and beta (13–30 Hz). The band power of channel c within frequency band b was calculated as follows:

$$P_{c,b} = \int_{f_{\text{low}}^{(b)}}^{f_{\text{high}}^{(b)}} S_c(f)\, df \qquad (1)$$

where $S_c(f)$ represents the estimated power spectral density of channel c, and $f_{\text{high}}^{(b)}$ and $f_{low}^{(b)}$ denote the lower and upper frequency limits of band b, respectively. The integration was approximated numerically. Four frequency bands from each of the 19 channels produced 76 spectral features per epoch. These features were log-transformed before classification. Three classification models were evaluated. XGBoost served as a feature-based machine learning baseline, using 300 estimators, a maximum tree depth of three, and a learning rate of 0.05 [7]. EEGNet employed temporal convolutions, depthwise spatial filtering, and separable convolutions to capture EEG-specific patterns with a relatively compact architecture [3]. The Transformer combined convolutional temporal embeddings with two encoder layers, four attention heads, and a 64-dimensional embedding space. Recent studies have investigated Transformer-based architectures for extracting temporal and spatial information from EEG recordings [16], [17].

For the deep learning models, normalization parameters were estimated exclusively from the training data. To address the unequal class distribution, weighted cross-entropy was used:

$$\mathcal{L}_{\mathrm{WCE}} = -\frac{1}{N}\sum_{i=1}^{N} w_{y_i} \log p_\theta\,(y_i \mid x_i) \qquad (2)$$

where N is the number of training samples, w_{y_i} denotes the weight assigned to the true class of sample i, and $\mathrm{p}_\theta(y_i \mid x_i)$ represents the predicted probability of that class. For each class k, its weight was calculated as $w_k = \frac{N}{2N_k}$ where N_k is the number of training samples belonging to class k. The class weights were recomputed for each training fold. Both neural networks were trained using the AdamW optimizer, with learning rates of 0.001 for EEGNet and 0.0003 for the Transformer. Training was limited to 80 epochs, with early stopping after 12 consecutive epochs without improvement in validation loss.

C. EEG Channel Selection. Three channel selection strategies were investigated to determine whether a reduced number of electrodes could preserve useful classification information: anatomical, data-driven, and random selection. Each strategy was evaluated using subsets of three, five, and ten channels. The complete 19-channel EEGNet served as the reference configuration. The anatomical strategy used predefined electrode groups representing different scalp regions. The random strategy selected channels without replacement, with five independently sampled subsets for each channel count and cross-validation fold. For data-driven selection, XGBoost was trained on spectral features obtained exclusively from the training subjects. Feature importance values were aggregated across the four frequency bands associated with each electrode. The overall importance of channel c was defined as:

$$I(c) = \sum_{b\in\{\delta,\theta,\alpha,\beta\}} \mathrm{Imp}_{\mathrm{XGB}}(c,b) \qquad (3)$$

where $\mathrm{Imp}_{\mathrm{XGB}}(c,b)$ represents the XGBoost feature importance assigned to frequency band b of channel c. Channels were ranked according to their aggregated importance scores, and the three, five, or ten highest-ranked electrodes were selected. Recent research has explored feature-based channel selection as a means of reducing EEG acquisition requirements while retaining useful classification performance [18]. In the present study, channel ranking was performed independently within each training fold to prevent information from held-out subjects from influencing the selection process. EEGNet was subsequently retrained from scratch for each selected channel configuration. To examine selection stability, the frequency with which each electrode appeared among the five highest-ranked channels across the five folds was also recorded.

D. Subject-Independent Evaluation. A five-fold GroupKFold cross-validation procedure was employed to evaluate generalization to unseen participants. All epochs belonging to the same participant were assigned to the same fold, ensuring that recordings from one subject did not appear in both training and testing partitions. This distinction is important in EEG classification because inappropriate data splitting may produce overly optimistic results through subject-specific information leakage [19].

Within each outer fold, a separate subject-disjoint validation subset was created from the training participants. This subset was used for early stopping and model selection, while the held-out test subjects were reserved for final evaluation. Recent cross-subject EEG research has also explored transfer learning and attention-based architectures to address variability between participants [20]. Four evaluation metrics were considered: accuracy, balanced accuracy, macro-averaged F1-score, and ROC-AUC. Balanced accuracy and macro-F1 were particularly important because the dataset contained substantially more baseline epochs than mental arithmetic epochs. The results were summarized as the mean and standard deviation across the five test folds. The complete experimental workflow is illustrated in Fig. 1.

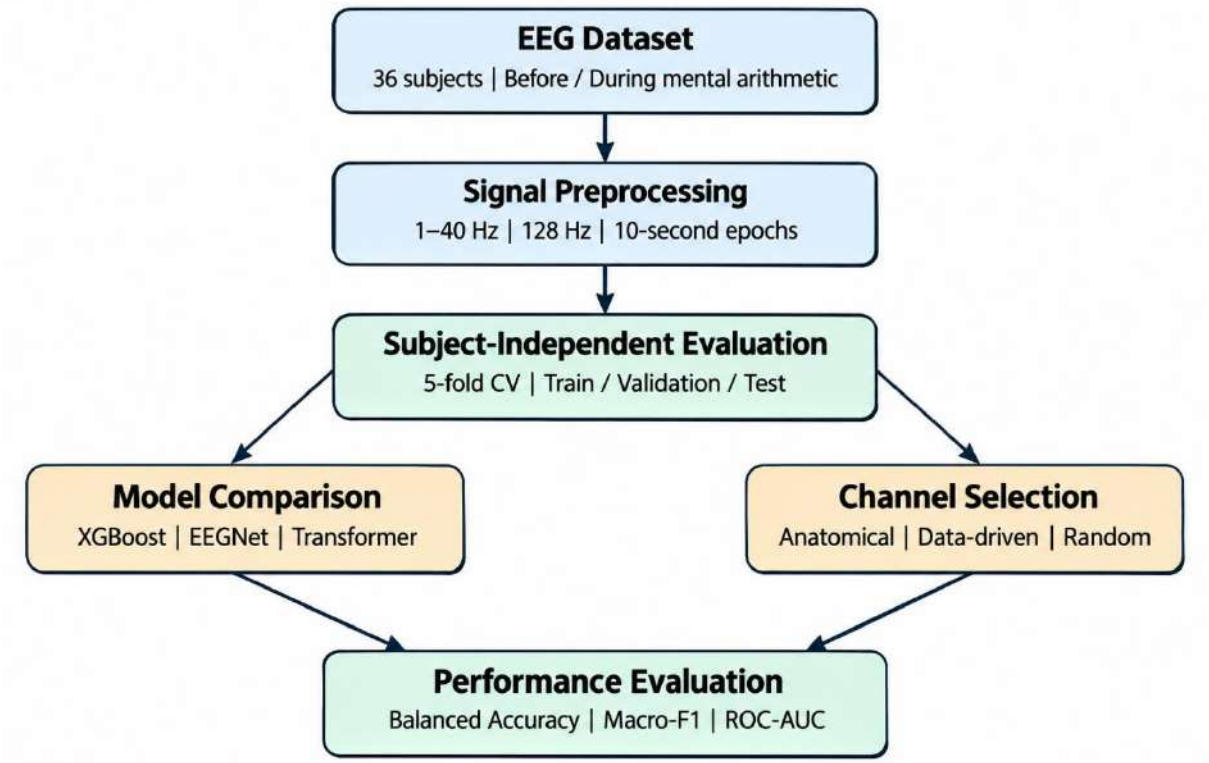


Fig. 1. Overview of the EEG classification framework, including signal preprocessing, subject-independent evaluation, model comparison, channel selection, and performance assessment.

As shown in Fig. 1, the framework consists of two complementary experiments: comparing classification architectures and investigating EEG channel reduction. Both experiments follow the same subject-independent evaluation protocol, while data-driven channel ranking is restricted to the corresponding training data. This allows model performance, electrode selection strategies, and channel selection stability to be examined within a consistent experimental setting.

IV. EXPERIMENTAL RESULTS

A. Experimental Setting. All experiments were evaluated using five-fold subject-independent cross-validation on 853 EEG epochs from 36 participants. The same outer folds were used for model comparison and channel selection experiments. Performance was reported as the mean and standard deviation across the five test folds. The initial experiment compared XGBoost, EEGNet, and a compact Transformer using the complete 19-channel EEG recordings. The second experiment evaluated EEGNet with three, five, and ten channels selected through anatomical, data-driven, and random strategies. The full 19-channel EEGNet was retained as the reference configuration.

B. Classification Model Comparison. Table II presents the performance of the three classification models. EEGNet achieved the highest balanced accuracy (0.7275 ± 0.0982) and macro-F1 (0.6969 ± 0.0912). XGBoost obtained the highest overall accuracy (0.7476 ± 0.0537), although its balanced accuracy was lower at 0.6473 ± 0.0660. EEGNet also achieved the highest mean ROC-AUC (0.7722 ± 0.1151), slightly exceeding XGBoost (0.7672 ± 0.0703). The compact Transformer produced lower results across all four metrics, with balanced accuracy of 0.5818 ± 0.0814 and macro-F1 of 0.5387 ± 0.0558.

Model	Accuracy	Balanced Accuracy	Macro-F1	ROC-AUC
XGBoost	0.7476 ± 0.0537	0.6473 ± 0.0660	0.6475 ± 0.0708	0.7672 ± 0.0703
EEGNet	0.7432 ± 0.0894	0.7275 ± 0.0982	0.6969 ± 0.0912	0.7722 ± 0.1151
Transformer	0.6384 ± 0.0701	0.5818 ± 0.0814	0.5387 ± 0.0558	0.6781 ± 0.0725

TABLE II. Classification Performance of XGBoost, EEGNet, and Transformer Models

(Mean ± Standard Deviation Across Five Folds).

C. Performance of EEG Channel Selection Strategies. The channel selection experiment evaluated anatomical, data-driven, and random strategies using three, five, and ten EEG channels. Data-driven selection achieved the highest mean balanced accuracy at every channel count, reaching 0.6628, 0.6709, and 0.6874, respectively. In comparison, anatomical selection achieved 0.6164, 0.6376, and 0.6600, while random selection obtained 0.6173, 0.6578, and 0.6782.

The five-channel data-driven configuration achieved a ROC-AUC of 0.7705 ± 0.0878, close to the full 19-channel EEGNet result of 0.7722 ± 0.1151. However, its balanced accuracy remained lower (0.6709 ± 0.0618 versus 0.7275 ± 0.0982). Among the reduced-channel configurations, the ten-channel data-driven model achieved the highest mean balanced accuracy (0.6874 ± 0.1135) and ROC-AUC (0.7767 ± 0.0988). The highest reduced-channel macro-F1 was obtained with the three-channel data-driven configuration (0.6193 ± 0.0696).

The Figure 2 given below presents the relationship between the number of selected EEG channels and classification performance. The two panels show balanced accuracy and ROC-AUC for anatomical, data-driven, and random selection strategies, with error bars indicating the standard deviation across the five cross-validation folds.

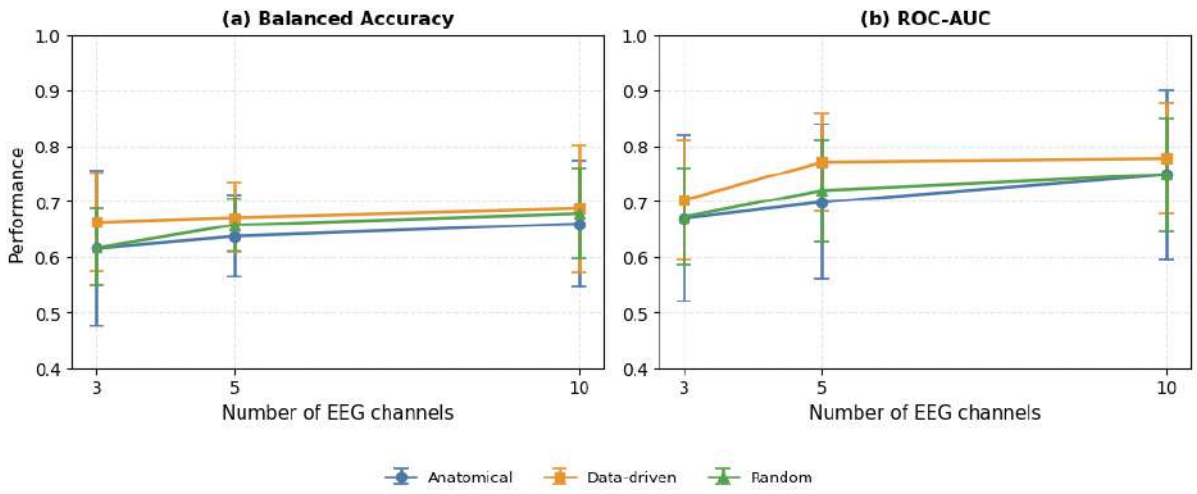


Fig. 2. Balanced accuracy and ROC-AUC across reduced EEG channel configurations (3, 5, and 10 channels) for anatomical, data-driven, and random selection strategies. Error bars represent standard deviations across five folds.

D. Channel Selection Stability. The stability of data-driven channel selection was examined by recording how frequently each electrode appeared among the five highest-ranked channels across the cross-validation folds.

As shown in Fig. 3, Fp1 was selected in all five folds, followed by O1 in four folds and Pz in three folds. F8, Fp2, and O2 each appeared in two folds, while several other electrodes were selected only once.

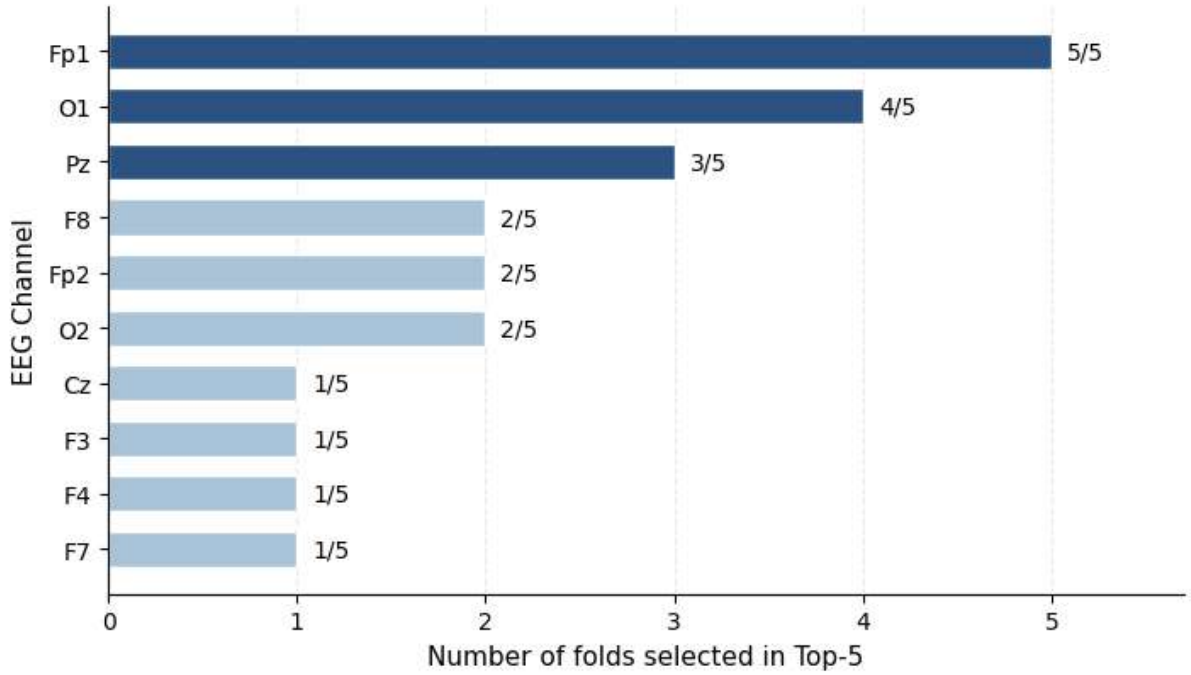


Fig. 3. Frequency of EEG electrode selection among the five highest-ranked channels across five subject-independent cross-validation folds.

The channel ranking results show that Fp1, O1, and Pz were selected more frequently than other electrodes across the five cross-validation folds. However, the remaining channels appeared less consistently, indicating some variation in electrode importance across different training partitions.

V. DISCUSSION

The experimental results highlight the importance of model architecture and electrode selection in EEG-based cognitive activity classification. EEGNet achieved higher balanced accuracy and macro-F1 than XGBoost and the compact Transformer, suggesting that its EEG-specific convolutional structure was better suited to the available recordings. Although XGBoost achieved slightly higher overall accuracy, its lower balanced accuracy indicates less consistent performance across the two classes. The Transformer produced weaker results, which may partly reflect the limited number of participants and training samples. The channel selection experiments revealed a trade-off between electrode count and classification performance. Data-driven selection achieved the highest mean balanced accuracy across all reduced-channel configurations. In particular, the five-channel model obtained a ROC-AUC close to that of the full 19-channel EEGNet, although its balanced accuracy and macro-F1 remained lower. This suggests that a smaller electrode set can retain useful discriminative information, but similar ROC-AUC values should not be interpreted as equivalent overall performance. These findings are consistent with previous research highlighting the potential of informed EEG channel selection [11], [18]. The frequent selection of Fp1, O1, and Pz indicates that certain electrodes contributed more consistently to the classification task across training folds. However, feature importance does not establish a direct physiological explanation for these patterns.

Several limitations should be acknowledged. The dataset included only 36 participants and showed substantial class imbalance, limiting the generalizability of the findings. Moreover, the experiments were conducted on a single dataset, without external validation or statistical significance testing between configurations. Although subject-independent cross-validation reduced the risk of participant-level data leakage, further evaluation is needed before drawing conclusions about performance in real-world EEG monitoring systems.

VI. CONCLUSION

This study compared XGBoost, EEGNet, and a compact Transformer for mental arithmetic EEG classification and investigated three electrode selection strategies under subject-independent evaluation. EEGNet achieved the highest balanced accuracy (0.7275), while data-driven channel selection consistently outperformed anatomical and random selection in balanced accuracy across the reduced-channel configurations. Notably, the five-channel data-driven model achieved a ROC-AUC of 0.7705, close to the full 19-channel reference of 0.7722, although other performance measures remained lower. Future work will focus on evaluating the proposed approach using larger and independent EEG datasets, examining the statistical reliability of performance differences, and assessing channel selection stability across recording sessions. Further investigation of lightweight models and practical electrode configurations may also help determine whether reduced-channel EEG systems can support reliable cognitive activity monitoring.

REFERENCES

[1] H. W. Ng and C. Guan, “Subject-independent meta-learning framework towards optimal training of EEG-based classifiers,” Neural Networks, vol. 172, Art. no. 106108, 2024, doi: 10.1016/j.neunet.2024.106108.

[2] S. Sartipi and M. Cetin, “Subject-independent deep architecture for EEG-based motor imagery classification,” IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 32, pp. 718–727, 2024, doi: 10.1109/TNSRE.2024.3360194.

[3] V. J. Lawhern et al., “EEGNet: A compact convolutional neural network for EEG-based brain–computer interfaces,” Journal of Neural Engineering, vol. 15, no. 5, Art. no. 056013, 2018, doi: 10.1088/1741-2552/aace8c.

[4] T. Alotaiby, F. E. Abd El-Samie, S. A. Alshebeili, and I. Ahmad, “A review of channel selection algorithms for EEG signal processing,” EURASIP Journal on Advances in Signal Processing, vol. 2015, Art. no. 66, 2015, doi: 10.1186/s13634-015-0251-9.

[5] C.-M. Huang, W.-L. Lai, C.-C. Yang, Y.-J. Hsieh, C.-M. Wu, and C.-H. Lee, “EEG channel localization and selection via training with noise injection for BCI applications,” in Proc. 46th Annu. Int. Conf. IEEE Engineering in Medicine and Biology Society (EMBC), 2024, pp. 1–4, doi: 10.1109/EMBC53108.2024.10782774.

[6] I. Zyma, S. Tukaev, I. Seleznov, K. Kiyono, A. Popov, M. Chernykh, and O. Shpenkov, “Electroencephalograms during mental arithmetic task performance,” Data, vol. 4, no. 1, Art. no. 14, 2019, doi: 10.3390/data4010014.

[7] T. Chen and C. Guestrin, “XGBoost: A scalable tree boosting system,” in Proc. 22nd ACM SIGKDD Int. Conf. Knowledge Discovery and Data Mining (KDD), 2016, pp. 785–794, doi: 10.1145/2939672.2939785.

[8] C. Sun and C. Mou, “Survey on the research direction of EEG-based signal processing,” Frontiers in Neuroscience, vol. 17, Art. no. 1203059, 2023, doi: 10.3389/fnins.2023.1203059.

[9] I. Mikheev, H. Steiner, and O. Martynova, "Detecting cognitive traits and occupational proficiency using EEG and statistical inference," Scientific Reports, vol. 14, Art. no. 5605, 2024, doi: 10.1038/s41598-024-55163-w.

[10] D. A. Coman, S. Ionita, and I. Lita, "Evaluation of EEG signals by spectral peak methods and statistical correlation for mental state discrimination induced by arithmetic tasks," Sensors, vol. 24, no. 11, Art. no. 3316, 2024, doi: 10.3390/s24113316.

[11] E. Guttmann-Flury, X. Sheng, and X. Zhu, "Channel selection from source localization: A review of four EEG-based brain-computer interfaces paradigms," Behavior Research Methods, vol. 55, no. 4, pp. 1980–2003, 2023, doi: 10.3758/s13428-022-01897-2.

[12] M. Aljalal, S. A. Aldosari, M. Molinas, and F. A. Alturki, "Selecting EEG channels and features using multi-objective optimization for accurate MCI detection: Validation using leave-one-subject-out strategy," Scientific Reports, vol. 14, Art. no. 12483, 2024, doi: 10.1038/s41598-024-63180-y.

[13] S. Y. Dharia, S. G. Camorlinga, C. E. Valderrama, and M. Hojjati, "Dataset-independent EEG channel selection for emotion recognition," in Proc. 46th Annu. Int. Conf. IEEE Engineering in Medicine and Biology Society (EMBC), 2024, pp. 1–4, doi: 10.1109/EMBC53108.2024.10782444.

[14] T. Mwata-Velu, E. Zamora, J. I. Vasquez-Gomez, J. Ruiz-Pinales, and H. Sossa, "Multiclass classification of visual electroencephalogram based on channel selection, minimum norm estimation algorithm, and deep network architectures," Sensors, vol. 24, no. 12, Art. no. 3968, 2024, doi: 10.3390/s24123968.

[15] M. Aslam, "Electroencephalograph (EEG) based classification of mental arithmetic using explainable machine learning," Biocybernetics and Biomedical Engineering, vol. 45, no. 2, pp. 154–169, 2025, doi: 10.1016/j.bbe.2025.02.002.

[16] E. Shi et al., "MEET: A multi-band EEG Transformer for brain states decoding," IEEE Transactions on Biomedical Engineering, vol. 71, no. 5, pp. 1442–1453, 2024, doi: 10.1109/TBME.2023.3339892.

[17] M. A. Pfeffer, S. S. H. Ling, and J. K. W. Wong, "Exploring the frontier: Transformer-based models in EEG signal analysis for brain-computer interfaces," Computers in Biology and Medicine, vol. 178, Art. no. 108705, 2024, doi: 10.1016/j.compbiomed.2024.108705.

[18] L. Wang, J. Wang, H. Su, X. Zhang, L. Zhang, and X. Kang, "A zero precision loss framework for EEG channel selection: Enhancing efficiency and maintaining interpretability," Computer Methods in Biomechanics and Biomedical Engineering, vol. 29, no. 3, pp. 528–543, 2026, doi: 10.1080/10255842.2024.2401918.

[19] G. Brookshire et al., "Data leakage in deep learning studies of translational EEG," Frontiers in Neuroscience, vol. 18, Art. no. 1373515, 2024, doi: 10.3389/fnins.2024.1373515.

[20] J. Luo, W. Cui, S. Xu, L. Wang, H. Chen, and Y. Li, "A cross-scale Transformer and triple-view attention-based domain-rectified transfer learning for EEG classification in RSVP tasks," IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 32, pp. 672–683, 2024, doi: 10.1109/TNSRE.2024.3359191.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

CAN AI REALLY FORGET? EVALUATING MACHINE UNLEARNING UNDER DATA POISONING

Etibar Vazirov
ADA University, School of IT and Engineering, Baku, Azerbaijan
Marat Salim
Czech Technical University in Prague, Prague, Czech Republic

Abstract

Machine unlearning aims to remove the influence of selected training samples from a machine learning model without the computational cost of complete retraining. However, determining whether a model has genuinely forgotten unwanted information remains challenging, particularly when its training data have been deliberately manipulated. This study investigates the effectiveness and reliability of approximate machine unlearning under targeted label-flipping attacks, focusing on whether improvements in classification performance reflect meaningful reductions in poisoning effects. Experiments are conducted using a convolutional neural network trained on Fashion-MNIST, where selected Sneaker images are intentionally mislabeled as Ankle Boots. We evaluate retain-only fine-tuning against poisoned baselines, retrained reference models, and ordinary fine-tuning without data removal. Additionally, three sample-selection strategies—gradient norm, poisoning confidence, and gradient alignment—are compared with random selection. Evaluation considers classification accuracy, attack-related errors, prediction agreement, target-class probabilities, and forgetting stability. In the final experimental setup, the poisoned model achieves 83.38% test accuracy, with 43.90% of Sneaker test images incorrectly classified as Ankle Boots. Following three fine-tuning epochs, retain-only training reduces the mean target-class probability on poisoned training samples from 49.54% to 11.64%, compared with 28.24% under full-data fine-tuning. Both approaches maintain approximately 87% test accuracy. Across three training seeds, gradient norm and random selection produce similar mean absolute residual gaps of 0.0261 and 0.0297, respectively, while gradient alignment achieves the highest average prediction agreement. These findings highlight the importance of distinguishing reduced poisoning behaviour from verified data forgetting. Although the experiments demonstrate measurable improvements after data removal, differences across evaluation metrics and reference models limit stronger conclusions. The study provides an exploratory comparison emphasizing careful evaluation of machine unlearning in adversarial learning settings.

Keywords: Machine Unlearning; Data Poisoning; Approximate Unlearning; Label-Flipping Attacks; Forgetting Evaluation; Gradient-Based Sample Selection.

I. INTRODUCTION

Machine learning models increasingly rely on large datasets whose contents may later need to be corrected or removed. However, deleting training records does not necessarily eliminate their influence on an already trained model. Machine unlearning addresses this challenge by attempting to remove the effects of selected training samples without the computational expense of complete retraining [1-3]. Although several approaches have been developed, reliably evaluating whether a model has forgotten specific information remains an open problem, particularly for deep neural networks. This challenge becomes more significant when training data have been deliberately manipulated. Data poisoning attacks introduce misleading information during training to influence a model's predictions [4]. In label-flipping attacks, an adversary changes the class labels of selected examples while leaving their original features unchanged. Such manipulation can create systematic classification errors that may persist even after the poisoned samples are removed. Consequently, improved prediction accuracy alone cannot establish that the model has eliminated the influence of malicious training data. Recent studies have explored approximate unlearning techniques for deep learning models [5], [6]. However, the effectiveness of these methods can depend on which samples are selected for removal and how forgetting is measured. Zhao et al. [7] demonstrated that forget-set characteristics substantially affect

unlearning difficulty, while Pawelczyk et al. [8] showed that existing unlearning methods may fail to eliminate poisoning effects. These findings highlight the need for evaluation strategies that consider both general predictive performance and attack-specific behaviour. Motivated by these challenges, this study investigates approximate machine unlearning under targeted label-flipping attacks using Fashion-MNIST and a convolutional neural network. Selected Sneaker images are deliberately mislabelled as Ankle Boots, and the resulting poisoning effects are examined through different unlearning configurations. We compare gradient norm, poisoning confidence, gradient alignment, and random sample selection, using retrained models as references. A separate fine-tuning control further examines whether improvements arise from removing poisoned examples or simply from additional training. The main contribution of this work is a comparative experimental evaluation of poisoning mitigation and forgetting behaviour rather than a new unlearning algorithm. By examining classification accuracy, attack-related errors, target-class probabilities, and prediction agreement, we investigate whether different evaluation metrics support consistent conclusions about unlearning effectiveness. The findings provide insights into the practical limitations of approximate unlearning and emphasize the importance of distinguishing improved model behaviour from verified forgetting. The remainder of this paper is organized as follows. Section II discusses related work, Section III presents the methodology, and Section IV reports the experimental results. Section V discusses the findings and limitations, while Section VI concludes the paper and outlines future research directions.

II. RELATED WORK

Research on machine unlearning has developed alongside growing concerns about the reliability of training data and the persistence of unwanted information in learned models. Existing approaches range from certified removal procedures to approximate methods that update model parameters without complete retraining [2], [3], [5]. Kurmanji et al. [6] examined unlearning across different objectives, including correcting errors caused by mislabelled examples, while Zhao et al. [7] demonstrated that the characteristics of the forget set can substantially affect the difficulty of removal. These studies suggest that unlearning effectiveness cannot be assessed independently of the data being forgotten.

Data poisoning presents a particularly challenging setting because malicious examples are introduced during training to influence subsequent predictions. Xu et al. [9] investigated label-flipping attacks and showed how carefully selected label modifications can compromise learning systems. In this context, identifying which examples contribute most strongly to undesirable behavior becomes an important consideration. Koh and Liang [10] introduced influence functions for tracing model predictions back to individual training samples, while Pruthi et al. [11] proposed TracIn, which estimates training-data influence using gradients collected during optimization. Ghorbani and Zou [12] further explored the valuation of individual training examples through Data Shapley. Although these methods offer useful perspectives on sample importance, their scores do not automatically establish how effectively a model will forget a selected example. Evaluating the outcome of unlearning introduces another challenge. Triantafillou et al. [13] examined methods and evaluation practices from the first NeurIPS machine unlearning competition, emphasizing the need to consider forgetting quality alongside model utility. Broader assessments of unlearning techniques have similarly identified trade-offs between removal effectiveness, computational efficiency, and verification [14]. More recently, Dorna et al. [15] demonstrated the importance of comparing multiple evaluation metrics rather than relying on a single indicator of forgetting, although their benchmark focuses on large language models. Particularly relevant to adversarial settings, Pawelczyk et al. [8] reported that approximate unlearning may leave poisoning effects insufficiently removed. Building on these findings, the present study examines targeted label poisoning through a controlled image-classification experiment. Unlike work primarily concerned with proposing new removal algorithms or estimating sample influence, our focus is on comparing practical selection criteria and interpreting their outcomes against retrained references. By including random selection and a separate full-data fine-tuning control, we investigate whether apparent recovery reflects sample removal, additional optimization, or differences between evaluation measures.

III. METHODOLOGY

A. Dataset and Targeted Poisoning. The experiments were conducted using Fashion-MNIST [16], consisting of 70,000 grayscale images across ten clothing categories. A balanced training subset of 12,000 images was selected, with 1,200 samples per class, while the original 10,000-image test set was used for evaluation. A convolutional neural network (CNN) with two convolutional blocks and fully connected classification layers was trained using cross-entropy loss and the Adam optimizer [17]. A targeted label-flipping attack was introduced by changing the labels of 360 Sneaker images (class 7) to Ankle Boot (class 9), without modifying their visual content. This represents 3% of the training subset and 30% of its Sneaker samples. Following the general label-manipulation setting described in [9], the poisoning procedure is defined in Eq. (1).

$$\tilde{y}_i = \begin{cases} 9, & i \in \mathcal{P} \\ y_i, & i \notin \mathcal{P} \end{cases} \quad (1)$$

Here, $\mathcal{P}$ denotes the set of poisoned training samples, y_i is the original label, and $\tilde{y}_{i\text{i}}$ is the modified label.

B. Approximate Unlearning and Sample Selection. The poisoned CNN was used as the starting point for approximate unlearning. Selected poisoned samples were excluded from subsequent training, and the existing model was fine-tuned using the retained dataset. For comparison, a reference model was trained from its initial parameters on the corresponding retained samples, following retraining-based evaluation practices [2], [3]. Four selection strategies were examined: gradient norm, poisoning confidence, gradient alignment, and random selection. Gradient norm measured the magnitude of the final-layer loss gradient, while poisoning confidence represented the probability assigned to the incorrect target class. Gradient alignment evaluated the similarity between individual sample gradients and a reference gradient associated with the attack objective. These criteria draw on established approaches to training-data influence and sample selection [7], [10], [11]. For each strategy, 120 of the 360 poisoned examples were selected for removal, leaving the other 240 in the retained training data. Random selection served as a baseline. For gradient alignment, the reference gradient was calculated using 256 held-out Sneaker test images assigned the attack target label. Because this procedure used test data during selection, the resulting comparisons were treated as exploratory rather than fully test-independent. The overall experimental process is illustrated in Fig. 1, covering data poisoning, sample selection, approximate unlearning, reference retraining, and evaluation.

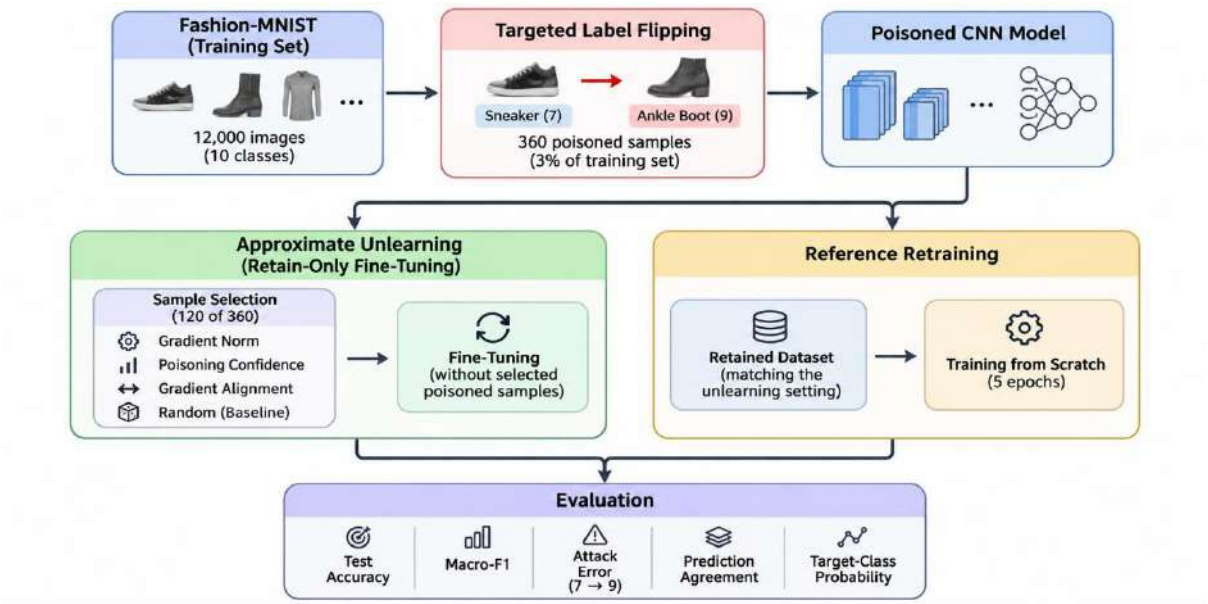


Fig. 1. Experimental workflow for targeted label flipping, sample selection, approximate unlearning, and reference retraining.

C. Experimental Configuration. The poisoned CNN was initially trained for five epochs using Adam with a learning rate of 0.001 and a batch size of 128. In the sample-selection experiments, approximate unlearning

was performed for two epochs at a learning rate of 0.0001, while reference models were retrained for five epochs at 0.001. To examine variability, the four selection strategies were evaluated across three downstream training seeds: 42, 123, and 2026. The same poisoned checkpoint was reused throughout these comparisons, with score-based forget sets held fixed. An additional control experiment compared three epochs of fine-tuning on the complete poisoned dataset against fine-tuning after removing all 360 poisoned samples. Both models were initialized from the same poisoned checkpoint.

D. Evaluation Metrics. Model performance was assessed using classification accuracy, macro-F1, source-to-target attack error, prediction agreement, and the mean target-class probability assigned to forgotten examples. In line with poisoning-aware unlearning evaluation [8], the absolute residual gap was used to compare the unlearned model with its retrained reference.

$$G_{\text{abs}} = \left| \frac{1}{|\mathcal{F}|} \sum_{x \in \mathcal{F}} p_{\theta_u}(9 \mid x) - \frac{1}{|\mathcal{F}|} \sum_{x \in \mathcal{F}} p_{\theta_r}(9 \mid x) \right| \quad (2)$$

Here, $\mathcal{F}$ is the selected forget set, and $p_{\theta_u}(9 \mid x)$ and $p_r(9 \mid x)$denote the probabilities assigned to class 9 by the unlearned and retrained models, respectively. A smaller residual gap indicates closer agreement in average target-class probability but does not guarantee complete removal of the forgotten samples' influence.

IV. EXPERIMENTAL RESULTS

A. Poisoning Impact and Initial Unlearning. The initial experiments examined how targeted label flipping affected classification performance and whether subsequent training on retained data could reduce the resulting errors. In the first experimental phase, the clean CNN achieved 87.23% test accuracy, compared with 85.66% for the poisoned model. The source-to-target error increased from 2.7% to 11.6%, indicating that the altered labels influenced predictions on previously unseen Sneaker images. After approximate unlearning through retain-only fine-tuning, test accuracy reached 88.07%, while the source-to-target error decreased to 4.7%. Additional training revealed fluctuations in attack-related measurements, suggesting that improved classification performance did not necessarily correspond to consistently stable forgetting behaviour. The gradient-based grouping experiment also produced non-monotonic residual gaps across low-, medium-, and high-gradient samples, indicating that larger gradient magnitudes were not consistently associated with greater remaining poisoning effects.

B. Comparison of Sample Selection Strategies. The subsequent experimental phase evaluated four strategies for selecting poisoned samples for removal: Gradient Norm, Poisoning Confidence, Gradient Alignment, and Random selection. Each method was assessed across three downstream training seeds, with the same poisoned checkpoint used throughout. Table I reports the mean absolute residual gap relative to reference retraining and prediction agreement on the test set.

Selection Strategy	Absolute Res. Gap (Mean ± SD)	Pred. Agreement (Mean ± SD)
Gradient Norm	0.0261 ± 0.0321	0.9381 ± 0.0156
Poisoning Confidence	0.0883 ± 0.0497	0.9220 ± 0.0037
Gradient Alignment	0.0898 ± 0.0170	0.9458 ± 0.0076
Random	0.0297 ± 0.0388	0.9286 ± 0.0279

TABLE I. Comparison of Sample Selection Strategies Across Three Downstream Training Seeds.

Gradient Norm produced the lowest mean absolute residual gap (0.0261), although Random selection achieved a comparable value (0.0297). Gradient Alignment obtained the highest prediction agreement (94.58%) but showed a larger residual gap (0.0898). These results indicate that methods yielding similar predictions to a

retrained model do not necessarily exhibit comparable behaviour on the selected forgotten samples. Given the limited number of downstream runs and the observed variability, the results do not establish a consistent advantage of gradient-based selection over the random baseline.

C. Fine-Tuning With and Without Poisoned Samples. The final experiment investigated whether the observed reduction in poisoning effects could be attributed to removing corrupted examples rather than simply continuing model training. Two copies of the same poisoned CNN were fine-tuned for three epochs: one using the complete poisoned dataset (Full-Data) and the other using only the retained samples after removing all 360 poisoned examples (Retain-Only).

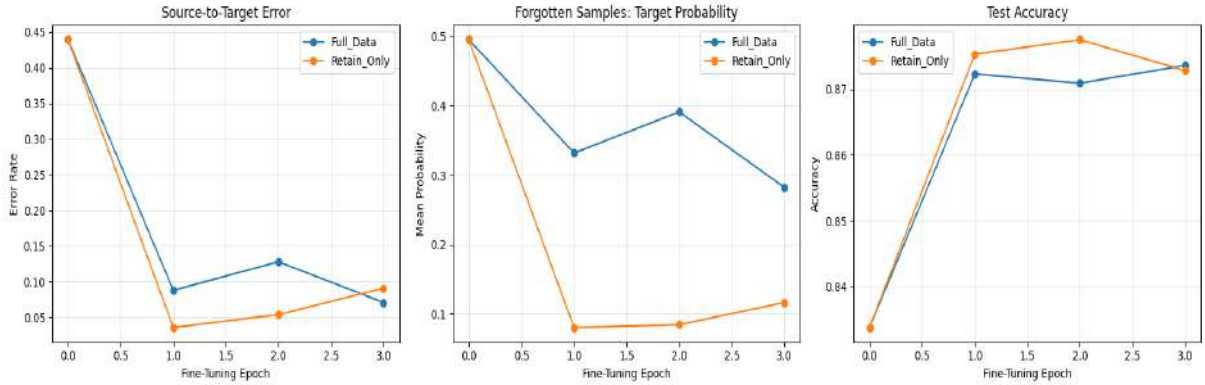


Fig. 2. Comparison of full-data and retain-only fine-tuning in terms of source-to-target error, forgotten-sample target probability, and test accuracy across three epochs.

As illustrated in Fig. 2, both approaches improved test accuracy from 83.38% to approximately 87%. However, their responses on the poisoned samples differed substantially. After three epochs, the mean probability assigned to the incorrect target class decreased from 49.54% to 11.64% under Retain-Only fine-tuning, compared with 28.24% under Full-Data fine-tuning. The source-to-target error followed a different pattern. Retain-Only fine-tuning achieved lower error rates during the first two epochs, but at the third epoch, Full-Data produced a slightly lower error (7.1% versus 9.1%). Meanwhile, their final test accuracies remained close, at 87.36% and 87.28%, respectively. This contrast shows that reduced target-class confidence on forgotten training examples does not always translate into a lower attack error on unseen test samples. Overall, the experiments demonstrate measurable reductions in poisoning effects following fine-tuning and sample removal, while revealing differences between evaluation metrics and sample-selection strategies. These observations motivate a closer examination of what such improvements can establish about machine unlearning.

V. DISCUSSION AND LIMITATIONS

The experimental findings suggest that approximate unlearning can reduce the effects of targeted label poisoning, although its effectiveness depends on both the removal strategy and the evaluation criterion. Gradient Norm achieved the lowest average absolute residual gap, but its performance was close to Random selection, providing insufficient evidence of a consistent advantage. Meanwhile, Gradient Alignment produced the highest prediction agreement with retrained models without achieving a similarly low residual gap. This difference illustrates why agreement on the test set should not be interpreted as direct evidence of successful forgetting, consistent with concerns raised in earlier studies [7], [8]. The fine-tuning control provides an additional perspective. Removing all poisoned samples resulted in a substantially lower target-class probability on the forgotten examples than continuing training with the complete dataset. However, both approaches improved overall accuracy, and Full-Data fine-tuning achieved a slightly lower source-to-target error at the final epoch. These observations indicate that data removal may offer benefits beyond additional optimization, but the magnitude and direction of those benefits depend on the selected metric. Several limitations should be considered. The experiments used a single dataset, a relatively small CNN, and one targeted label-flipping

scenario, limiting their generalizability to larger models or more sophisticated attacks. The repeated comparisons relied on a fixed poisoned checkpoint and only three downstream training seeds, rather than independent end-to-end repetitions. Furthermore, Gradient Alignment used held-out test images to construct its reference gradient, introducing potential evaluation leakage. The unlearning and retraining procedures also differed in their optimization budgets, while the full-deletion control used datasets of different sizes. Finally, the study assessed observable prediction changes rather than formal removal guarantees. Consequently, the results should be interpreted as exploratory evidence of poisoning mitigation, not proof of complete or certified unlearning.

VI. CONCLUSION AND FUTURE WORK

This study examined approximate machine unlearning under targeted label-flipping attacks through a comparative evaluation of sample-selection strategies, reference retraining, and fine-tuning controls. The experiments showed that removing poisoned examples can reduce incorrect target-class probabilities while largely preserving classification accuracy. However, gradient-based selection did not consistently outperform random removal, and different evaluation metrics sometimes led to contrasting conclusions. The main contribution is an empirical assessment of the distinction between reducing poisoning effects and demonstrating genuine forgetting. The findings underline the importance of using complementary evaluation measures and appropriately controlled comparisons rather than relying on overall accuracy or a single forgetting score. Future work could extend the analysis to additional datasets, deeper architectures, and different poisoning strategies, including multiple source-target class pairs and varying attack intensities. Independent training repetitions, validation-based gradient selection, and matched computational budgets would strengthen the reliability of the comparisons. Further investigation of privacy-oriented and certified-unlearning evaluations could also help determine whether observed improvements correspond to more rigorous removal guarantees.

REFERENCES

[1] Y. Cao and J. Yang, “Towards Making Systems Forget with Machine Unlearning,” in *2015 IEEE Symposium on Security and Privacy*, 2015, pp. 463–480, doi: 10.1109/SP.2015.35.

[2] L. Bourtoule et al., “Machine Unlearning,” in *2021 IEEE Symposium on Security and Privacy (SP)*, 2021, pp. 141–159, doi: 10.1109/SP40001.2021.00019.

[3] C. Guo, T. Goldstein, A. Hannun, and L. van der Maaten, “Certified Data Removal from Machine Learning Models,” in *Proceedings of the 37th International Conference on Machine Learning*, vol. 119, 2020, pp. 3832–3842.

[4] B. Biggio, B. Nelson, and P. Laskov, “Poisoning Attacks against Support Vector Machines,” in *Proceedings of the 29th International Conference on Machine Learning*, 2012.

[5] V. S. Chundawat, A. K. Tarun, M. Mandal, and M. Kankanhalli, “Can Bad Teaching Induce Forgetting? Unlearning in Deep Networks Using an Incompetent Teacher,” in *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 37, no. 6, 2023, pp. 7210–7217, doi: 10.1609/aaai.v37i6.25879.

[6] M. Kurmanji, P. Triantafillou, J. Hayes, and E. Triantafillou, “Towards Unbounded Machine Unlearning,” in *Advances in Neural Information Processing Systems*, vol. 36, 2023.

[7] K. Zhao, M. Kurmanji, G.-O. Barbulescu, E. Triantafillou, and P. Triantafillou, “What Makes Unlearning Hard and What to Do About It,” in *Advances in Neural Information Processing Systems*, vol. 37, 2024.

[8] M. Pawelczyk, J. Z. Di, Y. Lu, G. Kamath, A. Sekhari, and S. Neel, "Machine Unlearning Fails to Remove Data Poisoning Attacks," in *Proceedings of the International Conference on Learning Representations (ICLR)*, 2025.

[9] Q. Xu, Z. Yang, Y. Zhao, X. Cao, and Q. Huang, "Rethinking Label Flipping Attack: From Sample Masking to Sample Thresholding," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 45, no. 6, pp. 7668–7685, 2023, doi: 10.1109/TPAMI.2022.3220849.

[10] P. W. Koh and P. Liang, "Understanding Black-box Predictions via Influence Functions," in *Proceedings of the 34th International Conference on Machine Learning*, vol. 70, 2017, pp. 1885–1894.

[11] G. Pruthi, F. Liu, S. Kale, and M. Sundararajan, "Estimating Training Data Influence by Tracing Gradient Descent," in *Advances in Neural Information Processing Systems*, vol. 33, 2020.

[12] A. Ghorbani and J. Zou, "Data Shapley: Equitable Valuation of Data for Machine Learning," in *Proceedings of the 36th International Conference on Machine Learning*, vol. 97, 2019, pp. 2242–2251.

[13] E. Triantafillou et al., "Are We Making Progress in Unlearning? Findings from the First NeurIPS Unlearning Competition," arXiv preprint arXiv:2406.09073, 2024.

[14] T. Shaik, X. Tao, H. Xie, L. Li, X. Zhu, and Q. Li, "Exploring the Landscape of Machine Unlearning: A Comprehensive Survey and Taxonomy," *IEEE Transactions on Neural Networks and Learning Systems*, vol. 36, no. 7, pp. 11676–11696, 2025, doi: 10.1109/TNNLS.2024.3486109.

[15] V. Dorna, A. Mekala, W. Zhao, A. McCallum, Z. Kolter, Z. C. Lipton, and P. Maini, "OpenUnlearning: Accelerating LLM Unlearning via Unified Benchmarking of Methods and Metrics," in *Advances in Neural Information Processing Systems*, vol. 38, 2025.

[16] H. Xiao, K. Rasul, and R. Vollgraf, "Fashion-MNIST: A Novel Image Dataset for Benchmarking Machine Learning Algorithms," arXiv preprint arXiv:1708.07747, 2017.

[17] D. P. Kingma and J. Ba, "Adam: A Method for Stochastic Optimization," in *Proceedings of the 3rd International Conference on Learning Representations (ICLR)*, 2015.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

GENERATIVE AI TOOLS IN HIGHER EDUCATION: OPPORTUNITIES, RISKS AND ACADEMIC INTEGRITY

Huseyn Huseynov
ORCID: 0009-0008-3816-6467
Department of Robotics Engineering, Azerbaijan State Oil and Industry University, Azerbaijan

Abstract

The swift adoption of content-creating artificial intelligence tools such as ChatGPT into higher education is transforming how students learn, write, and conduct research, while questioning deeply-rooted beliefs about assessment, attribution, and academic integrity.

This transformation creates a critical tension between utilizing technological innovations and preserving academic standards. This study examines the key opportunities and systemic risks associated with GenAI in higher education and seeks to establish a structure of data-driven guidelines for its responsible and effective implementation.

Methodologically, the research utilizes a systematic contrastive examination of contemporary refereed scholarly publications, evidential student questionnaires, and higher education policy documents to explore current uses of GenAI by students and academic staff, reported pedagogical gains, arising moral concerns, and institutional reactions.

The results suggest that GenAI may enhance personalized learning experiences, provide immediate and tailored feedback, help non-native English speakers with academic writing and reduce operational tasks for educators.

But these benefits don't come without significant risks. These include: - fake or misleading information - overdependence that could undermine critical thinking - uneven access to sophisticated AI tools - data privacy issues - novel types of unauthorized content generation that traditional similarity checking systems cannot reliably detect

Institutional approaches continue to be inconsistent. Responses vary from outright bans on GenAI to its controlled introduction into educational programs under a regime of clear guidelines and policies for acceptable use.

Analysis shows that strict prohibitions are neither a realistic nor a lasting solution. Instead, universities should create proactive and transparent governance frameworks around three mutually-reinforcing pillars. But they need to build holistic AI literacy first, for students and staff. Secondly, evaluation frameworks must be rethought to focus on the process of learning, and not just the outcome, and there must be clear institutional policies to guide acceptable and responsible use of AI.

This way, higher education can effectively tap into Generative Artificial Intelligence while balancing innovation and academic responsibility and adhering to the principles of academic integrity. The study offers practical suggestions to university administrators and decision makers. These findings hold significant relevance for evolving higher education systems that are adapting to the rapid evolution of artificial intelligence.

Keywords: Generative Artificial Intelligence, Academic Integrity, Higher Education.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ADOPTION AND USE OF GENERATIVE ARTIFICIAL INTELLIGENCE IN TEACHING AND RESEARCH: A TECHNOLOGY ACCEPTANCE MODEL SURVEY OF MOROCCAN ACADEMICS AND DOCTORAL STUDENTS

Mohamed Ziad Mammass
Hasna Abioui
RF-SIC Laboratory, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco
High School of Education and Training, Ibn Zohr University, Agadir, Morocco.

Abstract

This communication explores how Moroccan academics and doctoral students adopt and use generative artificial intelligence (GenAI) in teaching and research. A questionnaire of 14 questions divided into three sections was designed and shared with this academic community in July 2026. The first section focused on respondents' profiles and digital literacy. The second examined how GenAI is used in teaching and research, while the third explored future perspectives and users' willingness to adopt GenAI if its content were structured, reliable, and validated by experts.

The questionnaire combined items based on the Technology Acceptance Model (TAM) with a five-point Likert measurement scale, multiple-choice questions, and open-ended questions. A total of 150 responses were analyzed using regression models, correspondence factor analysis, and k-means clustering.

The results show a high level of digital literacy among respondents. They also indicate that GenAI is already widely adopted, although its use remains mainly focused on popular conversational tools in teaching and research. Adoption is positively and significantly associated with perceived usefulness, which shows the strongest correlation.

The adoption of GenAI in this academic population follows a classic TAM pattern, mainly driven by perceived usefulness, and does not appear to depend strongly on academic status or disciplinary field. The third block shows that the average score on a five-point scale rises from 2.90 for current use to 4.23 for intention to use if the content generated by GenAI were organized and validated within a reliable knowledge structure with concepts and relationships verified by experts.

Keywords: Generative AI; Technology Acceptance Model (TAM); Technology Adoption, Higher Education; Teaching and Research.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

PLANNING NATURAL GAS INFRASTRUCTURE FOR ALBANIAN CITIES: SPATIAL SEQUENCING, DEMAND-LED NETWORKS AND REGIONAL CORRIDOR INTEGRATION

Ardi DHIMA
Stavri DHIMA
ORCID: 0009-0007-2591-2267, Department of Engineering and Architecture, Faculty of Engineering, Informatics and Architecture, European University of Tirana, Albania
Independent Energy and Oil and Gas Consultant, Tirana, Albania

Abstract

Albania is crossed by the Trans Adriatic Pipeline (TAP), operational since 2020, yet the country still lacks a domestic natural gas market and urban distribution networks. This paper treats gas development as an urban and infrastructure planning problem rather than a supply question: under what spatial, institutional and demand conditions can national transmission be translated into city-scale networks that strengthen energy security without locking cities into high-carbon infrastructure? The study combines documentary analysis of the national Gas Master Plan approved in 2018 and the current project portfolio with descriptive analysis of official energy statistics and a qualitative comparison of three scenarios: a regional gas hub, a demand-led domestic market and a transit-only pathway. Korça, the first city-scale pilot, serves as a case study of how a transmission exit point, pressure-reduction stations and about 70 km of urban mains interact with street corridors, existing utilities, heritage areas and household connection costs. The 2025 electricity balance, with net imports of 877 GWh and hydropower supplying 87% of domestic generation, confirms continuing vulnerability. Sectoral data, however, indicate that potential gas demand is concentrated in public buildings, industry and power generation rather than spread evenly across settlements. The findings support a phased, demand-led strategy in which each network extension passes five decision gates: validated demand, secure upstream access, committed anchor customers, environmental and social appraisal, and monitored utilisation. The paper proposes embedding these gates in municipal spatial plans and national corridor planning for 2026–2040, positioning gas as a bounded transition layer alongside energy efficiency, electrification and renewable generation.

Keywords: urban infrastructure planning, natural gas networks, Albania.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

STRUCTURAL, MORPHOLOGICAL AND OPTICAL PROPERTIES OF THE LA2W2O9/FE2O3 COMPOSITE FOR UV-SHIELDING APPLICATIONS

L.H. Omari
J. Louafi
LPMAT, Faculty of Sciences Ain Chock, Hassan II University, Casablanca, Morocco

Abstract

Currently, research has been conducted on the individual oxides $La_2W_2O_9$ and Fe_2O_3 but not on its composite form. Using a solid-state reaction technique, a $La_2W_2O_9/Fe_2O_3$ composite was created. A particular calcination cycle was followed by mixing the raw precursors. Scanning electron microscopy (SEM) was used to investigate the morphological microstructure, and X-ray diffraction (XRD) was used to examine the structural characteristics. The thermal and gravimetric properties were examined via differential thermal analysis (DTA) and thermogravimetric analysis (TGA). The optical characteristics were investigated via UV–visible spectroscopy, which investigated included the transmittance, absorbance, absorption coefficient, band gap (E_g), penetration depth (β), Urbach energy (E_U), refractive index, optical conductivity, and dielectric function. These findings indicate that the optical properties improved after the addition of Fe_2O_3 compared with those of pure $La_2W_2O_9$. The $La_2W_2O_9/Fe_2O_3$ composite holds promise as a prospective material for use in the fields of optoelectronic, sunscreen products, UV shielding or solar filtration.

This study aims to synthesize a $La_2W_2O_9/Fe_2O_3$ composite powder via conventional solid-state reactions and evaluate how incorporating Fe_2O_3 influences the optical characteristics of $La_2W_2O_9$. Specifically, we propose that a conceivably higher energy level associated with an absorption wavelength of approximately 303 nm might emerge within the conduction band of α-Fe_2O_3. On the basis of this hypothesis, we posit that the underlying mechanism responsible for enhancing the photoelectric response of the $La_2W_2O_9/Fe_2O_3$ composite can be attributed to the migration of photogenerated electrons from the putative elevated energy level present in the conduction band of α-Fe_2O_3 to $La_2W_2O_9$. Through a detailed investigation, we aim to elucidate the intricacies surrounding this proposed charge transfer process and assess its importance in modulating the optoelectronic attributes of the developed composite system.

Keywords: Optical properties; Solid-state reaction; X-ray diffraction; Composite; UV-shielding; Solar filter.

COMPARATIVE EVALUATION OF COMMERCIAL FEED AND AZOLLA (AZOLLA PINNATA) ON GROWTH PERFORMANCE AND ZOOTECHNICAL PARAMETERS OF TILAPIA (*OREOCHROMIS NILOTICUS*)

Khadija OUAISSA
Jamila BOUCHGL
M'Hamed HMAMOU
Mustapha Hasnaoui
Aquaculture laboratory; Higher institute of maritime Fisheries. Agadir. Moroc
Environmental, Ecological and Agro-Industrial Engineering Laboratory. Department of Biology, Faculty of Sciences and Techniques. University Sultan Moulay Slimane. Beni-Mellal, Morocco.
Laboratory of energy Engineering, Materials and Systems, ENSA, Ibn Zohr University, Agadir, Morocco.

Abstract

Aquaculture plays a crucial role in global food security, but high feed costs challenge sustainable fish farming. **Azolla pinnata**, a fast-growing aquatic plant, offers a nutrient-rich, low-cost alternative for fish diets. This study evaluated the effects of partially replacing commercial feed with Azolla on the growth and zootechnical performance of tilapia (*Oreochromis niloticus*). Juveniles were reared under controlled conditions for eight weeks and divided into two groups: one receiving a standard commercial diet and the other receiving 50% of the feed as Azolla. Growth performance, including final weight, specific growth rate (SGR), feed conversion ratio (FCR), and survival, was recorded. Fish fed Azolla reached a final mean weight of 40.8 ± 2.4 g, compared to 42.5 ± 2.1 g in the commercial feed group ($p > 0.05$). SGR was 2.38 ± 0.10 %/day versus 2.45 ± 0.08 %/day, and FCR slightly improved with Azolla (1.45 ± 0.05 vs. 1.52 ± 0.07). Survival remained high in both groups (98–100%). These results indicate that Azolla can serve as a partial, sustainable, and cost-effective feed alternative without compromising growth or health, demonstrating its potential to enhance environmentally friendly aquaculture practices.

Keywords: Tilapia; Azolla; Growth Performance; Feed Conversion Ratio; Sustainable Aquaculture, Zootechnical Parameters.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

AZOLLA PINNATA AS A LOCAL BIOMASS RESOURCE FOR SUSTAINABLE AQUACULTURE: A LABORATORY MONITORING APPROACH AND RESEARCH PRIORITIES FOR FEED APPLICATIONS

Khadija OUAISSA
Jamila BOUCHGL
Zakaria ACHTOUK
M'Hamed HMAMOU
Mustapha HASNAOUI
Aquaculture Laboratory, Higher Institute of Maritime Fisheries, Agadir, Morocco.
Environmental, Ecological and Agro-Industrial Engineering Laboratory, Department of Biology, Faculty of Sciences and Techniques, Sultan Moulay Slimane University, Beni-Mellal, Morocco.
Laboratory of Energy Engineering, Materials and Systems, ENSA, Ibn Zohr University, Agadir, Morocco.

Abstract

The development of sustainable aquaculture requires the identification of alternative, locally available biomass resources that can contribute to reducing dependence on conventional feed ingredients. Azolla pinnata, a free-floating aquatic fern associated with nitrogen-fixing cyanobacteria, has attracted increasing interest because of its potential for rapid biomass production and nutritional applications. This study aims to present a laboratory-scale monitoring framework for A. pinnata cultivation and to identify the key parameters required to assess its potential use as an aquaculture feed ingredient. The cultivation system described in the source study involved a 45-day freshwater culture period, initiated with 100 g of fresh biomass in a polyethylene tank. Biomass development, water temperature, pH and visual characteristics were considered as monitoring indicators. An illustrative dataset showed an increase in fresh biomass from 100 to 850 g over the cultivation period, with temperature ranging from 24 to 26 °C and pH from 7.0 to 8.1. However, these numerical values are hypothetical and are presented solely to illustrate data organization; they do not represent experimentally validated results. The analysis highlights the importance of standardized harvesting procedures, dry matter determination, culture-surface measurements and comprehensive water-quality monitoring for reliable productivity assessment. Furthermore, biochemical characterization, microbiological safety evaluation, digestibility studies and controlled feeding trials are necessary to establish the nutritional suitability of A. pinnata. Overall, this study provides a methodological framework for future investigations into the production and valorization of Azolla pinnata as a potential locally sourced resource for sustainable aquaculture feeds.

Keywords: Azolla pinnata; biomass production; aquaculture feed; culture monitoring; sustainable aquaculture.

INTRODUCTION

Aquaculture production depends on a reliable supply of nutritionally balanced feed. In many intensive systems, feed is among the principal operating costs, while the sourcing and manufacture of conventional ingredients raise questions about price, availability and environmental footprint. These challenges have encouraged research into alternative resources that can be produced locally and integrated into more circular production systems. The value of an alternative ingredient, however, cannot be judged only by its availability or growth potential. Its chemical composition, digestibility, safety, consistency and effects on cultured species must also be established.

Aquatic plants are one group of resources being investigated for this purpose. Azolla is a small floating fern that forms a symbiotic association with a nitrogen-fixing cyanobacterium. This association contributes to nitrogen acquisition and has supported the use of Azolla in agricultural systems, while also attracting interest

in biomass production and feed applications (Becking, 1979; Wagner, 1997). The growth and composition of Azolla are not fixed characteristics: they depend on species, culture conditions and management.

Temperature, light intensity, photoperiod, pH and nutrient availability are important factors affecting Azolla growth. Cary and Weir (1992) examined the effects of water temperature, nitrogen and phosphorus supply, light intensity and pH on A. pinnata and A. filiculoides, showing that responses depend on species and environmental conditions. A temperature close to 25 °C may be favourable in some experimental contexts, but it should not be considered a universal optimum.

The potential use of Azolla in animal and fish feeds is related to its protein and mineral contents. Nevertheless, nutritional composition varies with species, culture conditions and processing. Fibre, ash and phenolic compounds may influence digestibility and practical inclusion levels. Brouwer et al. (2018) reported variation in biomass productivity and chemical composition under different cultivation conditions. Yohana et al. (2023) likewise emphasized the importance of evaluating Azolla meal in relation to processing and the target aquatic animal.

The objective of this paper is to present a practical monitoring framework for laboratory-scale cultivation of A. pinnata and to identify the production, nutritional and safety assessments required before its potential as a complementary ingredient in sustainable aquaculture feeds can be established.

2. MATERIALS AND METHODS

2.1. Cultivation System of Azolla pinnata

The cultivation of Azolla pinnata was conducted in freshwater using a high-density polyethylene (HDPE) tank with a water capacity of 400 L under laboratory conditions over a 45-day period. The culture was initiated with an initial fresh biomass of 100 g of A. pinnata. A single culture medium was used throughout the cultivation period, without the application of comparative experimental treatments.

2.2. Biomass Development Monitoring

Fresh biomass was considered the primary indicator for monitoring plant growth throughout the cultivation period. At each sampling date, the plant material was harvested, drained to remove excess water, and weighed using a calibrated balance.

To ensure measurement consistency, standardized procedures were adopted for harvesting, draining and weighing. The harvesting equipment, mesh size, draining duration and sample-handling procedures were kept consistent to minimize variations in fresh-weight measurements caused by water retained between the fronds.

Dry matter determination was also considered through the drying of a representative plant subsample to constant weight. This measurement provides a more accurate assessment of actual plant biomass and a more reliable basis for productivity evaluation than fresh weight alone.

2.3. Monitoring of Water Physicochemical Parameters

Water quality monitoring included the measurement of temperature and pH as basic indicators for characterizing the cultivation environment. Measurements were performed using calibrated instruments at standardized times throughout the cultivation period.

Ammonia concentration was also included in the proposed monitoring scheme. For accurate characterization, future measurements should specify the nitrogen form analyzed, the analytical method employed and the corresponding measurement units.

A more comprehensive assessment of the cultivation environment could be achieved by incorporating additional parameters, including dissolved oxygen, electrical conductivity, alkalinity, light intensity, photoperiod and nutrient concentrations, particularly nitrogen and phosphorus.

2.4. Visual observations and data interpretation

Plant colour and general condition may be recorded as complementary observations, preferably using standardized photographs taken under comparable lighting. Categories such as green, dark green and very dark green describe appearance but cannot independently confirm nutrient sufficiency, physiological health or protein content. The numerical series in the source manuscript is explicitly illustrative and is reproduced only to demonstrate data presentation. It must not be interpreted as experimental measurements or used to claim a validated production yield.

3. RESULTS

The source manuscript provides an illustrative monitoring profile over 45 days. In this simulated example, fresh biomass increases from 100 g on day 1 to 850 g on day 45. Temperature ranges from 24 to 26 °C, while pH ranges from 7.0 to 8.1. The plant is described as green, dark green or very dark green. All values below are hypothetical and do not represent measured experimental data.

Table 1. *Illustrative monitoring values for Azolla pinnata; all numerical values are hypothetical, not experimental measurements.*

Day	Fresh biomass (g)	Temperature (°C)	pH	Visual condition
1	100	24	7.0	Green; initial biomass
5	135	24	7.2	Dark green
10	180	25	7.4	Dark green; progressive growth
15	245	25	7.6	Very dark green
20	330	26	7.8	Very dark green; development
25	430	26	8.0	Very dark green; high coverage
30	540	26	8.1	Dark green; abundant biomass
35	650	25	7.9	Very dark green; high density
40	750	25	7.7	Dark green; high coverage
45	850	24	7.5	Very dark green; final biomass

4. DISCUSSION

4.1. Biomass production and assessment of Azolla growth

The evaluation of *Azolla pinnata* production requires careful consideration of the distinction between fresh biomass and dry matter. Although fresh biomass is a convenient parameter for routine monitoring, its measurement can be strongly influenced by water retained between the fronds and variations in harvesting and draining procedures. Consequently, fresh-weight measurements alone may not accurately reflect actual

biological growth. Determination of dry matter, combined with standardized harvesting procedures, is therefore essential for obtaining reliable estimates of biomass production.

Furthermore, biomass productivity should be expressed in relation to the culture surface area and cultivation period, preferably as grams of dry matter per square metre per day (g DM m^{-2} day^{-1}). This approach allows more meaningful comparisons between cultivation systems and experimental conditions. Relative growth rate and doubling time can also provide useful information on plant development, provided that reliable biomass measurements are available at successive sampling dates.

Previous research has demonstrated that Azolla biomass productivity and biochemical composition are influenced by species characteristics and cultivation conditions (Brouwer et al., 2018). These findings highlight the importance of controlling and documenting the main environmental and operational parameters when assessing the production potential of *A. pinnata*. In the present study, the absence of verified dry-weight measurements and culture-surface data limits the possibility of establishing quantitative productivity estimates.

4.2. Influence of environmental conditions on Azolla cultivation

Environmental conditions play a central role in regulating Azolla growth and biomass development. Temperature, light intensity, photoperiod, pH and nutrient availability interact to influence physiological activity and nutrient assimilation. Cary and Weir (1992) demonstrated that the growth and nutrient composition of *A. pinnata* and *A. filiculoides* respond differently to variations in water temperature, nitrogen and phosphorus availability, light intensity and pH.

A temperature close to 25 °C may be favourable under certain experimental conditions; however, this value should not be considered a universal optimum because growth responses depend on the species, environmental conditions and cultivation management. In addition, adequate nitrogen and phosphorus availability is important for maintaining plant development and biomass production.

Variations in pH may also provide information about biological and physicochemical processes occurring within the culture medium. Photosynthetic uptake of dissolved carbon dioxide may contribute to an increase in pH during daylight, whereas respiration and organic-matter decomposition may contribute to a decrease. Nevertheless, these mechanisms cannot be confirmed from pH measurements alone. Monitoring dissolved oxygen, alkalinity, nutrient concentrations and water-renewal conditions, together with standardized measurement times, would provide a more reliable interpretation of pH fluctuations.

4.3. Nutritional potential of Azolla for aquaculture feed applications

The potential use of *A. pinnata* as an alternative feed ingredient is related to its capacity to produce biomass locally and its nutritional composition. However, biomass availability alone is insufficient to establish its suitability for aquaculture diets. Its nutritional value must be assessed through comprehensive biochemical characterization, including dry matter, crude protein, crude lipid, crude fibre and ash content.

Additional analyses of amino-acid composition, mineral profile and phenolic compounds are also necessary to identify possible nutritional limitations. In particular, high fibre or ash contents may influence nutrient digestibility and the maximum practical inclusion level in formulated diets. Brouwer et al. (2018) highlighted the variability of Azolla biomass productivity and chemical composition under different cultivation conditions, indicating that nutritional characterization should be performed on the actual biomass intended for feed production.

Processing techniques, including washing, drying and milling, may also influence the final quality of Azolla meal. Therefore, these procedures should be standardized and documented to ensure consistency between production batches. Microbiological quality and potential contaminants should also be investigated, particularly when the plant is cultivated in nutrient-rich water or reused aquaculture effluents.

Yohana et al. (2023) reviewed the potential use of Azolla meal in aquatic animal diets and emphasized the importance of considering processing conditions, nutritional composition and target species. Nevertheless, its

practical inclusion level cannot be established without species-specific digestibility studies and controlled feeding experiments.

4.4. Implications for sustainable aquaculture

The local production of *A. pinnata* could contribute to the diversification of biomass resources investigated for sustainable aquaculture feed development. Its cultivation may be of particular interest in integrated production systems where nutrient resources are recovered and reused. However, the environmental and economic benefits of such an approach should be assessed through appropriate experimental and production-scale studies.

Before recommending Azolla as a complementary feed ingredient, its production performance, nutritional quality, microbiological safety and effects on fish growth must be evaluated. Feeding trials using species such as Nile tilapia (*Oreochromis niloticus*) could provide relevant information on feed intake, growth performance, survival, feed conversion ratio and nutrient utilization. Diets should be formulated to meet the nutritional requirements of the target species, with clearly defined Azolla inclusion levels. Digestibility measurements would further help determine the availability of nutrients and the actual contribution of Azolla meal to fish nutrition.

4.5. Study limitations and future research perspectives

The present study has several methodological limitations that should be considered when interpreting its contribution. The cultivation system was based on a single experimental unit, without biological replication or comparative treatments. Furthermore, the numerical biomass dataset presented in the source manuscript is illustrative and hypothetical rather than experimentally measured. Consequently, it cannot be used to establish actual biomass productivity, statistical differences or validated growth performance.

The absence of verified dry-matter measurements and detailed information on culture-surface area also limits quantitative assessment of production efficiency. These limitations indicate that the current work should be considered a preliminary monitoring framework rather than a completed experimental evaluation of Azolla productivity.

Future investigations should include independent replicated culture units, clearly defined cultivation conditions, standardized sampling procedures and repeated measurements of biomass and water-quality parameters. Particular attention should be given to dry-matter determination and the calculation of surface-based productivity. Subsequent research should focus on biochemical and microbiological characterization of the harvested biomass, followed by digestibility assessments and controlled feeding trials.

Overall, establishing the suitability of *A. pinnata* for aquaculture feed applications requires an integrated approach linking cultivation performance, nutritional quality, processing conditions and fish feeding responses. Such an approach would provide a stronger scientific basis for evaluating Azolla as a locally produced biomass resource within sustainable aquaculture systems.

CONCLUSION

Azolla pinnata is a potentially useful local biomass resource for research on sustainable aquaculture feeds, but its practical value cannot be established through visual monitoring or fresh biomass alone. A reliable assessment requires standardized harvesting, dry-matter determination, culture-surface measurements and a more complete record of water-quality and nutrient conditions. The illustrative dataset reproduced here is hypothetical and must not be treated as experimental evidence. Further replicated cultivation trials, biochemical characterization, microbiological safety assessment, digestibility studies and controlled feeding experiments are required before recommending A. pinnata as a feed ingredient.

REFERENCES

Becking JH 1979. An analysis of the N_2-fixing cyanobacterium–Azolla association. Plant and Soil, 52: 337–349.

Brouwer P, Schluepmann H, Nierop KGJ, Elderson J, Bijl PK, van der Meer I, de Visser W, Reichart GJ, Smeekens S, van der Werf A 2018. Growing Azolla to produce sustainable protein feed: The effect of differing species and CO_2 concentrations on biomass productivity and chemical composition. Journal of the Science of Food and Agriculture, 98(12): 4759–4768. https://doi.org/10.1002/jsfa.9016

Cary PR, Weir PR 1992. Growth and nutrient composition of Azolla pinnata R. Brown and Azolla filiculoides Lamarck as affected by water temperature, nitrogen and phosphorus supply, light intensity and pH. Aquatic Botany, 43(2): 163–180. https://doi.org/10.1016/0304-3770(92)90041-G

Lumpkin TA, Plucknett DL 1980. Azolla: Botany, physiology, and agronomic significance. Economic Botany, 34: 111–153.

Wagner GM 1997. Azolla: A review of its biology and utilization. The Botanical Review, 63: 1–26. https://doi.org/10.1007/BF02857915

Yohana C et al. 2023. A review on the use of Azolla meal as a feed ingredient in aquatic animals' diets. Aquaculture Research. https://doi.org/10.1155/2023/2633412

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

EFFECT OF SULFURIZED OLEFIN ON WEAR BEHAVIOR IN LITHIUM COMPLEX GREASES AND EVALUATION OF AW/EP ADDITIVE SYSTEMS

Kübranur AĞTOPRAK
Uğur KARAASLAN
0000-0002-9125-5644, Belgin Oil, R&D Center, Kocaeli, Türkiye.
0000-0003-2972-4224, Dr., Belgin Oil, R&D Center, Kocaeli, Türkiye.

Abstract

Greases are semi-solid lubricants used in industrial and automotive applications, particularly for bearing lubrication. By reducing friction and wear between contacting surfaces, they protect components and extend service life. Under high-load conditions, grease performance depends on both load-carrying capacity and wear protection. Although extreme-pressure (EP) and anti-wear (AW) performance are related, they represent distinct aspects of tribological behaviour: EP performance concerns protection under severe loading, whereas AW performance focuses on limiting material loss. In this context, sulfurized olefins enhance EP performance and can support the formation of iron sulfide (FeS)-based tribofilms at the friction interface, thereby limiting direct contact between metal surfaces. However, additives that support EP performance do not necessarily improve AW performance. This makes it important to investigate the effect of sulfurized olefins on wear behaviour and evaluate the contribution of additives with different chemical structures to AW/EP performance. In this study, four-ball wear tests were conducted on an NLGI 2 lithium complex grease without sulfurized olefin and formulations containing different concentrations of the additive. The results indicated that sulfurized olefin addition adversely affected wear behaviour, with increasing additive concentrations leading to larger wear scar diameters (WSDs) within the formulations investigated. These findings highlight the importance of evaluating the effects of sulfurized olefins on anti-wear performance alongside their extreme-pressure functionality. Based on these findings, this study evaluates the effects of triphenyl phosphorothionate (TPPT), amine phosphate, zinc dialkyldithiophosphate (ZDDP), molybdenum dialkyldithiophosphate (MoDTP), and organomolybdenum complex-based additives in combination with sulfurized olefin. The results showed that some combinations continued to exhibit adverse effects on wear, whereas others reduced WSD. These findings demonstrate the importance of considering additive compatibility and synergistic interactions when developing formulations that reduce WSD and improve AW performance while maintaining EP performance.

Keywords: Lithium complex grease, sulfurized olefin, anti-wear (AW), extreme pressure (EP), four-ball tester.

Greases are semi-solid lubricants used in industrial and automotive applications, particularly for bearing lubrication. By reducing friction and wear between contacting surfaces, they protect components and extend service life. Under high-load conditions, grease performance depends on both load-carrying capacity and wear protection. Although extreme-pressure (EP) and anti-wear (AW) performance are related, they represent distinct aspects of tribological behaviour: EP performance concerns protection under severe loading, whereas AW performance focuses on limiting material loss. In this context, sulfurized olefins enhance EP performance and can support the formation of iron sulfide (FeS)-based tribofilms at the friction interface, thereby limiting direct contact between metal surfaces. However, additives that support EP performance do not necessarily improve AW performance. This makes it important to investigate the effect of sulfurized olefins on wear behaviour and evaluate the contribution of additives with different chemical structures to AW/EP performance. In this study, four-ball wear tests were conducted on an NLGI 2 lithium complex grease without sulfurized olefin and formulations containing different concentrations of the additive. The results indicated that sulfurized olefin addition adversely affected wear behaviour, with increasing additive concentrations leading to larger wear scar diameters (WSDs) within the formulations investigated. These findings highlight the importance of evaluating the effects of sulfurized olefins on anti-wear performance alongside their extreme-pressure functionality. Based on these findings, this study evaluates the effects of triphenyl phosphorothionate (TPPT),

amine phosphate, zinc dialkyldithiophosphate (ZDDP), molybdenum dialkyldithiophosphate (MoDTP), and organomolybdenum complex-based additives in combination with sulfurized olefin. The results showed that some combinations continued to exhibit adverse effects on wear, whereas others reduced WSD. These findings demonstrate the importance of considering additive compatibility and synergistic interactions when developing formulations that reduce WSD and improve AW performance while maintaining EP performance.

Keywords: Lithium complex grease, sulfurized olefin, anti-wear (AW), extreme pressure (EP), Four-Ball tester.

Introduction

Lubricating greases are widely used in industrial and automotive applications, particularly in rolling bearings and other components subjected to mechanical loads. As semi-solid lubricants, greases generally consist of a base oil, a thickener and a package of performance-enhancing additives. Their tribological behaviour is governed not only by the properties of the base oil but also by the thickener structure and the interactions among the formulation components. Under demanding operating conditions, the ability of grease to minimize friction, prevent material loss and protect contacting surfaces against severe loading is particularly important. Therefore, the selection and compatibility of AW and EP additives play a significant role in grease formulation and performance [1,2].

Although AW and EP additives are frequently used together in lubricant formulations, their functions are not identical. AW additives primarily reduce surface damage and material loss under boundary and mixed lubrication conditions, whereas EP additives provide protection against severe contact pressures and prevent surface welding and seizure. This distinction is also reflected in standardized tribological evaluation methods. ASTM D2266 evaluates the wear-preventive characteristics of lubricating greases using the four-ball wear test, whereas ASTM D2596 determines their load-carrying properties through parameters such as the load-wear index and weld point. Consequently, an additive system exhibiting improved EP performance cannot necessarily be assumed to provide improved AW protection [3,4].

Sulfurized olefins are commonly employed as EP additives due to their ability to react with metallic surfaces under severe tribological conditions. Their tribochemical reactions can result in the formation of iron sulfide-containing boundary films, which reduce direct metal-to-metal contact and improve load-carrying capability. However, the contribution of sulfur-containing additives to wear protection is strongly dependent on their chemical characteristics, particularly their active sulfur content, concentration and interaction with other additives. Recent investigations have demonstrated that sulfur-containing EP additives can influence the adsorption and tribochemical reactions of phosphorus-based AW additives at metal interfaces. In particular, differences in active sulfur content have been associated with changes in the composition and wear-preventive effectiveness of the resulting tribofilms [5,6].

Phosphorus- and molybdenum-containing compounds represent important additive chemistries for improving the tribological performance of lubricants. Phosphorus-based additives can react with iron-containing surfaces to generate phosphate-containing reaction films, which may provide protection against surface wear. For example, Mangolini et al. investigated the surface reactivity of triphenyl phosphorothionate (TPPT) on oxidized iron surfaces using ATR/FT-IR and XPS, identifying the formation of pyrophosphate, organophosphate and sulfate species [7]. Molybdenum-containing additives, on the other hand, exhibit different tribological mechanisms depending on their chemical structures and ligand compositions. Furthermore, the interaction between sulfur- and phosphorus-containing additives may lead to either synergistic or antagonistic effects. Yu et al. demonstrated that the combined use of sulfurized and phosphorus-based additives could improve the antiwear performance of lithium complex grease under selected formulation and temperature conditions [2]. More recently, experimental and theoretical investigations have further highlighted the distinct surface interactions and protective functions of phosphorus- and sulfur-derived tribofilms [8].

In addition to their anti-wear properties, certain phosphorus- and molybdenum-based additives have also been reported to contribute to extreme-pressure performance. However, their load-carrying effectiveness depends strongly on their chemical structures. Forbes et al. demonstrated that the extreme-pressure properties of amine phosphates varied significantly depending on the molecular structures of the phosphate and amine components [9]. Similarly, Barber reported that certain N-alkylammonium alkyl hydrogen phosphites were particularly effective in increasing the initial seizure load during four-ball testing [10]. Regarding molybdenum-based additives, Singh investigated Mo-S complexes in lithium-base greases and reported increased weld loads compared with the additive-free grease [11]. These findings indicate that phosphorus- and molybdenum-containing additives may contribute differently to extreme-pressure performance depending on their chemical composition and formulation. Therefore, their ability to maintain or enhance the EP performance of sulfur-containing grease formulations requires further investigation.

Despite these findings, the influence of sulfurized olefin concentration on the wear behaviour of a specific lithium complex grease formulation, as well as the ability of different AW additive chemistries to mitigate its potential adverse effects, requires further investigation. In this study, the effect of sulfurized olefin addition on the wear-preventive performance of an NLGI 2 lithium complex grease was investigated using the four-ball wear test in accordance with ASTM D2266. Subsequently, different phosphorus- and molybdenum-based AW additive systems, including TPPT, amine phosphate, zinc dialkyldithiophosphate (ZnDTP), dioleyl hydrogen phosphite, molybdenum dialkyldithiophosphate (MoDTP) and an organomolybdenum complex, were evaluated in combination with sulfurized olefin. The effects of additive concentration and chemical type on wear scar diameter were examined to identify formulation-dependent changes in wear behaviour. The EP performance of the selected formulations was also considered through a separate four-ball extreme-pressure evaluation in accordance with ASTM D2596.

MATERIALS AND METHODS

Materials

In this study, an NLGI Grade 2 lithium complex grease (LitX) was used as the reference grease matrix. Sulfurized olefin (SO), containing 29 wt% total sulfur and 14 wt% active sulfur, was used as the sulfur-based EP additive. Different phosphorus- and molybdenum-based additives were incorporated into the formulations to investigate their effects on wear behaviour. The chemical names and classifications of the investigated materials are presented in Table 1.

Table 1. Chemical names and classifications of the investigated materials

Abbreviation	Chemical name	Additive category
LitX	Lithium complex grease	Reference grease
SO	Sulfurized olefin	Sulfur-based
TPPT	O,O,O-Triphenyl phosphorothioate	Phosphorus-based
Amine phosphate	Amine phosphate	Phosphorus-based
ZnDTP	Zinc dialkyldithiophosphate	Phosphorus-based
DHP	Dioleyl hydrogen phosphite	Phosphorus-based
MoDTP	Molybdenum dialkyldithiophosphate	Molybdenum-based
Mo-complex	Organomolybdenum complex	Molybdenum-based

Methods

The kinematic viscosity of the base oil was determined at 40 °C in accordance with ASTM D445 using a kinematic viscometer. The consistency of the grease formulations was evaluated by measuring worked penetration according to ASTM D217 at 25 °C. Prior to measurement, grease samples were subjected to 60 strokes using a mechanical grease worker. All formulations were prepared at comparable penetration levels to maintain consistent grease consistency.

The anti-wear properties of the grease formulations were evaluated using a four-ball wear tester in accordance with ASTM D2266. The tests were conducted at 75 °C, under a load of 40 kgf (392 N), at a rotational speed

of 1200 rpm for 60 min. Following each test, the wear scar diameters (WSD) on the three stationary steel balls were measured, and the average value was reported. Additionally, the wear scars on the steel balls were examined using an Olympus DSX1000 digital microscope, and two-dimensional optical images were captured for visual evaluation. The extreme-pressure properties of the grease formulations were evaluated using a four-ball EP tester in accordance with ASTM D2596. The weld point was determined to assess the load-carrying capacity of the formulations. All tests were measured according to American Society for Testing and Materials (ASTM) test methods.

The four-ball test configurations and their respective evaluation principles for AW and EP performance are schematically illustrated in Figure 1. The figure shows the formation of wear scars on the stationary balls during the AW test and the occurrence of contact welding under increasing loads during the EP test.

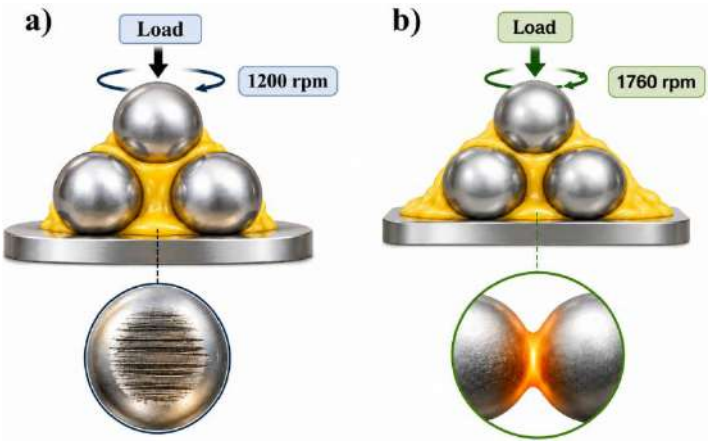


Figure 1. Schematic representation of the four-ball test configurations for **a)** AW and **b)** EP evaluation.

Experiment

The experimental study was designed to investigate the effect of sulfurized olefin concentration on the wear behaviour of NLGI Grade 2 lithium complex grease (LitX). Initially, formulations containing different SO concentrations (0%, 2%, 4%, and 6%) were prepared to evaluate the influence of SO on the wear performance of the reference grease.

Following the initial evaluation, different phosphorus- and molybdenum-based additives were incorporated into selected grease formulations to investigate their effects on wear behaviour. The additive concentrations were varied depending on the chemical type and formulation. The consistency of all formulations was maintained at a comparable penetration level to ensure consistent grease consistency during tribological evaluation.

The chemical structures of the investigated additives are presented in Figure 2.

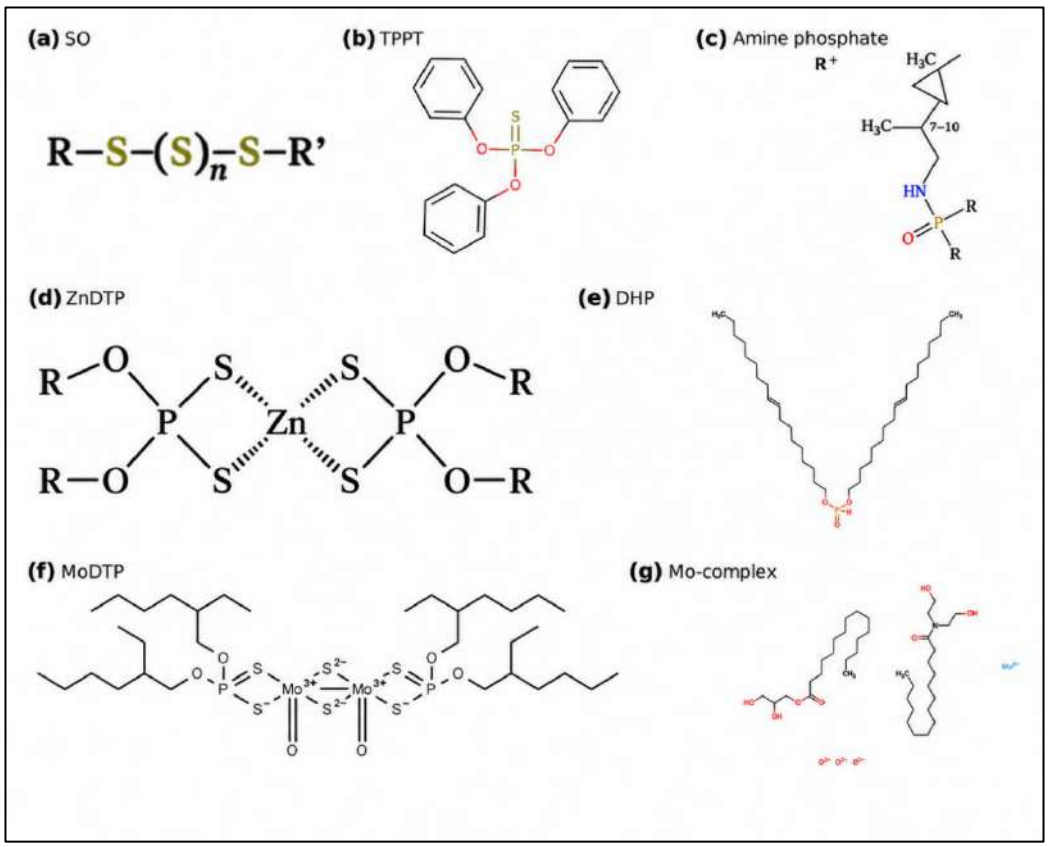


Figure 2. Chemical structures of the investigated additives.

The experimental formulations were divided into three groups according to the additive systems investigated: sulfurized olefin concentration, phosphorus-based additives and molybdenum-based additives. The formulation compositions are presented in Tables 2, 3, 4 and 5, respectively.

Table 2. Formulations containing different sulfurized olefin concentrations

Grease matrix	SO (%)
LitX	-
LitX	2
LitX	4
LitX	6

Table 3. Formulations containing phosphorus-based (Amine phosphate, ZnDTP and DHP) additives

Grease matrix	SO (%)	Amine phosphate (%)	ZnDTP (%)	DHP (%)
LitX	2	-	-	-
LitX	2	3	-	-
LitX	2	-	3	-
LitX	2	-	-	3

Table 4. Formulations containing phosphorus-based (TPPT) additive

Grease matrix	SO (%)	TPPT (%)
LitX	2	-
LitX	-	2
LitX	2	1
LitX	2	2
LitX	2	3
LitX	2	4

Table 5. Formulations containing molybdenum-based additives

Grease matrix	SO (%)	Mo-complex (%)	MoDTP (%)
LitX	2	-	-
LitX	-	2	-
LitX	-	3	-
LitX	2	2	-
LitX	2	3	-
LitX	2	4	-
LitX	2	-	3

RESULTS AND DISCUSSION

The experimental results are presented in this section. The technical properties of the reference LitX grease are summarized in Table 6.

Table 6. Technical Data of LitX Grease

Technical Properties	Typical Values	Test Method
NLGI Grade	2	ASTM D217
Thickener Type	Lithium complex	-
Base Oil Type	Mineral	-
Base Oil Viscosity (@40°C, mm²/s)	150	ASTM D445
Worked Penetration (25°C, 60 strokes, 0.1 mm)	280	ASTM D217
Wear Scar Diameter (mm)	0.737	ASTM D2266
Weld Point (kgf)	200	ASTM D2596

The anti-wear and extreme-pressure properties of the lithium complex grease formulations were evaluated to investigate the effects of sulfur-, phosphorus- and molybdenum-based additives. The results are presented and discussed according to the additive type and concentration, with particular emphasis on their effects on wear scar diameter.

Effect of Sulfurized Olefin Concentration on Wear Behaviour

As shown in Figure 3, the reference lithium complex grease exhibited a wear scar diameter of 0.737 mm. The addition of 2% SO increased the WSD to 1.033 mm, while increasing the SO concentration to 4% resulted in a further increase to 1.248 mm. These results indicate that SO addition adversely affected the anti-wear

performance of the grease, with higher concentrations resulting in larger wear scar diameters. No evaluable WSD result was obtained for the formulation containing 6% SO.

Overall, SO addition alone did not improve the wear protection of the investigated lithium complex grease.

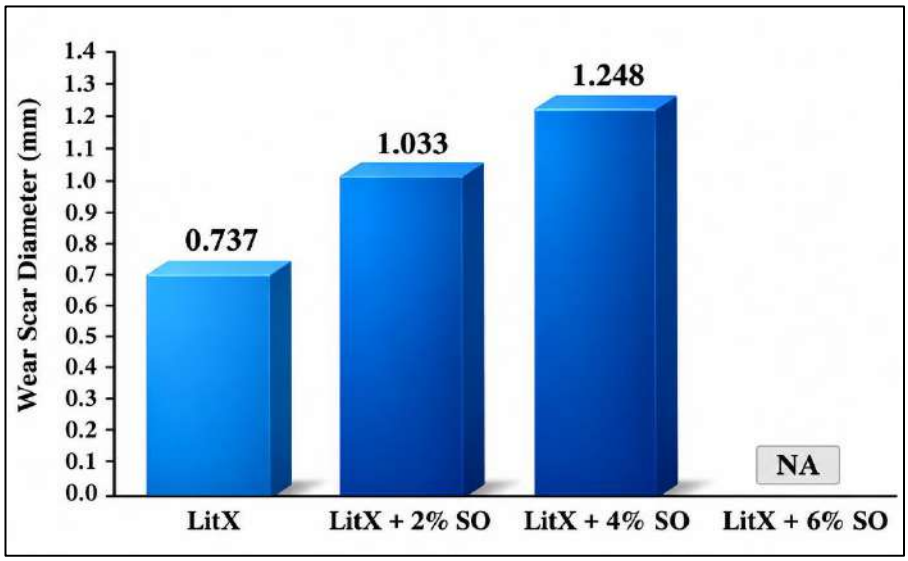


Figure 3. Effect of SO Concentration on the AW Performance of LitX Grease

Effect of Amine Phosphate on Wear Behaviour

As shown in Figure 4, the addition of 3% amine phosphate to the grease containing 2% SO reduced the wear scar diameter from 1.0333 mm to 0.978 mm. This result indicates that amine phosphate partially improved the anti-wear performance of the SO-containing formulation. However, the WSD remained higher than that of the reference LitX grease (0.737 mm).

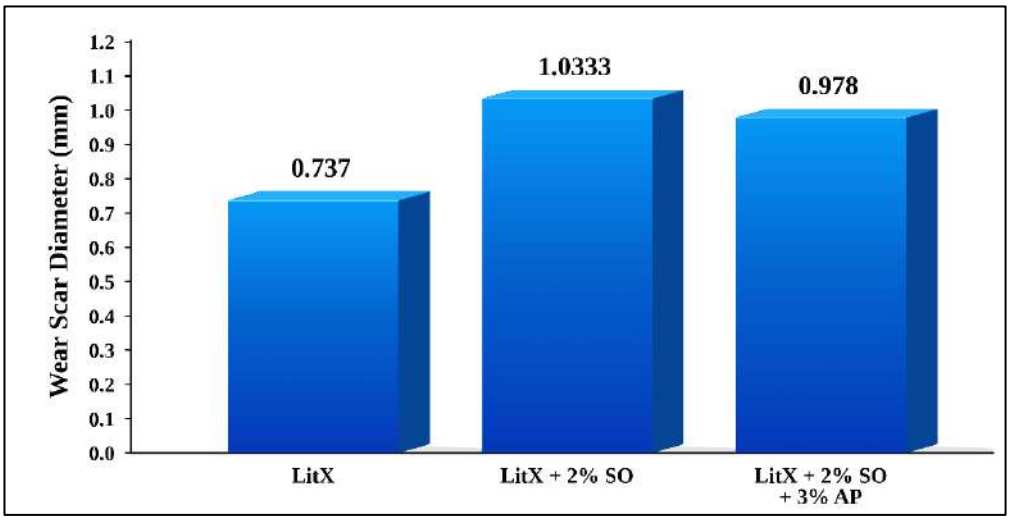


Figure 4. Effect of Amine Phosphate on the AW Performance of SO-Containing LitX Grease

Effect of ZnDTP on Wear Behaviour

As presented in Figure 5, the formulation containing 3% ZnDTP exhibited a lower WSD (0.926 mm) compared with the formulation containing 2% SO alone (1.0333 mm). This reduction indicates that ZnDTP contributed to improving the anti-wear performance of the SO-containing grease. Nevertheless, the wear scar diameter remained above the reference LitX value (0.737 mm), indicating that the improvement was partial.

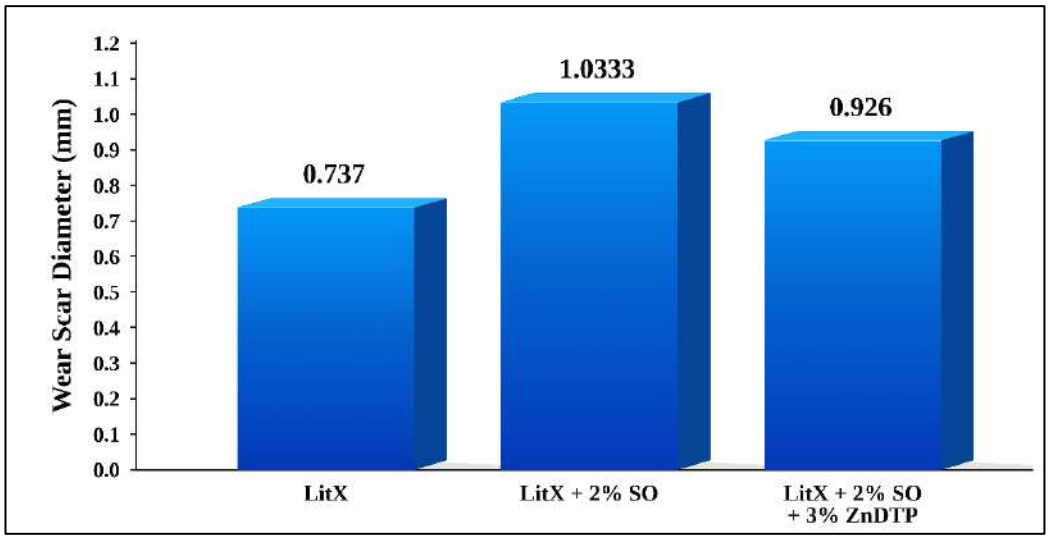


Figure 5. Effect of ZnDTP on the AW Performance of SO-Containing LitX Grease

Effect of TPPT on Wear Behaviour

As shown in Figure 6, the addition of 2% TPPT to the reference LitX grease increased the WSD from 0.737 mm to 0.933 mm, indicating an adverse effect on anti-wear performance when used alone. However, in the presence of 2% SO, TPPT addition progressively reduced the WSD from 1.0333 mm to 0.882 mm, 0.8345 mm and 0.402 mm at concentrations of 1%, 2% and 3%, respectively. The lowest WSD (0.402 mm) was obtained with 3% TPPT. This result suggests a synergistic interaction between 2% SO and 3% TPPT, leading to a substantial improvement in anti-wear performance. Notably, the resulting WSD was also lower than that of the reference LitX grease. However, increasing the TPPT concentration to 4% resulted in an increase in WSD to 0.826 mm, indicating that the improvement was concentration dependent.

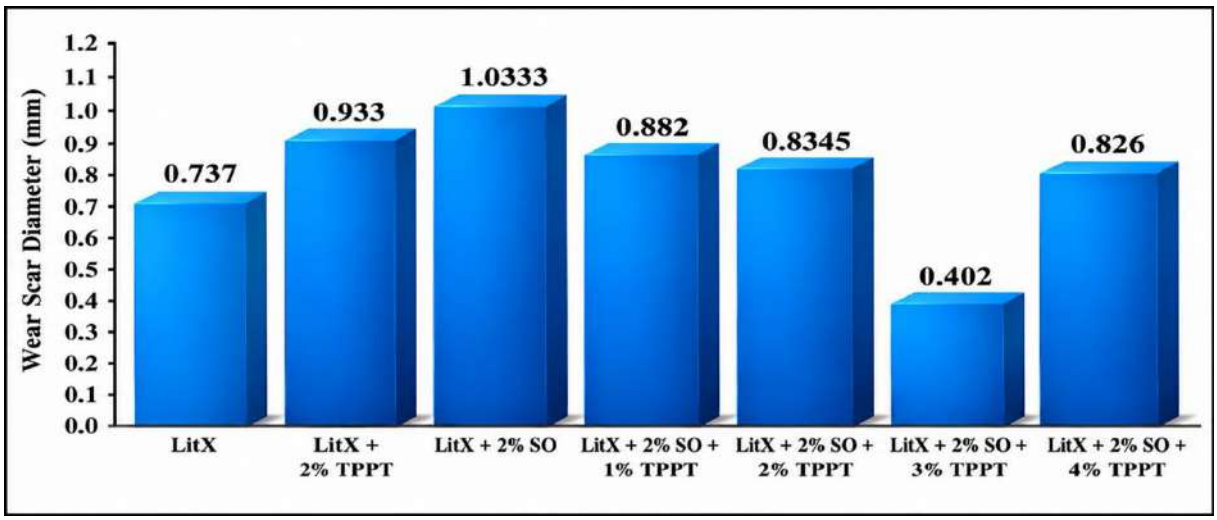


Figure 6. Effect of TPPT on the AW Performance of LitX Grease with and without SO

Effect of Dioleyl Hydrogen Phosphite (DHP) on Wear Behaviour

As shown in Figure 7, the addition of 3% DHP to the grease containing 2% SO reduced the WSD from 1.0333 mm to 0.893 mm. This result indicates that DHP partially improved the anti-wear performance of the SO-containing formulation. However, the WSD remained higher than that of the reference LitX grease (0.737 mm), indicating that the improvement was insufficient to restore the wear performance of the reference formulation.

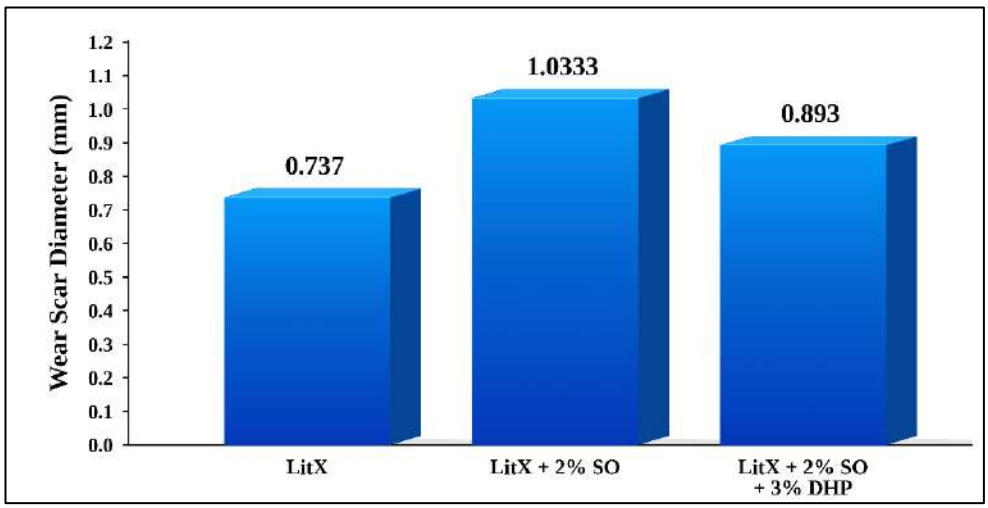


Figure 7. Effect of DHP on the AW Performance of SO-Containing LitX Grease

Effect of Mo-Complex on Wear Behaviour

As shown in Figure 8, the addition of Mo-complex to the reference LitX grease slightly reduced the WSD from 0.737 mm to 0.725 mm and 0.655 mm at concentrations of 2% and 3%, respectively. In the presence of 2% SO, the addition of 2% Mo-complex resulted in a slight reduction in WSD from 1.0333 mm to 0.994 mm. However, increasing the Mo-complex concentration to 3% and 4% led to a substantial reduction in WSD to 0.4116 mm and 0.406 mm, respectively. These results suggest a beneficial synergistic interaction between SO and Mo-complex, resulting in a significant improvement in anti-wear performance. Although the lowest WSD was obtained with 4% Mo-complex, the 3% formulation provided a comparable wear performance at a lower additive concentration, suggesting a more favourable balance between additive concentration and anti-wear effectiveness.

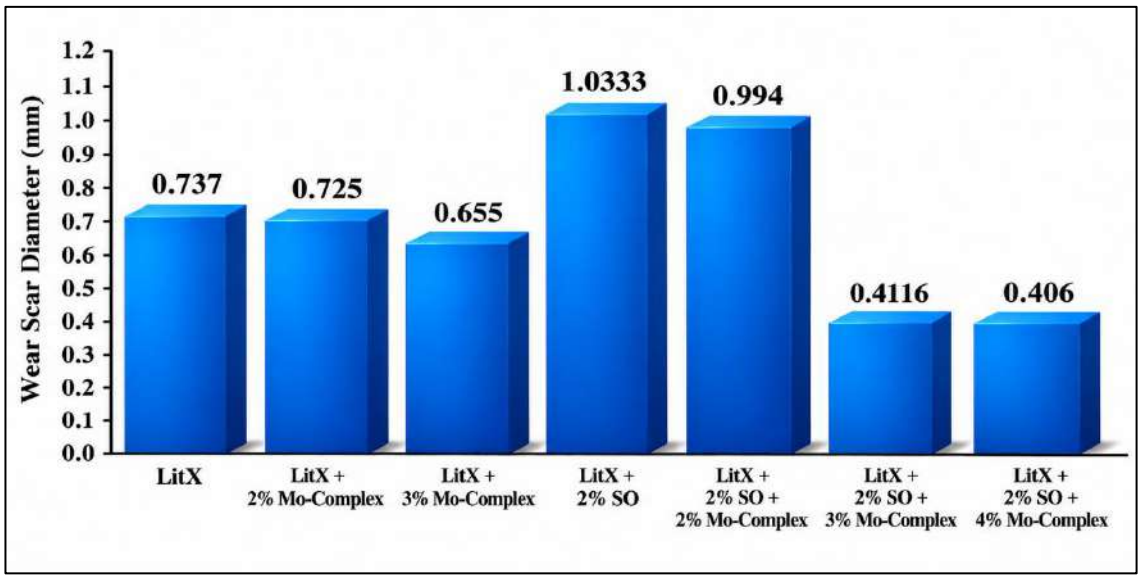


Figure 8. Effect of Mo-Complex on the AW Performance of LitX Grease with and without SO

Effect of MoDTP on Wear Behaviour

As shown in Figure 9, the addition of 3% MoDTP to the grease containing 2% SO reduced the wear scar diameter (WSD) from 1.0333 mm to 0.814 mm. This result indicates that MoDTP improved the anti-wear performance of the SO-containing formulation. However, the WSD remained higher than that of the reference LitX grease (0.737 mm), indicating a limited improvement compared with the other investigated additive systems.

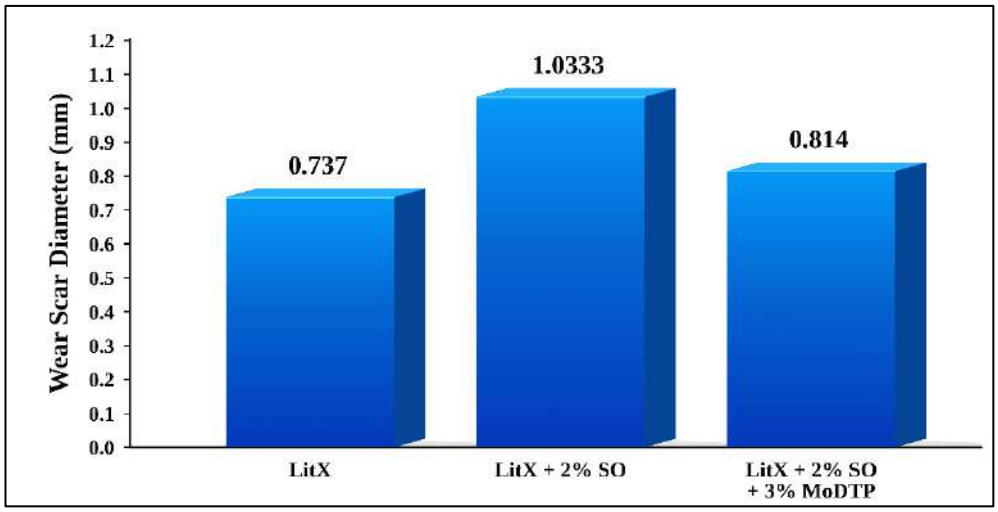


Figure 9. Effect of MoDTP on the AW Performance of SO-Containing LitX Grease

As shown in Figure 10, the optical micrographs of the wear scars provide a visual comparison of the anti-wear performance of the investigated formulations. The addition of 2% SO resulted in a larger wear scar compared with the reference LitX grease, confirming its adverse effect on wear behaviour. In contrast, the incorporation of 3% TPPT or 3% Mo-complex into the SO-containing grease resulted in considerably smaller wear scars. These observations are consistent with the WSD measurements and further support the improved anti-wear performance achieved by the SO–TPPT and SO–Mo-complex additive combinations.

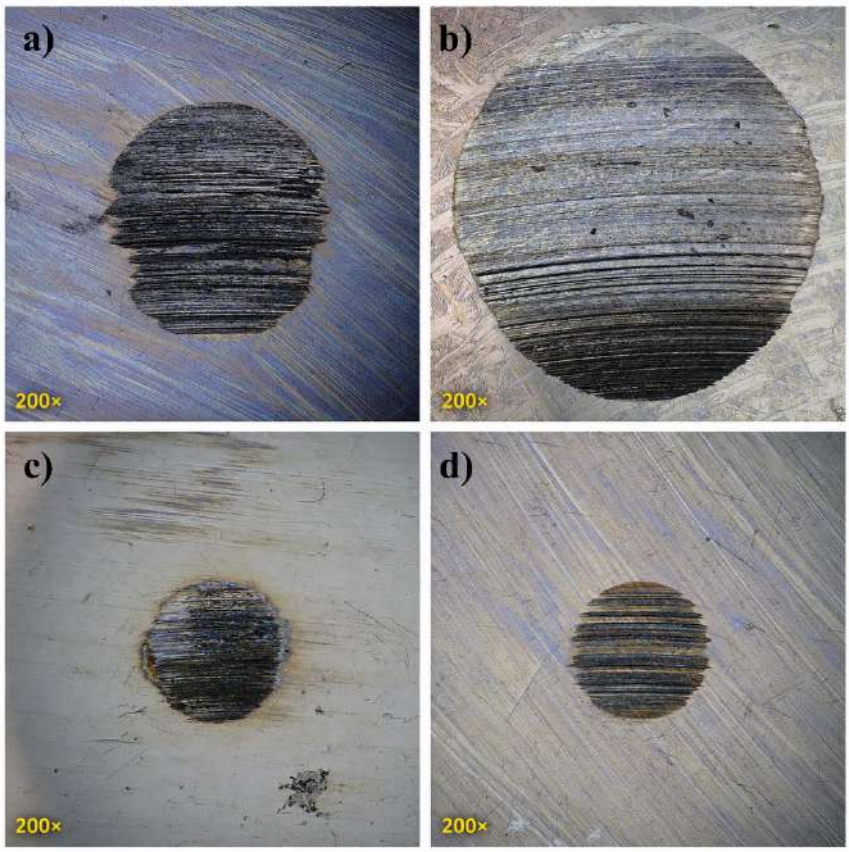


Figure 10. Optical micrographs of wear scars on steel balls after four-ball wear testing: **a)** LitX, **b)** LitX + 2% SO, **c)** LitX + 2% SO + 3% TPPT, and **d)** LitX + 2% SO + 3% Mo-complex

The anti-wear performance was strongly influenced by the chemical structure of the additives. Among the investigated formulations, the combinations of 2% SO with 3% TPPT and 3% Mo-complex provided the most effective wear reduction. The 3% Mo-complex concentration was selected as the preferred formulation because it achieved a substantial reduction in WSD without requiring the additional additive loading of 4%, which resulted in only a slight further decrease in WSD. Therefore, these two formulations were selected for further evaluation of their extreme-pressure performance.

Effect of TPPT on Extreme-Pressure Performance

As shown in Figure 11, the reference LitX grease exhibited a weld load of 200 kgf. The addition of 2% SO increased the weld load to 315 kgf, demonstrating an improvement in load-carrying capacity. The incorporation of 3% TPPT into the SO-containing formulation maintained the weld load at 315 kgf, with no further increase observed. These results indicate that TPPT, which provided significant improvement in anti-wear performance, maintained the EP performance achieved by SO without compromising its load-carrying capacity.

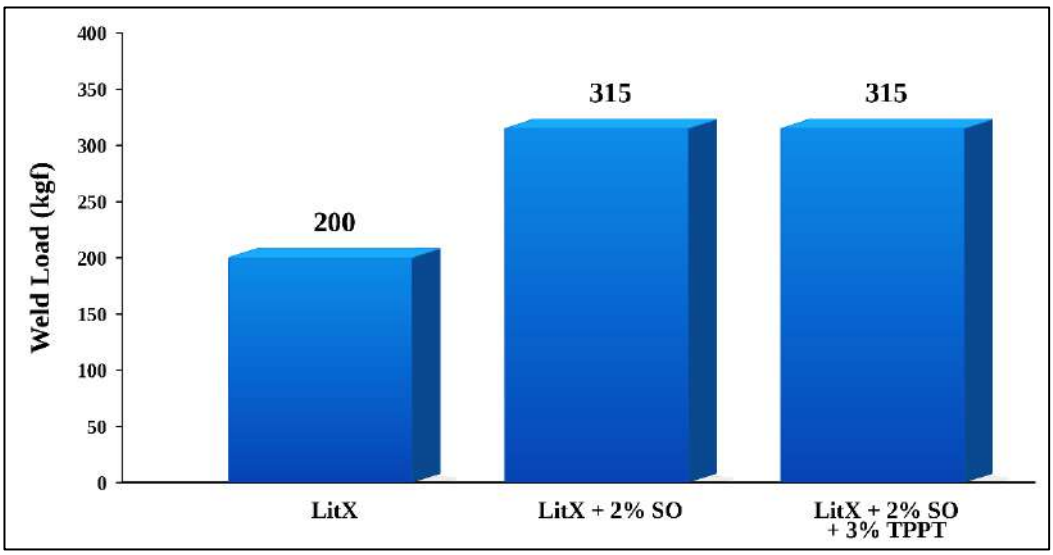


Figure 11. Effect of SO and TPPT on the EP Performance of LitX grease

Effect of Mo-complex on Extreme-Pressure Performance

As shown in Figure 12, the addition of 3% Mo-complex to the formulation containing 2% SO increased the weld load from 315 kgf to 400 kgf. This result demonstrates that Mo-complex further enhanced the load-carrying capacity of the SO-containing grease. Considering the significant reduction in WSD observed with the same additive combination, these findings suggest a beneficial synergistic interaction between SO and Mo-complex, contributing to improvements in both anti-wear and extreme-pressure performance.

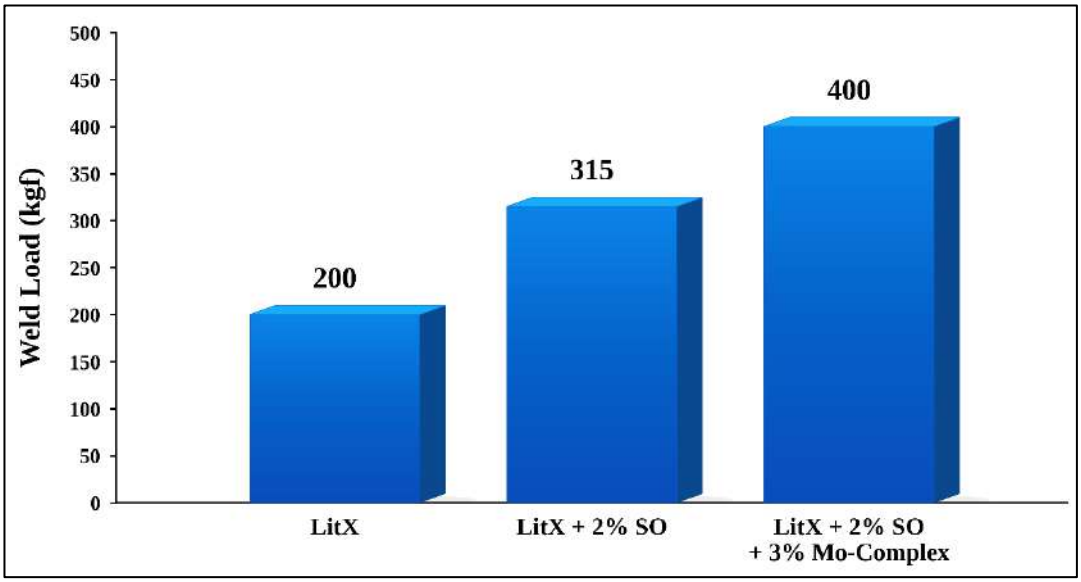


Figure 12. Effect of SO and Mo-Complex on the EP Performance of LitX grease

CONCLUSION

The experimental findings demonstrated that the addition of sulfurized olefin (SO) adversely affected the anti-wear performance of lithium complex grease, despite its positive contribution to EP performance. The

evaluation of different phosphorus- and molybdenum-based additives revealed that their effectiveness varied depending on their chemical structures and compatibility with SO.

Among the phosphorus-based additives, TPPT demonstrated the most effective anti-wear performance when combined with SO. The formulation containing 2% SO and 3% TPPT resulted in a substantial decrease in wear scar diameter. However, increasing the TPPT concentration to 4% did not provide further improvement. Similarly, the organomolybdenum complex exhibited a significant contribution to wear protection, with the combination of 2% SO and 3% Mo-complex providing an effective balance between additive concentration and anti-wear performance. In comparison, the addition of amine phosphate, ZnDTP, DHP and MoDTP to SO-containing formulations resulted in more limited improvements in wear behaviour.

The extreme-pressure evaluation further demonstrated the beneficial contribution of these additive systems. While the addition of TPPT maintained the EP performance provided by SO, the Mo-complex combination increased the weld load to 400 kgf. This result, together with its favourable anti-wear performance, highlights the potential of combining SO with organomolybdenum compounds to improve the overall tribological properties of lithium complex grease.

These findings demonstrate that the selection of AW and EP additives should consider not only their individual properties but also their interactions within the grease formulation. Further investigations will focus on surface characterization to better understand the tribochemical interactions between sulfur-, phosphorus- and molybdenum-containing additives, as well as evaluating the selected formulations under different operating conditions to assess their potential for practical applications.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to Belgin Oil for its valuable support and contributions throughout this study.

REFERENCES

[1] Lugt, P. M., & Pallister, D. M. (2012). Grease composition and properties. In P. M. Lugt (Ed.), Grease Lubrication in Rolling Bearings (pp. 23–69). Wiley. https://doi.org/10.1002/9781118483961.ch3

[2] Yu, W., Zhang, C., Dong, Y., & Reddyhoff, T. (2016). Research on mutual synergy of antiwear additives in lithium complex grease. *Tribology Transactions, 59*(2), 330–339. https://doi.org/10.1080/10402004.2015.1077411

[3] ASTM International. (2023). *ASTM D2266-23: Standard test method for wear preventive characteristics of lubricating grease (Four-Ball Method).* ASTM International. https://doi.org/10.1520/D2266-23

[4] ASTM International. (2026). *ASTM D2596-26: Standard test method for measurement of extreme-pressure properties of lubricating grease (Four-Ball Method).* ASTM International. https://doi.org/10.1520/D2596-26

[5] Chen, Y.-L., Ma, R., Dong, J.-Y., Han, Y.-M., Ma, W.-W., Zhang, E.-H., & Li, W.-M. (2025). New insights into the interactions between phosphorus- and sulfur-containing lubricating additives. *Tribology International, 211*, 110870. https://doi.org/10.1016/j.triboint.2025.110870

[6] Wang, J., Zheng, J., Wang, J., Yao, X., Xiong, X., & Huang, H. (2025). Synergistic tribological performance of phosphorus- and sulfur-based extreme pressure and anti-wear additives. *Lubricants, 13*(2), 55. https://doi.org/10.3390/lubricants13020055

[7] Mangolini, F., Rossi, A., & Spencer, N. D. (2011). Chemical reactivity of triphenyl phosphorothionate (TPPT) with iron: An ATR/FT-IR and XPS investigation. *The Journal of Physical Chemistry C, 115*(4), 1339–1354. https://doi.org/10.1021/jp107617d

[8] Koshima, H., Hamano, A., Kinoshita, H., Aoki, A., & Washizu, H. (2026). Experimental and theoretical study on adsorption and reaction behavior of phosphorus antiwear and sulfur extreme pressure additives. *Tribology International, 216*, 111597. https://doi.org/10.1016/j.triboint.2025.111597

[9] Forbes, E. S., Neustadter, E. L., Silver, H. B., & Upsdell, N. T. (1971). The effect of chemical structure on the load-carrying properties of amine phosphates. Wear, 18(4), 269–278. https://doi.org/10.1016/0043-1648(71)90070-6

[10] Barber, R. I. (1976). The preparation of some phosphorus compounds and their comparison as load-carrying additives by the four-ball machine. ASLE Transactions, 19(4), 319–328. https://doi.org/10.1080/05698197608982809

[11] Singh, T. (2008). Tribochemistry and EP activity assessment of Mo-S complexes in lithium-base greases. Advances in Tribology, 2008, Article 947543. https://doi.org/10.1155/2008/947543

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

DISPERSION, AGGLOMERATION, AND MECHANICAL PERFORMANCE IN EPOXY COMPOSITES INCORPORATING GREEN-SYNTHESIZED METAL OXIDE NANOPARTICLES: A CRITICAL REVIEW

Mukaddes Karataş
Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ-Türkiye.
ORCID: 0000-0001-5803-6821
Buket Erzen
Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ-Türkiye.
ORCID: 0000-0001-5098-7171
Şermin Deniz
Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ-Türkiye.
ORCID: 0000-0001-5074-0777
Ramazan Orhan
Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ-Türkiye.
ORCID: 0000-0003-2287-4238

Abstract

Plant-extract-assisted synthesis offers an alternative route for producing metal oxide nanoparticles for polymer reinforcement. However, their incorporation into epoxy matrices requires careful consideration of particle dispersion, surface chemistry, and interfacial compatibility. This review aims to critically examine the relationships between processing conditions, dispersion characteristics, and mechanical performance in epoxy composites containing green-synthesized metal oxide nanoparticles. Particular attention is directed toward zinc oxide, copper oxide, titanium dioxide, and iron oxide fillers prepared using plant-derived extracts, including agricultural waste sources. The discussion considers how synthesis and post-treatment conditions may influence particle morphology and surface characteristics, and how these features interact with filler loading, mixing procedures, ultrasonication, and surface modification during composite preparation. Tensile strength, elastic modulus, elongation at break, and hardness are considered alongside morphological evidence to assess the balance between reinforcement and agglomeration-related limitations. The review also addresses the interpretation of fracture-surface observations and the need to distinguish nanoparticle effects from changes in curing conditions and specimen preparation. A central focus is the extent to which reported improvements can be attributed to the green synthesis route, particularly when comparisons with conventionally synthesized nanoparticles are unavailable. By connecting nanoparticle preparation with composite processing and mechanical response, this review seeks to identify practical considerations for epoxy nanocomposite design and priorities for future research. These include clearer reporting of filler content, quantitative evaluation of dispersion, appropriate reference materials, and independent assessment of environmental benefits.

Keywords: Green synthesis; epoxy nanocomposites; metal oxide nanoparticles; dispersion; agglomeration; mechanical properties.

1. Introduction

Plant-extract-assisted metal oxide synthesis has become relevant to epoxy reinforcement because it offers opportunities to alter particle formation while using renewable biological inputs. Its value, however, must be assessed at the composite level. Direct investigations already include turmeric-derived CuO in epoxy (Orhan, 2025), nettle-derived CuO in ramie/bio-epoxy hybrids (Velmurugan et al., 2024), and walnut-husk-derived oxides in epoxy (Oner et al., 2024). These studies place green-synthesized fillers within an experimentally accessible materials-design problem: whether the final powder can be dispersed and incorporated without introducing defects that offset reinforcement.

The term green synthesis describes a preparation strategy, rather than a guarantee of particle uniformity or favorable interfacial chemistry. *Moringa oleifera*-assisted ZnO synthesis illustrates how plant constituents participate in particle formation (Matinise et al., 2017). Comparative CuO and magnetite investigations further show that biological and chemical routes can produce powders with different aggregation and surface characteristics (Keabadile et al., 2020; Piro et al., 2023). Such differences justify evaluating the route, but do not establish that its product will outperform conventional particles in a cured epoxy network.

Mechanical performance also comprises distinct outcomes. Increased modulus or hardness does not necessarily imply increased strength, failure strain, or fracture toughness. Conventional epoxy nanocomposite research provides useful explanations of stress transfer and damage development (Wetzel et al., 2006; Johnsen et al., 2007). Here, those investigations serve a limited mechanistic role; conclusions about green-synthesized fillers are grounded in studies that actually used those fillers.

This critical narrative review examines how plant-extract-assisted nanoparticle synthesis and composite processing influence dispersion, agglomeration, and mechanical performance in epoxy. Particular attention is given to ZnO, CuO, TiO_2, and iron oxides. Selected studies involving ZrO_2, SrO, Ce_2O_3, and NiO provide complementary comparisons of loading-dependent behavior and reinforcement architecture. Evidence from particle-filled epoxy is considered separately from fiber hybrids and coatings, while synthesis-only studies inform the discussion of powder characteristics. The assessment distinguishes improvements achieved with green-synthesized fillers from advantages attributable specifically to the synthesis route.

2. Scope and Evidence Selection

The literature was examined through targeted searches combining epoxy with green synthesis, plant extract, the oxide name, dispersion, and mechanical properties. Publisher records, DOI metadata, and accessible article texts or abstracts were checked through 5 November 2026. This is a focused narrative assessment, without an exhaustive systematic-search claim or pooled effect estimate. Retracted articles identified during screening were excluded. Publications in which only the epoxy matrix was bio-based were not classified as evidence of green nanoparticle synthesis.

Three evidence levels guide the discussion. Direct studies establish incorporation of plant-assisted oxides into epoxy and, where reported, mechanical response. Powder studies support statements about synthesis, morphology, or surface characteristics, without being treated as composite tests. Conventional-particle research is retained only for processing, cure, dispersion measurement, and fracture mechanisms. Where only a publisher abstract was accessible, interpretation is restricted to information explicitly available there; unreported loading, curing, and statistical details are not reconstructed.

3. From Green Synthesis to Dispersion in Epoxy

3.1. Extract chemistry and particle formation

Extract identity alone does not define a reproducible filler. Plant part, extraction solvent, solids-to-liquid ratio, pH, precursor, and separation procedure can change the material entering the resin. Vera et al. (2023) evaluated antioxidant activity as an indicator of plant-extract-mediated ZnO synthesis efficiency, supporting the characterization of the extract itself. Bozkurt and Şahin (2025) varied microwave-assisted ZnO synthesis conditions using rosehip seed extract. Such work motivates reporting measurable preparation variables instead of attributing particle characteristics solely to the botanical species.

Precursor selection remains influential within a green route. Fakhari et al. (2019) used *Laurus nobilis* extract with zinc acetate and zinc nitrate, while Sedefoglu (2024) varied precursor and calcination temperature for *Myrtus communis*-assisted ZnO. These studies show why two powders described simply as green ZnO need not be equivalent. López-López et al. (2022) also compared several biological extracts for ZnO preparation. Their powder characterization supports extract-dependent material formation, but its photocatalytic outcome does not establish epoxy reinforcement.

CuO provides comparable evidence of morphological diversity. Sukumar et al. (2020) obtained rice-shaped particles using *Caesalpinia bonducella* seed extract, whereas Selvanathan et al. (2021) prepared CuO nanorods

with *Muntingia calabura* leaves. Keabadile et al. (2020) compared conventional synthesis with *Terminalia phanerophlebia* extracts prepared using different solvents. These examples challenge the assumption of a universal spherical, uniformly capped green filler. The implication for epoxy is a need to characterize aspect ratio, size distribution, and aggregation before selecting a mixing procedure.

The chemical pathway also requires precise language. Formation of an oxide from a metal salt can involve complexation, hydrolysis, precipitation, and thermal conversion; use of an extract does not by itself demonstrate reduction through a zero-valent metal intermediate. Phase identification should accompany the proposed mechanism. Different oxides, hydroxide residues, or precursor remnants would introduce different surface and curing interactions even at the same nominal filler loading.

3.2. Thermal history and the surface delivered to the resin

Post-treatment creates a balance between precursor conversion, organic removal, and particle growth. Karam and Abdulrahman (2022) investigated thyme-assisted ZnO across several calcination temperatures and observed changes in morphology and aggregation. For TiO_2, Sundrarajan and Gowri (2011) established an early *Nyctanthes arbor*-tristis-assisted route; more recent studies examined Inula viscosa-derived powders at different calcination temperatures (Moghni et al., 2025) and varied neem leaf condition, solvent, and thermal treatment (Zahan et al., 2025). These are synthesis findings, not demonstrations of improved epoxy mechanics.

Surface-organic retention cannot be inferred from the use of a plant extract before calcination. Manimehala U et al. (2025), studying *Camellia sinensis*-assisted CuO, associated thermal treatment with changes in surface functionality and porosity. That observation supports examining the final powder, although their antibacterial measurements cannot predict adhesion to epoxy. FTIR and thermogravimetric analysis can help assess organic material and moisture; surface-sensitive measurements are desirable when a persistent phytochemical layer is central to the explanation.

Particle-size terminology must also remain consistent. An XRD-derived coherent-domain size, a microscopy-derived particle dimension, and a suspension-based hydrodynamic size measure different features. Aalami et al. (2024) combined XRD, microscopy, dynamic light scattering, and zeta potential when comparing plant-assisted ZnO with chemically precipitated material. Mousa et al. (2024) likewise characterized ZnO from chemical and plant-assisted routes using complementary methods. These comparisons are useful for powder selection, while leaving the dispersion retained in cured epoxy to be measured separately.

For iron oxides, Piro et al. (2023) reported route-dependent differences in aggregation, surface stabilization, and magnetic properties for *Rhus coriaria*-assisted magnetite. These characteristics matter when selecting a candidate filler, but magnetic response is not a proxy for dispersion in epoxy. The screened evidence does not support assigning the same confidence to plant-assisted iron oxide–epoxy mechanics as to the direct CuO examples. An uneven evidence base should remain visible rather than being filled with results from conventionally synthesized iron oxide composites.

3.3. Mixing and preservation of dispersion

Dry-powder morphology does not determine the distribution achieved in viscous resin. Wetting, particle contacts, mixing temperature, and the available interval before gelation jointly influence the final structure. Bittmann et al. (2009, 2011) demonstrated the relevance of ultrasonic processing in conventional inorganic-particle/epoxy systems. Choi et al. (2021) further compared sonication approaches for TiO_2-filled epoxy. These studies justify monitoring dispersion during processing, without establishing a transferable sonication duration for a different green-synthesized powder.

Ultrasound used during green synthesis must be distinguished from ultrasound used to disperse the isolated powder in resin. Sathya et al. (2017) examined ultrasound-assisted iron oxide formation with *Coriandrum sativum* extract. Their results concern nanoparticle preparation, not cluster breakup in an epoxy formulation. Composite processing therefore needs its own record of mixing sequence, equipment, batch volume, temperature, degassing, and, where applicable, solvent removal.

Increasing filler loading simultaneously changes interparticle spacing, the amount of interface, and processing difficulty. Constant mixing settings may consequently produce different void populations or cluster distributions across a loading series. Aqueous stability or zeta potential measured for the powder cannot be directly translated into compatibility with an organic resin. Figure 1 outlines the general preparation sequence, from plant extraction and metal oxide nanoparticle synthesis to dispersion in epoxy, curing, and composite evaluation. The processing conditions should be selected according to the oxide chemistry, extract characteristics, and resin–hardener system (Matinise et al., 2017; Bittmann et al., 2009; Orhan, 2025).

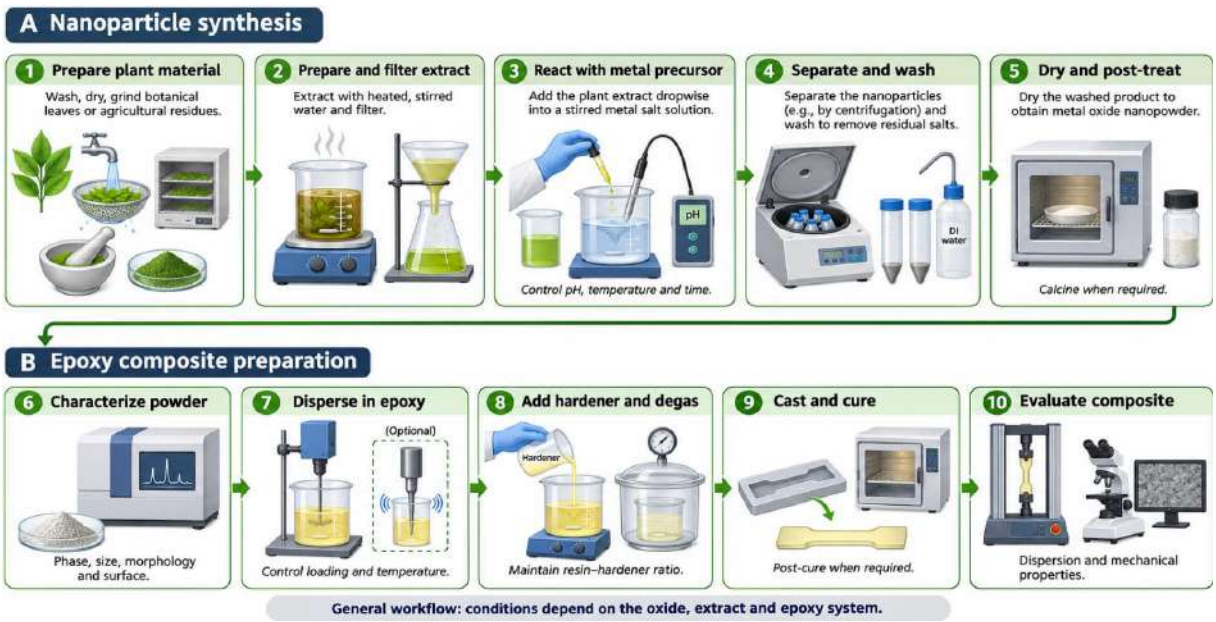


Figure 1. General workflow for plant-extract-assisted synthesis of metal oxide nanoparticles and preparation of epoxy composites. Calcination, ultrasonic dispersion, and post-curing are applied where required by the selected material system. The diagram presents a general preparation sequence rather than a single experimental protocol.

4. Mechanical Evidence from Green-Synthesized Oxide–Epoxy Systems

4.1. Particle-filled epoxy

Orhan (2025) provides direct evidence for *Curcuma longa*-assisted CuO in epoxy at 0.5, 1.0, and 2.0 wt.%. Tensile strength increased from approximately 20 MPa for neat epoxy to 30 MPa at 1.0 wt.%, followed by a decline at 2.0 wt.%. Shore D hardness also increased with CuO addition. The strength maximum is relevant because it demonstrates a formulation-dependent balance rather than an unrestricted loading benefit. The proposed role of aggregation and pores at higher content should be evaluated alongside processing and cure effects. A conventional-CuO control was not included, so this result demonstrates reinforcement by a plant-assisted filler without isolating an advantage of the synthesis route.

Complementary evidence from other plant-assisted oxides helps contextualize the loading-dependent behavior observed in epoxy composites. Oner et al. (2024) incorporated walnut-husk-assisted Ce_2O_3 and SrO into epoxy at 0.3, 0.6, and 1 wt.%. They reported a 21% increase in flexural strength for 0.3 wt.% SrO. Although these oxides fall outside the principal material group considered here, the study offers a relevant comparison of low-loading reinforcement using agricultural-waste-derived fillers. Nevertheless, flexural strength cannot be substituted for tensile strength, and the observed low-loading benefit cannot define the appropriate concentration for CuO or ZnO.

As a complementary example, Bishwokarma et al. (2021) prepared *Curcuma longa*-assisted ZrO_2 and tested epoxy composites containing 1, 3, 5, and 10 wt.% filler. Their tabulated compressive response reached a maximum at 5 wt.% and declined at 10 wt.%, while remaining above the neat-epoxy value. The paper reports

unusual strength units and specimen dimensions, limiting quantitative comparison with standard MPa datasets. Its qualitative loading trend is retained here, without converting or pooling the reported values. The authors also identified the need for additional morphological examination; aggregation therefore remains an interpretation rather than a directly quantified cause.

4.2. Fiber hybrids and attribution of the nanoparticle contribution

Velmurugan et al. (2024) used *Urtica dioica*-derived CuO in ramie-fiber/bio-epoxy hybrids and reported improvements in mechanical and dynamic mechanical properties up to 4.5 wt.% CuO. The study connects a plant-assisted oxide with a structural composite, but the measured response includes fiber architecture and fiber–matrix interactions. Its optimum cannot be transferred to particle-only epoxy. A comparison series maintaining the same fiber fraction, treatment, and orientation is essential for interpreting the nanoparticle contribution.

Vivek R. et al. (2026) examined neem-extract-assisted ZnO in ramie/bamboo/epoxy hybrids. Their publisher abstract describes 27 formulations spanning 0.5–1.5 wt.% ZnO alongside changing fiber contents. The selected formulation contained 15 wt.% ramie, 12 wt.% bamboo, and 1.5 wt.% ZnO and achieved 67.71 MPa tensile strength. ANOVA attributed 70.70% of the tensile-response variation to ramie, 20.30% to bamboo, and 7.70% to ZnO within that design. This illustrates the importance of separating filler and fiber effects; those percentages are not universal contributions to strength. The publisher identifies the article as a conference proceeding.

A further comparison involving an oxide outside the principal material group is provided by Murali et al. (2025), who investigated waste-onion-peel-derived NiO in silk-fabric/bamboo/epoxy laminates. The abstract reports tensile and flexural strengths of 180.4 and 237.6 MPa for formulation ES2. These are properties of a multicomponent laminate, and neither an isolated NiO effect nor an optimum NiO concentration can be inferred from the accessible abstract. Its mechanical results are therefore included as hybrid evidence, without interpreting its electromagnetic shielding measurements as proof of reinforcement mechanisms.

Table 1. Direct mechanical evidence for plant-assisted oxide fillers in epoxy.

Study and plant source	Oxide and epoxy system	Mechanical finding	Main limitation
Orhan (2025); turmeric	CuO; particle-filled epoxy	Strength maximum at 1 wt.%; decline at 2 wt.%.	No conventional-CuO control.
Oner et al. (2024); walnut husk	Ce_2O_3/SrO; particle-filled epoxy	21% flexural-strength gain at 0.3 wt.% SrO.	Flexural result; route advantage not isolated.
Bishwokarma et al. (2021); turmeric	ZrO_2; particle-filled epoxy	Compressive response peaked at 5 wt.%; lower at 10 wt.%.	Reported units and dimensions limit comparison.
Velmurugan et al. (2024); nettle	CuO; ramie/bio-epoxy hybrid	Mechanical benefits reported up to 4.5 wt.% CuO.	Fiber and particle contributions require separation.
Vivek R. et al. (2026); neem	ZnO; ramie/bamboo/epoxy hybrid	Selected formulation: 67.71 MPa tensile strength.	Abstract-based; changing fiber fractions; conference proceeding.
Murali et al. (2025); onion peel	NiO; silk/bamboo/epoxy hybrid	ES2: tensile 180.4 MPa; flexural 237.6 MPa.	Abstract-based; NiO-only effect unresolved.

Note: Values are within-study observations, not a cross-study ranking. Loadings retain the authors' wt.% notation; denominators must be checked before comparison. Abstract-based entries are restricted to publisher-reported information. CuO- and ZnO-containing systems represent the principal oxide group, whereas studies involving Ce_2O_3, SrO, ZrO_2, and NiO are included as complementary comparisons.

4.3. Coatings and the interpretation of mechanical indicators

Bundele et al. (2023) prepared *Plumeria rubra*-assisted TiO_2 for an epoxy-based anticorrosive application. This supports the relevance of plant-derived TiO_2 to epoxy formulations, but does not supply a basis for asserting a general tensile-strength improvement. Adhesion and barrier performance in coatings answer different questions from bulk specimen mechanics. This distinction is particularly important when functional outcomes are more extensively reported than tensile modulus, elongation, or fracture toughness.

Across the direct studies, a strength maximum at one loading should be described as the best tested formulation. It is not necessarily the true optimum, especially when neighboring concentrations, preparation variability, or rheology were not evaluated. Increasing hardness can coexist with reduced failure strain or strength because indentation resistance and crack-sensitive failure respond to different structural features. Accordingly, hardness trends should complement, rather than replace, stress–strain data and fracture observations.

The elastic and viscoelastic results should be interpreted with similar care. A storage-modulus increase in a fiber hybrid can reflect fiber load bearing, particle constraints on the matrix, or changes in cure. A shift in the damping peak may provide additional information about network mobility, but does not uniquely identify stronger particle adhesion. The dynamic mechanical findings of Velmurugan et al. (2024) are therefore most informative when considered with the hybrid composition and the temperature range, rather than being summarized as an unconditional stiffness advantage of green CuO.

A rough fracture surface or visible cluster can support a structural interpretation, but neither establishes interfacial chemistry by itself. Conventional nanosilica work demonstrated that particle debonding followed by plastic void growth can contribute to epoxy toughening (Johnsen et al., 2007). Applying that mechanism to green oxides requires comparable local evidence. Figure 2 is a conceptual representation of separated and clustered arrangements; it does not depict measured dispersion or a predicted damage field.

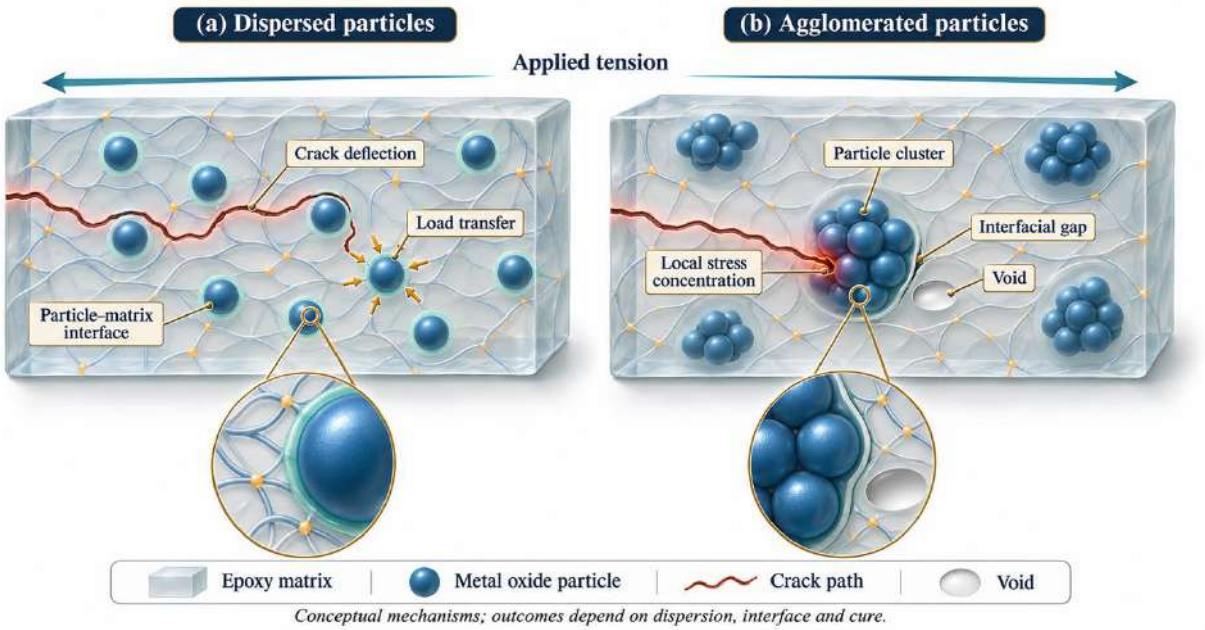


Figure 2. Conceptual illustration of particle dispersion and possible damage mechanisms in oxide-filled epoxy composites: (a) dispersed particles with particle–matrix load transfer and crack deflection; (b) agglomerated particles with interfacial gaps, voids, and local stress concentration. The illustrated mechanisms are schematic and require experimental verification.

5. Critical Assessment and Research Priorities

5.1. Route controls and curing effects

The decisive comparison is between neat epoxy and formulations containing plant-assisted and conventional particles of the same oxide. An extract-free synthesis control can further reveal how the botanical medium changes the powder. Piro et al. (2023) and Keabadile et al. (2020) demonstrate route comparisons at the nanoparticle level; those comparisons should be extended to consistently processed epoxy specimens. Differences in particle size, phase, surface area, and organic content must be measured, since a route comparison inevitably compares the materials those routes produce.

Equal curing schedules do not ensure equal network conversion. Ghaffari et al. (2015) examined ZnO-size effects on epoxy/polyaminoamide curing, and Sanctuary et al. (2009) observed changes in epoxy cure with alumina addition. These conventional systems provide a reason to test cure state in green-particle composites, rather than assuming the same effect occurs. Residual reaction enthalpy, glass transition, and controlled resin-to-hardener stoichiometry can help distinguish network changes from dispersion-related reinforcement.

A retained plant-derived surface layer is a testable hypothesis. Comparing washed, unwashed, or thermally treated powder fractions may be informative, provided associated changes in morphology and moisture are also measured. FTIR band changes alone do not establish covalent particle–epoxy bonding. If an interface explanation is central, it should be consistent with surface characterization, cure measurements, and the observed mechanical response.

5.2. Dispersion measurement and mechanical comparability

Quantification should extend beyond one selected SEM image. Yourdkhani and Hubert (2013) developed an image-based approach for inclusion dispersion in polymer composites, illustrating how spatial distribution can be assessed explicitly. For oxide-filled epoxy, multiple regions and magnifications should capture cluster dimensions, particle-rich areas, and voids. Elemental maps can confirm local filler distribution, but a homogeneous map at one scale does not establish nanoscale separation throughout a specimen.

Mechanical comparisons require consistent conditioning, specimen geometry, strain measurement, and loading rate. The filler-content denominator should be stated, including whether it refers to resin alone or the complete cured formulation. Equal mass fractions of different oxides are not equal volume fractions. In hybrids, fiber content, orientation, and treatment must be retained alongside nanoparticle loading. Reporting absolute control values with uncertainty also prevents large percentage gains from concealing unusually weak baseline specimens.

Independent preparation batches are particularly valuable when both extract composition and compounding can vary. Several specimens from one mixture estimate within-batch variation; they do not establish reproducibility of the synthesis or mixing process. A practical design first identifies a workable dispersion range, then compares particle routes at selected loadings, and finally evaluates conditioning or aging. Table 2 summarizes the evidence needed to connect these stages without attributing every response to the green route.

Table 2. Experimental and reporting priorities for plant-assisted oxide–epoxy composites.

Unresolved question	Minimum comparison or evidence	Interpretation enabled
Route contribution	Neat epoxy and both particle routes; characterize powder differences.	Distinguishes route and filler effects.
Surface constituents	Surface and thermal analyses of the final powder.	Tests retained-organic hypotheses.
Dispersion	Multiple fields and scales; measure clusters and voids.	Connects structure with mechanics.
Cure state	Fixed stoichiometry; residual enthalpy and glass transition.	Separates cure and reinforcement.

Reproducibility	Independent batches, specimen counts, and uncertainty.	Assesses preparation variability.
Environmental burden	Common output basis; material, yield, and energy inventory.	Tests environmental advantage.

Note: Authors' synthesis informed by the cure, dispersion, and life cycle studies discussed in Section 5.

Dispersion analysis should also report how images were selected and processed. The same segmentation rule, magnification range, and sampling procedure should be applied across controls and filled specimens. Reporting a distribution of cluster sizes is more informative than a single mean because occasional large clusters may govern crack initiation. When microscopy is performed after failure, the sampled fracture plane should be distinguished from a polished cross-section; the former can preferentially expose damage-associated regions. Linking these observations to uncertainty in the mechanical measurements provides a stronger assessment than selecting a visually representative image after examining the strength trend.

5.3. Environmental claims and application boundaries

Environmental benefit requires a separate assessment from mechanical performance. Patiño-Ruiz et al. (2021) compared green and coprecipitation routes for iron oxide using life cycle assessment. Rodríguez-Rojas et al. (2024) evaluated green and chemical TiO_2 synthesis. These studies support examining the actual process inventory rather than assigning sustainability from the botanical reagent alone. Extraction, washing, solvent recovery, drying, calcination, yield, and waste treatment all belong within the chosen system boundary.

The relevant output basis also matters. Comparing one kilogram of powder may answer a synthesis question, whereas comparing a component meeting a specified mechanical requirement addresses an application question. A low-impact powder that requires higher loading or extensive redispersion may offer a different balance at the composite level. Conversely, agricultural-residue use can be valuable without proving that every impact category improves. Environmental and mechanical conclusions should therefore remain independently evidenced and then considered together.

Application conditions should determine which remaining tests are prioritized. A bulk structural formulation requires strength and deformation data, whereas a coating may be governed by adhesion, thickness, and resistance to moisture-assisted damage. Initial hardness cannot establish long-term mechanical retention. For the plant-assisted systems considered here, extended conditioning would be especially informative where residual moisture, extract-derived constituents, or fiber interfaces may influence the response. Comparisons before and after exposure should maintain the same conditioning and test protocol, with percentage retention accompanied by absolute properties. Such evidence would clarify whether a favorable initial formulation remains useful beyond the preparation and testing stage.

6. Conclusions and Future Perspectives

Plant-extract-assisted metal oxide synthesis offers opportunities for developing epoxy fillers with different particle morphologies and surface characteristics. However, their mechanical contribution depends on the final powder, dispersion quality, interfacial compatibility, and curing conditions. Among the principal oxides considered, CuO-filled epoxy and CuO- or ZnO-containing fiber hybrids provide direct examples of formulation-dependent reinforcement. Complementary studies involving SrO, Ce_2O_3, ZrO_2, and NiO broaden the comparison of filler loading and composite architecture. The available findings support carefully selected processing conditions, but do not establish a universal optimum loading or a general mechanical advantage over conventionally synthesized nanoparticles.

Future investigations should prioritize paired comparisons of plant-assisted and conventional particles of the same oxide within a consistent epoxy formulation. Characterizing particle phase, size distribution, surface composition, and moisture content would help explain differences between synthesis routes. Quantitative measurements of clusters and voids should accompany mechanical testing, while cure conversion and glass transition measurements would help distinguish network changes from interfacial reinforcement. Independently prepared nanoparticle and composite batches are also needed to assess reproducibility.

Further work should strengthen direct mechanical evidence for plant-assisted TiO_2 and iron oxide fillers in epoxy and clarify the nanoparticle contribution in fiber hybrids. Tensile strength, modulus, elongation, hardness, and fracture resistance should be evaluated as complementary outcomes. Moisture exposure, thermal cycling, and aging studies would establish whether initial improvements persist under application-relevant conditions.

Environmental assessment should develop alongside mechanical evaluation. Renewable or waste-derived extracts alone do not demonstrate lower environmental burdens; extraction, washing, drying, calcination, material yield, and composite processing must also be considered. Combining controlled mechanical comparisons with life cycle assessment would provide a stronger basis for identifying green-synthesized oxide–epoxy formulations that offer both useful performance and measurable environmental benefits.

References

Aalami, Z., Hoseinzadeh, M., Hosseini Manesh, P., Aalami, A. H., Es'haghi, Z., Darroudi, M., Sahebkar, A., & Hosseini, H. A. (2024). Synthesis, characterization, and photocatalytic activities of green sol-gel ZnO nanoparticles using Abelmoschus esculentus and Salvia officinalis: A comparative study versus co-precipitation-synthesized nanoparticles. Heliyon, 10(2), e24212. https://doi.org/10.1016/j.heliyon.2024.e24212

Bishwokarma, M., Bhujel, A., Baskota, M., & Pandit, R. (2021). Green Synthesis of Zirconia (ZrO_2) Nanoparticles using Curcuma Longa Extract and Investigation of Compressive Strength of Epoxy resin (EP)/ZrO_2 Nanocomposites. Journal of Nepal Chemical Society, 42(1), 45-50. https://doi.org/10.3126/jncs.v42i1.35328

Bittmann, B., Haupert, F., & Schlarb, A. K. (2009). Ultrasonic dispersion of inorganic nanoparticles in epoxy resin. Ultrasonics Sonochemistry, 16(5), 622-628. https://doi.org/10.1016/j.ultsonch.2009.01.006

Bittmann, B., Haupert, F., & Schlarb, A. K. (2011). Preparation of TiO_2/epoxy nanocomposites by ultrasonic dispersion and their structure property relationship. Ultrasonics Sonochemistry, 18(1), 120-126. https://doi.org/10.1016/j.ultsonch.2010.03.011

Bozkurt, R. N., & Şahin, S. (2025). Green Synthesis of Zinc Oxide Nanoparticles Including Rosehip (Rosa canina L.) Seed Extract: Evaluation of Its Characterization and Bioactivity Properties. Chemistry & Biodiversity, 22(5), e202402724. https://doi.org/10.1002/cbdv.202402724

Bundele, M., Rane, N., Lande, V., Dani, A., & Shende, S. (2023). Green synthesis of TiO_2 nanoparticle from Plumeria rubra L. leaves for anticorrosive application. Materials Today: Proceedings, 72, 1685-1691. https://doi.org/10.1016/j.matpr.2022.09.469

Choi, Y. M., Hwangbo, S. A., Lee, T. G., & Ham, Y. B. (2021). Effect of Particle Size on the Mechanical Properties of TiO_2–Epoxy Nanocomposites. Materials, 14(11), 2866. https://doi.org/10.3390/ma14112866

Fakhari, S., Jamzad, M., & Kabiri Fard, H. (2019). Green synthesis of zinc oxide nanoparticles: a comparison. Green Chemistry Letters and Reviews, 12(1), 19-24. https://doi.org/10.1080/17518253.2018.1547925

Ghaffari, M., Ehsani, M., Vandalvand, M., Avazverdi, E., Askari, A., & Goudarzi, A. (2015). Studying the effect of micro- and nano-sized ZnO particles on the curing kinetic of epoxy/polyaminoamide system. Progress in Organic Coatings, 89, 277-283. https://doi.org/10.1016/j.porgcoat.2015.08.016

Johnsen, B. B., Kinloch, A. J., Mohammed, R. D., Taylor, A. C., & Sprenger, S. (2007). Toughening mechanisms of nanoparticle-modified epoxy polymers. Polymer, 48(2), 530-541. https://doi.org/10.1016/j.polymer.2006.11.038

Karam, S. T., & Abdulrahman, A. F. (2022). Green Synthesis and Characterization of ZnO Nanoparticles by Using Thyme Plant Leaf Extract. Photonics, 9(8), 594. https://doi.org/10.3390/photonics9080594

Keabadile, O. P., Aremu, A. O., Elugoke, S. E., & Fayemi, O. E. (2020). Green and Traditional Synthesis of Copper Oxide Nanoparticles—Comparative Study. Nanomaterials, 10(12), 2502. https://doi.org/10.3390/nano10122502

López-López, J., Tejeda-Ochoa, A., López-Beltrán, A., Herrera-Ramírez, J., & Méndez-Herrera, P. (2022). Sunlight Photocatalytic Performance of ZnO Nanoparticles Synthesized by Green Chemistry Using Different Botanical Extracts and Zinc Acetate as a Precursor. Molecules, 27(1), 6. https://doi.org/10.3390/molecules27010006

Manimehala U, Asha, S., Tomy, M., Anu M. A., Sumitha M. S., Kumar, P., Xavier T. S., & Binoy J (2025). Green synthesis of copper oxide nanoparticles from Camellia sinensis extract: Effects of calcination temperatures on antimicrobial activity. Biochemical and Biophysical Research Communications, 769, 151963. https://doi.org/10.1016/j.bbrc.2025.151963

Matinise, N., Fuku, X. G., Kaviyarasu, K., Mayedwa, N., & Maaza, M. (2017). ZnO nanoparticles via Moringa oleifera green synthesis: Physical properties & mechanism of formation. Applied Surface Science, 406, 339-347. https://doi.org/10.1016/j.apsusc.2017.01.219

Moghni, N., Khalaf, H., Menseri, O., Boutoumi, H., Boudali, R., Dif, F., & Boucheffa, Y. (2025). One–pot green synthesis of TiO_2 nanoparticles using Inula Viscosa leaf extract as an efficient photocatalyst for organic dyes removal. Journal of Photochemistry and Photobiology A: Chemistry, 461, 116158. https://doi.org/10.1016/j.jphotochem.2024.116158

Mousa, S. A., Wissa, D. A., Hassan, H. H., Ebnalwaled, A. A., & Khairy, S. A. (2024). Enhanced photocatalytic activity of green synthesized zinc oxide nanoparticles using low-cost plant extracts. Scientific Reports, 14(1), 16713. https://doi.org/10.1038/s41598-024-66975-1

Murali, M., Kannan, A., Sudhaman, K., & Bennet, M. A. (2025). Microwave shielding behavior of conductive silk fabric and bamboo fiber reinforced green-synthesized NiO particle epoxy composite at E, F, I and J band frequencies. Polymer Bulletin, 82(16), 11169-11185. https://doi.org/10.1007/s00289-025-05966-2

Oner, G. A., Nadaroglu, H., Acar, V., & Gok, S. (2024). Flexural and thermal characterization of epoxy composites reinforced with nanoparticles synthesized from waste walnut husk with green synthesis method. Biomass Conversion and Biorefinery, 14(17), 20201-20212. https://doi.org/10.1007/s13399-023-04364-w

Orhan, R. (2025). Green synthesis of CuO nanoparticles using Curcuma longa L. extract: composite dielectric and mechanical properties. Materials Testing, 67(7), 1230-1241. https://doi.org/10.1515/mt-2024-0563

Patiño-Ruiz, D. A., Meramo-Hurtado, S. I., González-Delgado, Á. D., & Herrera, A. (2021). Environmental Sustainability Evaluation of Iron Oxide Nanoparticles Synthesized via Green Synthesis and the Coprecipitation Method: A Comparative Life Cycle Assessment Study. ACS Omega, 6(19), 12410-12423. https://doi.org/10.1021/acsomega.0c05246

Piro, N. S., Hamad, S. M., Mohammed, A. S., & Barzinjy, A. A. (2023). Green Synthesis Magnetite (Fe_3O_4) Nanoparticles From Rhus coriaria Extract: A Characteristic Comparison With a Conventional Chemical Method. IEEE Transactions on NanoBioscience, 22(2), 308-317. https://doi.org/10.1109/TNB.2022.3187344

Rodríguez-Rojas, M. d. P., Bustos-Terrones, V., Díaz-Cárdenas, M. Y., Vázquez-Vélez, E., & Martínez, H. (2024). Life Cycle Assessment of Green Synthesis of TiO_2 Nanoparticles vs. Chemical Synthesis. Sustainability, 16(17), 7751. https://doi.org/10.3390/su16177751

Sanctuary, R., Baller, J., Zielinski, B., Becker, N., Krüger, J. K., Philipp, M., Müller, U., & Ziehmer, M. (2009). Influence of Al_2O_3nanoparticles on the isothermal cure of an epoxy resin. Journal of Physics: Condensed Matter, 21(3), 035118. https://doi.org/10.1088/0953-8984/21/3/035118

Sathya, K., Saravanathamizhan, R., & Baskar, G. (2017). Ultrasound assisted phytosynthesis of iron oxide nanoparticle. Ultrasonics Sonochemistry, 39, 446-451. https://doi.org/10.1016/j.ultsonch.2017.05.017

Sedefoglu, N. (2024). Green synthesis of ZnO nanoparticles by Myrtus communis plant extract with investigation of effect of precursor, calcination temperature and study of photocatalytic performance. Ceramics International, 50(6), 9884-9895. https://doi.org/10.1016/j.ceramint.2024.01.387

Selvanathan, V., Aminuzzaman, M., Tey, L. H., Razali, S. A., Althubeiti, K., Alkhammash, H. I., Guha, S. K., Ogawa, S., Watanabe, A., Shahiduzzaman, M., & Akhtaruzzaman, M. (2021). Muntingia calabura Leaves Mediated Green Synthesis of CuO Nanorods: Exploiting Phytochemicals for Unique Morphology. Materials, 14(21), 6379. https://doi.org/10.3390/ma14216379

Sukumar, S., Rudrasenan, A., & Padmanabhan Nambiar, D. (2020). Green-Synthesized Rice-Shaped Copper Oxide Nanoparticles Using Caesalpinia bonducella Seed Extract and Their Applications. ACS Omega, 5(2), 1040-1051. https://doi.org/10.1021/acsomega.9b02857

Sundrarajan, M., & Gowri, S. (2011). Green synthesis of titanium dioxide nanoparticles by Nyctanthes arbor-tristis leaves extract. Chalcogenide Letters, 8(8), 447–451. https://chalcogen.ro/447_Sundrarajan.pdf

Velmurugan, G., Kumar, S. S., Chohan, J. S., Kumar, A. J. P., Manikandan, T., Raja, D. E., Saranya, K., Nagaraj, M., & Barmavatu, P. (2024). Experimental Investigations of Mechanical and Dynamic Mechanical Analysis of Bio-synthesized CuO/Ramie Fiber-Based Hybrid Biocomposite. Fibers and Polymers, 25(2), 587-606. https://doi.org/10.1007/s12221-023-00432-0

Vera, J., Herrera, W., Hermosilla, E., Díaz, M., Parada, J., Seabra, A. B., Tortella, G., Pesenti, H., Ciudad, G., & Rubilar, O. (2023). Antioxidant Activity as an Indicator of the Efficiency of Plant Extract-Mediated Synthesis of Zinc Oxide Nanoparticles. Antioxidants, 12(4), 784. https://doi.org/10.3390/antiox12040784

Vivek R., Rasagopal P., Vijayasekaran G., Pushpalatha V., Girimurugan R., & Suriyaprakash L. (2026). Synergistic reinforcement of epoxy with ramie, bamboo, and green-synthesized neem–ZnO nanoparticles: Taguchi–ANOVA and AHP–TOPSIS optimization. Interactions, 247(1), 448. https://doi.org/10.1007/s10751-026-02781-7

Wetzel, B., Rosso, P., Haupert, F., & Friedrich, K. (2006). Epoxy nanocomposites – fracture and toughening mechanisms. Engineering Fracture Mechanics, 73, 2375–2398. https://doi.org/10.1016/j.engfracmech.2006.05.018

Yourdkhani, M., & Hubert, P. (2013). Quantitative Dispersion Analysis of Inclusions in Polymer Composites. ACS Applied Materials & Interfaces, 5(1), 35-41. https://doi.org/10.1021/am301459q

Zahan, N., Alam, M. R., Sultana, M., Sharmin, A., Ahmed, S., Jahan, S., & Bashar, M. S. (2025). Bioinspired synthesis of titania nanoparticles with enhanced crystallinity and tunable optoelectronic features. Ceramics International, 51(25), 46058-46072. https://doi.org/10.1016/j.ceramint.2025.07.318

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

SUSTAINABLE FERRITE–CARBON HYBRID COMPOSITES FOR MICROWAVE ABSORPTION: A CRITICAL REVIEW OF MATERIAL DESIGN AND PERFORMANCE

Buket Erzen
Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ-Türkiye.
ORCID: 0000-0001-5098-7171
Mukaddes Karataş
Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ-Türkiye.
ORCID: 0000-0001-5803-6821
Şermin Deniz
Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ-Türkiye.
ORCID: 0000-0001-5074-0777
Ramazan Orhan
Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ-Türkiye.
ORCID: 0000-0003-2287-4238

Abstract

Ferrite–carbon hybrid composites have attracted increasing attention in recent years as microwave-absorbing materials due to their combined magnetic and dielectric properties. However, achieving strong absorption over a broad frequency range while maintaining low thickness and filler content remains a significant challenge. This review discusses developments reported between 2024 and 2026, focusing on the relationships among material composition, synthesis methods, microstructure, and electromagnetic absorption performance. Particular attention is given to spinel ferrites, including $CoFe_2O_4$, $NiFe_2O_4$, $MnFe_2O_4$, and $ZnFe_2O_4$, combined with biochar, activated carbon, graphene-based materials, and carbon nanotubes. Carbonaceous components contribute to dielectric losses through interfacial polarization and electrical conduction, whereas ferrites provide magnetic loss mechanisms. Nevertheless, increasing the proportion of either component does not necessarily improve microwave absorption, since excessive conductivity or an unsuitable magnetic–dielectric balance may lead to impedance mismatch and increased reflection. An important limitation in the literature is the comparison of minimum reflection loss values without adequately considering absorber thickness, operating frequency, effective absorption bandwidth, and filler concentration. Biomass-derived carbon offers opportunities for converting agricultural residues into functional materials; however, its environmental advantages should be evaluated alongside carbonization conditions, chemical activation, and energy consumption. The influence of ferrite–carbon interactions, particle dispersion, and composite architecture on electromagnetic performance is also considered. Overall, the available literature indicates that effective microwave absorption depends not simply on maximizing individual loss mechanisms, but on balancing impedance matching, attenuation capability, material composition, and absorber thickness. Integrating these requirements with resource-efficient synthesis and reproducible processing is essential for developing lightweight, thin, and sustainable microwave-absorbing composites.

Keywords: Ferrite–carbon composites; Microwave absorption; Impedance matching; Biomass-derived carbon; Sustainable materials.

1. Introduction

The rapid development of wireless communication technologies, electronic systems, and advanced sensing devices has increased the demand for materials capable of controlling electromagnetic interference and attenuating unwanted microwave radiation. Microwave-absorbing materials have consequently received considerable attention in applications involving electromagnetic compatibility, communication systems, and

radar-related technologies. However, achieving broadband microwave absorption with low thickness and weight remains challenging (Meng et al., 2024; Mohapatra et al., 2025).

Ferrite-based materials are promising candidates for microwave absorption because of their magnetic properties, chemical stability, and compositional flexibility. Spinel ferrites, particularly $CoFe_2O_4$, $NiFe_2O_4$, $MnFe_2O_4$, and $ZnFe_2O_4$, offer opportunities to modify magnetic characteristics through variations in cation composition, crystallite structure, particle morphology, and synthesis conditions. However, ferrites alone may not provide sufficient absorption performance over a broad frequency range. Their electromagnetic response depends on magnetic loss behavior, dielectric characteristics, microstructure, and the compatibility between the absorber impedance and free-space impedance (Meng et al., 2024).

Carbonaceous materials, including graphene derivatives, carbon nanotubes, activated carbon, and biomass-derived porous carbon, have also attracted considerable interest because of their relatively low density, adjustable electrical conductivity, and dielectric response. Their microwave attenuation behavior can involve conduction loss, dipolar polarization, and interfacial polarization. However, excessive electrical conductivity may cause impedance mismatch, thereby increasing reflection at the absorber surface rather than improving the overall absorption performance (Li et al., 2024).

Combining ferrites with carbonaceous materials provides a strategy for integrating magnetic and dielectric loss mechanisms within a single composite system. The resulting interfaces, conductive networks, and heterogeneous microstructures can influence electromagnetic wave propagation and energy dissipation. Nevertheless, the simultaneous presence of magnetic and dielectric components does not automatically guarantee superior microwave absorption. Effective material design requires an appropriate balance between impedance matching and attenuation capability, together with careful control of filler concentration, particle dispersion, and absorber thickness (Mohapatra et al., 2025).

In parallel with electromagnetic performance optimization, increasing attention has been directed toward the use of renewable and waste-derived carbon precursors. Agricultural residues and other biomass resources can be converted into porous carbon materials through carbonization and activation processes. Such approaches offer potential opportunities for waste valorization and resource-efficient materials production. However, the sustainability of biomass-derived absorbers cannot be established solely from the renewable origin of the precursor. Carbonization temperature, chemical activation agents, energy consumption, processing yield, and reproducibility must also be considered (Ren et al., 2025).

Despite substantial progress in ferrite–carbon microwave absorbers, direct comparisons among published studies remain challenging (Yang et al., 2025). Minimum reflection loss values are frequently emphasized without sufficiently accounting for effective absorption bandwidth, operating frequency, absorber thickness, filler loading, and measurement conditions. Consequently, a material exhibiting a highly negative reflection loss at a particular frequency may not necessarily represent the most suitable option for practical broadband or lightweight applications.

This critical review examines developments reported between 2024 and 2026, focusing on sustainable ferrite–carbon hybrid composites and the relationships among material composition, preparation methods, microstructure, and microwave absorption performance. Particular attention is devoted to the balance between magnetic and dielectric losses, impedance matching, biomass-derived carbon production, and the comparability of reported performance parameters. By integrating these aspects, the review aims to identify current limitations and future research priorities for the development of efficient, thin, lightweight, and more sustainable microwave-absorbing materials.

2. Review Methodology

This study is structured as a critical narrative review of ferrite–carbon hybrid composites developed for microwave absorption applications, with particular emphasis on research published between 2024 and 2026. The review focuses on the relationships among material composition, synthesis strategies, microstructural characteristics, electromagnetic loss mechanisms, and reported microwave absorption performance.

The literature evaluation is organized around four principal material groups: cobalt ferrite ($CoFe_2O_4$), nickel ferrite ($NiFe_2O_4$), manganese ferrite ($MnFe_2O_4$), and zinc ferrite ($ZnFe_2O_4$). Carbonaceous components of interest include biomass-derived carbon, activated carbon, graphene-based materials, and carbon nanotubes. Studies involving other ferrite compositions or carbon structures may be considered when they provide relevant mechanistic insights or useful comparisons.

The critical evaluation considers the preparation methods, ferrite-to-carbon ratios, particle morphology, interfacial characteristics, and electromagnetic properties reported in the literature. Particular attention is given to minimum reflection loss (RL_{min}), effective absorption bandwidth (EAB), operating frequency, absorber thickness, and filler concentration. This approach enables performance comparisons that account for differences in material formulation and experimental conditions.

For comparative interpretation, EAB is defined as the frequency interval over which reflection loss remains below −10 dB, corresponding to at least 90% power attenuation relative to the incident wave under the commonly adopted metal-backed absorber model. Reported performance values are interpreted in relation to their corresponding thicknesses, frequency ranges, composite formulations, and measurement conditions.

The sustainability assessment considers precursor origin, waste valorization potential, processing requirements, and material yield, with particular attention to biomass-derived carbon production.

As a critical narrative review rather than a systematic review or meta-analysis, the study does not aim to provide a statistically pooled estimate of microwave absorption performance. The analysis therefore emphasizes qualitative comparisons and the critical interpretation of reported findings.

3. Ferrite–Carbon Hybrid Systems and Material Design

3.1. Spinel Ferrites and Composition–Property Relationships

Spinel ferrites with the general formula MFe_2O_4, where M represents a divalent metal cation, constitute an important class of magnetic materials for microwave absorption applications. Their cubic spinel structure contains tetrahedral (A) and octahedral (B) crystallographic sites, and the distribution of metal cations between these sites significantly influences their structural, magnetic, and electrical properties. Depending on the cation distribution, spinel ferrites may exhibit normal, inverse, or partially inverse spinel configurations. Variations in cation occupancy modify magnetic superexchange interactions, saturation magnetization, magnetocrystalline anisotropy, and magnetic resonance behavior, thereby affecting their frequency-dependent electromagnetic response (Meng et al., 2024).

Among commonly investigated spinel ferrites, $CoFe_2O_4$, $NiFe_2O_4$, $MnFe_2O_4$, and $ZnFe_2O_4$ exhibit distinct magnetic characteristics associated with their chemical compositions and cation distributions. $CoFe_2O_4$ is generally characterized by relatively high magnetocrystalline anisotropy, whereas $NiFe_2O_4$ typically exhibits softer magnetic behavior. In contrast, the magnetic responses of $MnFe_2O_4$ and $ZnFe_2O_4$ are particularly sensitive to cation redistribution, particle dimensions, and synthesis conditions. These magnetic differences influence microwave absorption behavior but do not establish a definitive performance ranking among ferrite compositions (Meng et al., 2024).

Recent investigations have demonstrated that compositional engineering provides an effective strategy for tailoring the electromagnetic properties of spinel ferrites. Shao et al. (2025) developed multicomponent spinel ferrite/carbon nanofiber composites using an entropy-engineering approach. By adjusting the relative proportions of Mn, Ni, Zn, and Co cations, the authors demonstrated that compositional regulation could influence microwave absorption characteristics across different frequency regions. Their optimized $(Mn_{0.05}Ni_{0.45}Zn_{0.05}Co_{0.45})Fe_2O_4$/carbon nanofiber composite exhibited a minimum reflection loss of −54.62 dB at a matching thickness of 2.03 mm, while a maximum effective absorption bandwidth of 7.28 GHz was reported at a filler loading of 15 wt.%. The reported performance demonstrates the relevance of multication composition control in designing thin ferrite–carbon microwave absorbers.

Similarly, Zhang et al. (2026) investigated cation-engineered Co–Fe spinel/reduced graphene oxide composites, emphasizing the relationship between Co/Fe composition, magnetocrystalline anisotropy, and

broadband microwave absorption. Their study demonstrated the relevance of regulating magnetic properties through cation composition while integrating spinel nanoparticles with a conductive carbonaceous framework. Such approaches provide opportunities to modify magnetic and dielectric responses simultaneously, although the resulting absorption performance remains dependent on the structural organization and electromagnetic characteristics of the complete composite.

In addition to chemical composition, microstructural parameters such as crystallite size, grain boundaries, structural defects, particle agglomeration, and interfacial contact can influence electromagnetic behavior. Reduced particle dimensions may modify magnetic domain structures and surface-related effects, while defects and heterogeneous interfaces may contribute to polarization processes. Nevertheless, increased defect density or enhanced magnetic response does not necessarily produce superior microwave absorption, particularly when impedance matching becomes unfavorable.

The influence of ferrite composition on microwave absorption is ultimately governed by its interaction with the carbon framework and the resulting frequency-dependent electromagnetic response.

3.2. $CoFe_2O_4$ and $NiFe_2O_4$ Hybrids

$CoFe_2O_4$ is frequently investigated because of its magnetic anisotropy and chemical stability, while $NiFe_2O_4$ offers another tunable spinel composition. Coupling these ferrites with porous carbon, graphene derivatives, or carbon nanotubes can introduce interfaces and conductive networks that alter dielectric loss. Their absorption characteristics are strongly influenced by ferrite–carbon interactions and the resulting electromagnetic response (Mohapatra et al., 2025).

Recent research has highlighted the importance of hierarchical porous structures in $CoFe_2O_4$–carbon composites, particularly when carbon is obtained from agricultural residues. Cao et al. (2025) prepared carbon/$CoFe_2O_4$ composites using corn stalks as a biomass precursor through hydrothermal treatment and carbonization. The resulting hierarchical and gradient porous architecture provided a structural framework for regulating electromagnetic wave propagation and attenuation. The optimized composite exhibited a minimum reflection loss (RLmin) of −56.78 dB at a thickness of 2.50 mm, while an effective absorption bandwidth (EAB) of 8.00 GHz was obtained at 2.25 mm. These values correspond to different absorber thicknesses and therefore represent distinct measurement configurations.

Wen et al. (2025) investigated flower-like $NiFe_2O_4$/C composites to examine the influence of morphology and ferrite–carbon interactions on microwave absorption. The optimized material achieved a minimum reflection loss of −57.02 dB at a matching thickness of 2.4 mm, whereas its maximum effective absorption bandwidth reached 5.2 GHz at 1.9 mm. The flower-like morphology may contribute to the observed absorption behavior by modifying the composite microstructure and ferrite–carbon interfaces.

A comparison of these studies reveals distinct performance characteristics. Although the $NiFe_2O_4$/C composite exhibited a slightly more negative RLmin, the $CoFe_2O_4$–carbon system achieved a wider maximum EAB. Because these values were obtained at different absorber thicknesses, they should not be interpreted as a direct ranking of the two materials. Instead, the comparison illustrates the importance of considering absorption intensity, bandwidth, and thickness together when evaluating ferrite–carbon composites.

3.3. $MnFe_2O_4$- and $ZnFe_2O_4$-Based Carbon Composites

$MnFe_2O_4$–carbon composites combine the composition-dependent magnetic properties of manganese ferrite with the dielectric response of carbon frameworks. In $ZnFe_2O_4$-based systems, magnetic behavior is particularly sensitive to cation inversion, particle size, and synthesis conditions. Consequently, magnetic-loss contributions should be assessed using measured complex permeability rather than inferred solely from ferrite incorporation (Meng et al., 2024).

Ji et al. (2026) investigated $MnFe_2O_4$ nanoparticles combined with biomass-derived porous carbon fibers produced from cotton, hemp, and bamboo through pyrolysis and subsequent physical mixing. The $MnFe_2O_4$ concentration influenced the electromagnetic response of the composites. At an optimized ferrite content of 20 wt.%, the material achieved a minimum reflection loss of −43.4 dB and an effective absorption bandwidth

of 6.75 GHz at a thickness of 2.3 mm. This performance illustrates the influence of ferrite loading on the interaction between magnetic and dielectric components. The use of plant-derived carbon fibers also provides a route for incorporating renewable precursors into microwave-absorbing composites.

Xu et al. (2026) synthesized ultrafine $ZnFe_2O_4$ nanoparticles with an approximate particle size of 4 nm and investigated carbon- and silica-coated structures. The $ZnFe_2O_4$@C composite exhibited a minimum reflection loss of −46.2 dB at 8.80 GHz. The carbon coating may introduce additional polarization sites and modify the dielectric response through heterogeneous interfaces, while the ferrite contribution depends on its structural and magnetic characteristics. However, the individual contributions of magnetic and dielectric losses cannot be established from reflection-loss values alone. Frequency-dependent complex permittivity and permeability measurements are needed to distinguish these mechanisms and assess their relationship with the observed absorption performance.

3.4. Carbon Components and Composite Architectures

Graphene-based materials and carbon nanotubes can form interconnected conductive pathways, while activated and biomass-derived porous carbons provide adjustable porosity and defect-rich surfaces. Core–shell, layered, and porous architectures further modify interfacial polarization and the distribution of electromagnetic properties. Their structural advantages must be considered alongside processing complexity, reproducibility, and material requirements (Li et al., 2024; Ren et al., 2025).

Wang et al. (2025) developed graphene–(Fe_3O_4/FeO)@carbon composites containing multiple heterogeneous interfaces through an in situ carbonization and phase-transformation strategy. Graphene incorporation introduced additional conductive pathways and polarization sites, while the Fe_3O_4/FeO heterostructure contributed to the electromagnetic response. The optimized composite exhibited a minimum reflection loss of −55.54 dB at 15.12 GHz, with an effective absorption bandwidth of 4.8 GHz at a matching thickness of 1.55 mm. This combination of conductive networks and heterogeneous interfaces illustrates how structural design can influence microwave attenuation in thin composite absorbers.

Tian et al. (2025) investigated trimodal porous biomass-derived carbon composites. The optimized HBPC/paraffin composite containing 8 wt.% HBPC achieved a minimum reflection loss of −62.8 dB at 8.36 GHz and a thickness of 3.0 mm, with an effective absorption bandwidth of 4.24 GHz. The hierarchical pore structure may influence effective permittivity, conductive pathways, and interfacial polarization while reducing material density. Although this material provides a useful comparison for understanding pore-structure effects, it should not be classified as a ferrite–carbon composite. The processing complexity associated with hierarchical pore formation is an additional consideration for practical material development.

The relationships among material selection, composite architecture, electromagnetic attenuation mechanisms, and performance-related design parameters are schematically illustrated in Figure 1.

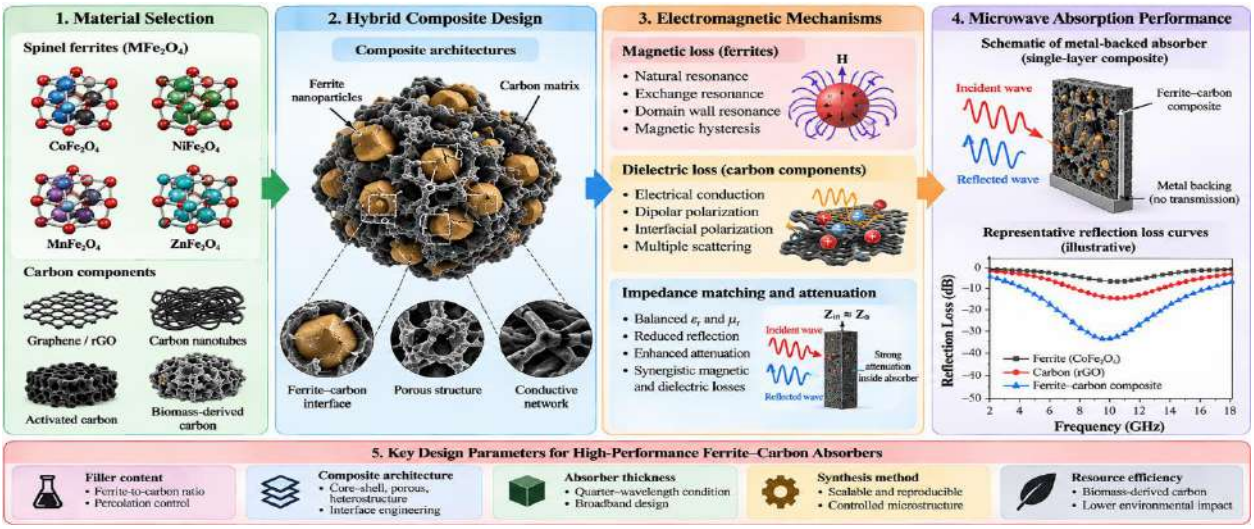


Figure 1. Schematic overview of ferrite–carbon hybrid microwave absorbers, illustrating material selection, composite architecture, electromagnetic attenuation mechanisms, and key design parameters. Reflection-loss curves are illustrative and do not represent experimental measurements.

4. Microwave Absorption Mechanisms and Performance Parameters

4.1. Complex Electromagnetic Parameters

The electromagnetic response of an absorber is commonly described by its complex relative permittivity $\varepsilon r = \varepsilon' - j\varepsilon''$ and complex relative permeability $\mu r = \mu' - j\mu''$. Their real components characterize energy storage, while their imaginary components represent loss contributions under the adopted time-harmonic convention. Dielectric losses can involve conduction, dipolar relaxation, and interfacial polarization, whereas magnetic losses may include resonance and other frequency-dependent processes. The dielectric and magnetic loss tangents, $\tan \delta\varepsilon = \varepsilon''/\varepsilon'$ and $\tan \delta\mu = \mu''/\mu'$, provide useful indicators of electromagnetic dissipation but do not independently determine microwave absorption performance (Meng et al., 2024; Mohapatra et al., 2025).

Lu et al. (2025) investigated $CoFe_2O_4$/activated carbon nanocomposites to examine the effects of carbon incorporation on electromagnetic losses and impedance matching. The conductive carbon component modified the dielectric response and introduced additional charge-transport pathways, while $CoFe_2O_4$ contributed to the magnetic response. The authors attributed the absorption behavior to the interaction between electromagnetic attenuation and impedance matching. Their investigation illustrates why increasing dielectric loss does not necessarily produce stronger microwave absorption, particularly when excessive conductivity promotes reflection at the absorber surface.

Si et al. (2026) investigated $CoFe_2O_4$ composites supported on coal slime-derived carbon. Their electromagnetic characterization covered complex permittivity, complex permeability, dielectric and magnetic loss tangents, and impedance matching across the 1–18 GHz frequency range. Dipolar and interfacial polarization were discussed as dielectric-loss mechanisms, while resonance and eddy-current effects were considered in interpreting the magnetic response. At an optimized $CoFe_2O_4$ loading of 12.52 wt.%, the composite achieved a minimum reflection loss of −32.08 dB at 12.73 GHz and a matching thickness of 3.5 mm, with a reported effective absorption bandwidth of 8.84 GHz. This study connects the measured electromagnetic parameters with the effects of ferrite loading and the carbon support on microwave absorption. Identification of individual magnetic-loss mechanisms, however, requires analysis of their frequency-dependent behavior rather than reliance on loss-tangent values alone.

4.2. Input Impedance and Reflection Loss

For a homogeneous, single-layer absorber backed by a perfect conductor at normal incidence, the normalized input impedance is described by:

$$Zin / Z0 = \sqrt{(\mu r / \varepsilon r)} \tanh[j(2\pi fd / c)\sqrt{(\mu r\, \varepsilon r)}]$$

where Z0 is the impedance of free space, f is frequency, d is absorber thickness, and c is the speed of light in vacuum. Reflection loss is then expressed as:

$$RL\ (dB) = 20 \log_{10} |(Zin - Z0) / (Zin + Z0)|$$

The equations apply to the specified metal-backed configuration and should not be interpreted as a universal description of every free-standing or multilayer measurement geometry. A large negative RL value indicates low reflected power at the stated frequency and thickness, but not necessarily broad bandwidth or low material consumption. The input impedance provides a fundamental link between the intrinsic electromagnetic properties of an absorber and its reflection characteristics. When the complex normalized input impedance approaches unity, the impedance discontinuity between free space and the absorber surface decreases, facilitating electromagnetic wave entry into the material. However, favorable impedance matching alone does not guarantee strong absorption, since the incident energy must also be sufficiently dissipated within the absorber. Recent research on biomass-derived Ni–Co–Zn ferrite/carbon composites has demonstrated that hierarchical porosity and heterogeneous interfaces can contribute to improved impedance matching and polarization losses. Chen et al. (2025) reported a minimum reflection loss of −38.04 dB and an effective absorption bandwidth of 4.32 GHz for a Ni–Co–Zn ferrite/carbon composite. However, inconsistent matching thicknesses (3.0 and 3.5 mm) are reported in the original article, limiting thickness-specific comparisons.

Absorber thickness represents another critical design parameter because electromagnetic wave propagation and interference conditions depend on frequency and the complex electromagnetic properties of the material. The quarter-wavelength matching concept is commonly employed to interpret thickness-dependent shifts in reflection-loss minima. Nevertheless, this relationship should not be regarded as a universal optimization criterion for heterogeneous or multilayer composites. Yang et al. (2025) critically examined conventional microwave absorber quality criteria and highlighted the limitations of evaluating materials primarily through minimum reflection-loss values. Their analysis reinforces the importance of considering absorber thickness, operating frequency, effective absorption bandwidth, and impedance matching collectively. Therefore, a highly negative RLmin value should not automatically be interpreted as evidence of superior practical absorption performance without examining the complete electromagnetic response and material requirements.

4.3. Effective Absorption Bandwidth and Performance Comparability

Effective absorption bandwidth (EAB) is generally defined as the contiguous frequency interval over which the reflection loss remains at or below −10 dB for a specified absorber configuration. At RL = −10 dB, 10% of the incident power is reflected; for an ideal metal-backed absorber with negligible transmission, the remaining 90% is absorbed. Meaningful comparison across studies requires reporting RLmin and EAB together with absorber thickness, operating frequency, filler fraction, matrix composition, and measurement conditions. When the minimum reflection loss and maximum EAB occur at different thicknesses, these configurations must be identified separately.

Mehdizadeh et al. (2025) investigated multiscale Fe_3O_4@$NiCo_2O_4$/PANI/nitrogen-doped reduced graphene oxide aerogels. The composite achieved a minimum reflection loss of −41.8 dB at 16.7 GHz and a thickness of 2.0 mm. The authors additionally reported absorption frequency coverage of 13.3 GHz, extending from 4.7 to 18 GHz across matching thicknesses of 1.6–5.0 mm. This cumulative coverage should not be interpreted as a fixed-thickness EAB, since the absorption regions correspond to different absorber configurations. Distinguishing these measures is essential when comparing broadband performance reported in the literature.

Yang et al. (2025) examined the limitations of conventional microwave absorber quality criteria, showing that highly negative reflection-loss minima may result from favorable impedance and phase-matching conditions without necessarily indicating superior intrinsic attenuation. Their analysis highlights the limitations of ranking absorbers by RLmin alone, particularly when bandwidth and thickness requirements differ. For ferrite–carbon composites, comparisons should therefore distinguish fixed-thickness EAB from cumulative absorption coverage and consider filler loading, electromagnetic properties, and processing requirements alongside the reported reflection-loss minima.

4.4. Balance Between Impedance Matching and Attenuation Capability

Effective microwave absorption requires both sufficient electromagnetic wave penetration and attenuation within the absorber. Excessive conductive carbon loading may increase dielectric losses while simultaneously producing an impedance mismatch that limits wave entry. In ferrite–carbon hybrids, this balance is influenced by the frequency-dependent complex permittivity and permeability, filler distribution, and absorber thickness (Li et al., 2024; Mohapatra et al., 2025).

Shao et al. (2025) investigated multicomponent spinel ferrite/carbon nanofibers using an entropy-engineering strategy. By adjusting the proportions of Mn, Ni, Zn, and Co cations in the spinel structure, the researchers explored the influence of ferrite composition on microwave absorption across different frequency regions. Their work demonstrates that compositional regulation provides an additional route for tailoring electromagnetic properties beyond modifying the carbon fraction alone. However, multicomponent ferrite synthesis also introduces challenges related to compositional control and reproducibility, which are relevant when considering practical absorber fabrication.

The principal dielectric and magnetic loss mechanisms and their contributions to microwave absorption are schematically illustrated in Figure 2.

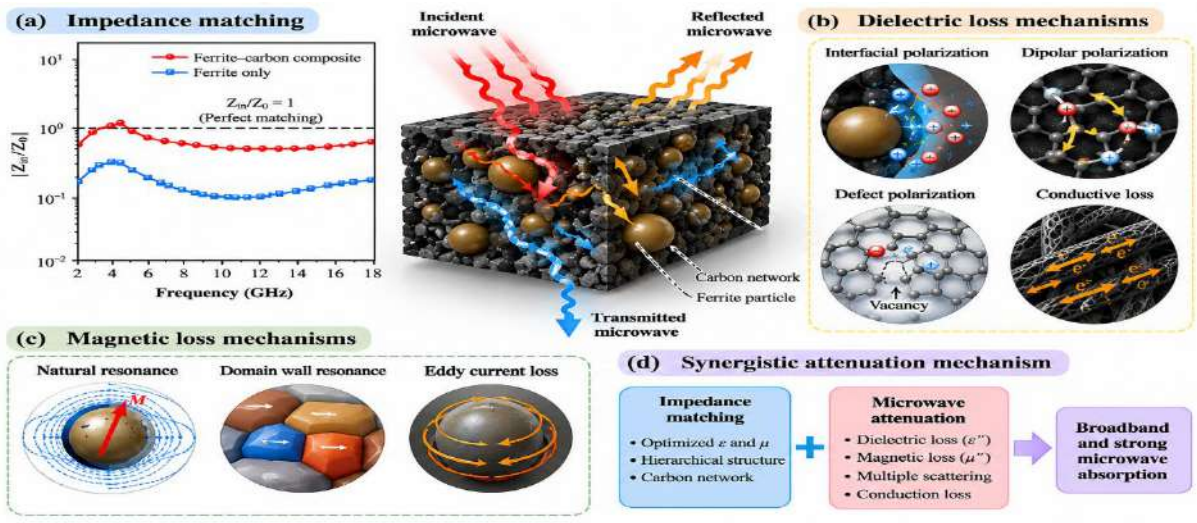


Figure 2. Schematic illustration of impedance matching and electromagnetic attenuation mechanisms in ferrite–carbon hybrid composites: (a) representative normalized input impedance profiles; (b) dielectric loss mechanisms, including interfacial, dipolar, and defect-related polarization and conductive loss; (c) magnetic loss mechanisms, including natural resonance, domain-wall motion, and eddy-current loss; and (d) the synergistic contribution of impedance matching and electromagnetic attenuation to microwave absorption. The impedance profiles are illustrative rather than experimental data.

5. Comparative Findings and Discussion

Table 1 presents a comparative overview of selected ferrite–carbon microwave absorbers, including their composite architectures, minimum reflection loss (RLmin), effective absorption bandwidth (EAB), and absorber thickness. The reported results provide a basis for examining how ferrite composition, carbon structure, and material design influence microwave absorption performance. Differences in filler loading and measurement conditions are considered when interpreting the relative performance of these systems.

Table 1. Comparative microwave absorption performance of selected ferrite–carbon hybrid composites (2025–2026).

Composite / sample	RLmin (dB)	dRL (mm)	Max. EAB (GHz)	dEAB (mm)	Composition / loading	Reference
$CoFe_2O_4$ / corn-stalk porous carbon	−56.78	2.50	8.00	2.25	$CoFe_2O_4$ precursor: 20 mmol L^{-1}	Cao et al. (2025)
$NiFe_2O_4$ / flower-like carbon (NFO/C-1.25)	−57.02	2.40	5.20	1.90	Fructose:metal-ion molar ratio 1.25	Wen et al. (2025)
$MnFe_2O_4$ / biomass-derived porous carbon	−43.40	2.30	6.75	2.30	$MnFe_2O_4$ content: 20 wt.%	Ji et al. (2026)
$MnFe_2O_4$ / waste-derived N-doped carbon (SCM-2)	−62.13	3.04	2.32	3.04	Composite filler loading: 25 wt.%	Shen et al. (2026)
$(Mn,Ni,Zn,Co)Fe_2O_4$ / carbon nanofibers	−54.62	2.03	7.28	NR	Composite filler loading: 15 wt.%	Shao et al. (2025)
$CoFe_2O_4$ / coconut activated carbon (S-8)	−42.99	5.50	0.96	5.50	AC:$CoFe_2O_4$ ratio 8:1 (as reported)	Lu et al. (2025)
$CoFe_2O_4$ / coconut activated carbon (S-12)	−24.00	1.50	3.44	1.50	AC:$CoFe_2O_4$ ratio 12:1 (as reported)	Lu et al. (2025)

Note: RLmin denotes minimum reflection loss; EAB denotes effective absorption bandwidth; dRL and dEAB indicate the absorber thicknesses corresponding to RLmin and maximum EAB, respectively; NR indicates not reported. Composition and loading values represent different experimental parameters as specified in the original studies and are not directly comparable across all samples.

Cao et al. (2025) developed $CoFe_2O_4$ composites incorporating corn-stalk-derived carbon and reported a minimum reflection loss (RLmin) of −56.78 dB at 2.50 mm, together with a maximum effective absorption bandwidth (EAB) of 8.00 GHz at 2.25 mm. Wen et al. (2025) reported a comparable RLmin of −57.02 dB at 2.40 mm for flower-like $NiFe_2O_4$/C composites, but a narrower maximum EAB of 5.20 GHz at 1.90 mm. Although the two systems exhibited similar reflection-loss minima, their bandwidth and thickness characteristics differed, illustrating the influence of composite architecture on the reported absorption performance.

Ferrite loading and carbon structure also influence the performance of $MnFe_2O_4$-based composites. Ji et al. (2026) reported that a biomass-derived porous carbon composite containing 20 wt.% $MnFe_2O_4$ achieved an RLmin of −43.40 dB and an EAB of 6.75 GHz at 2.30 mm. Shen et al. (2026), using $MnFe_2O_4$ nanoparticles supported on waste-derived nitrogen-doped porous carbon, obtained an RLmin of −62.13 dB and an EAB of 2.32 GHz at 3.04 mm, with a composite filler loading of 25 wt.%. The substantially deeper reflection-loss minimum reported by Shen et al. was accompanied by a narrower absorption bandwidth, demonstrating a trade-off between peak absorption intensity and usable frequency coverage under the respective reported conditions.

Shao et al. (2025) investigated multicomponent spinel ferrite/carbon nanofibers through compositional engineering and reported an RLmin of −54.62 dB at 2.03 mm and a maximum EAB of 7.28 GHz at a filler loading of 15 wt.%. Their findings illustrate the potential of adjusting magnetic cation proportions to modify electromagnetic properties, although multicomponent synthesis introduces additional requirements for compositional control and reproducibility.

A particularly informative comparison was reported by Lu et al. (2025) for $CoFe_2O_4$/activated carbon composites. One formulation exhibited an RLmin of −42.99 dB with an EAB of 0.96 GHz at 5.50 mm, whereas

another achieved an RLmin of −24.00 dB but a wider EAB of 3.44 GHz at a substantially lower thickness of 1.50 mm. This contrast demonstrates that the formulation producing the deepest reflection-loss minimum is not necessarily the most favorable in terms of bandwidth and absorber thickness.

Taken together, these studies reveal different relationships among reflection-loss intensity, absorption bandwidth, material composition, and thickness. Their comparison is most informative when the measurement configurations, filler concentrations, and matrix compositions are reported explicitly, particularly when RLmin and maximum EAB correspond to different absorber thicknesses.

6. Sustainability and Research Gaps

The sustainability of ferrite–carbon microwave absorbers depends not only on their electromagnetic performance but also on the resources and processes involved in their production. Agricultural residues and other biomass wastes offer alternative carbon precursors and opportunities for waste valorization. Nevertheless, the environmental benefits of these feedstocks depend on processing conditions, including carbonization temperature and duration, activation methods, chemical consumption, material yield, and energy demand. Metal salt precursors, additional thermal treatments, and polymer matrices must also be included when assessing the environmental implications of the complete composite (Ren et al., 2025; Saleem et al., 2025; Zhang et al., 2025). Table 2 summarizes the principal processing, performance, and life-cycle indicators relevant to sustainability assessment, together with the evidence gaps that currently limit comprehensive evaluation.

Table 2. Sustainability indicators, evidence gaps, and recommended reporting practices for ferrite–carbon microwave absorbers.

Assessment dimension	Relevant indicators	Common evidence gaps	Recommended research/reporting approach
Feedstock and circularity	Biomass type and origin; waste availability; transport distance; precursor yield	Waste-derived feedstocks are often labeled sustainable without quantifying collection, transport, or competing uses.	Specify feedstock origin, pretreatment, dry-mass balance, yield, and allocation assumptions.
Synthesis inputs	Calcination/carbonization temperature and duration; electricity/fuel demand; reagent and solvent consumption	Energy and chemical inputs are frequently omitted or reported without a functional basis.	Report energy (kWh), water (L), and chemical inputs per kg of usable composite, including washing and drying.
Process emissions and waste	Process emissions; wash-water quality; spent activating agents; recovery rates	Potential burdens of activation, washing, and thermal processing are rarely assessed together.	Quantify effluents, emissions, reagent recovery, and waste treatment; compare alternative routes.
Electromagnetic performance	RLmin; EAB at fixed thickness; operating frequency; absorber thickness; filler loading	Different thicknesses, matrices, and test conditions complicate cross-study comparison.	Report full RL–frequency curves, thickness-specific EAB, composition, measurement configuration, and uncertainty.
Material efficiency and durability	Areal density; service life; thermal, mechanical, and environmental stability	High absorption performance is not always linked to mass efficiency or long-term stability.	Normalize performance by thickness/areal mass where appropriate and test aging and repeatability.

Scale-up and reproducibility	Batch yield; batch-to-batch variation; process throughput; cost drivers	Laboratory-scale demonstrations often lack replicated batches and scale-up information.	Use independent batches; report variability, throughput, yield, and preliminary techno-economic indicators.
Life-cycle and end-of-life	Functional unit; cradle-to-gate impacts; reuse/recycling; disposal scenarios	Comparative life-cycle assessments and end-of-life data specific to ferrite–carbon absorbers remain limited.	Define a performance-based functional unit, system boundaries, sensitivity scenarios, and realistic end-of-life options.

Note: The indicators and research gaps are a critical synthesis of reporting needs, not experimentally measured results. RLmin, minimum reflection loss; EAB, effective absorption bandwidth (RL ≤ −10 dB). A performance-based functional unit should state the specified frequency range, attenuation threshold, thickness, and service conditions.

Table 2 identifies the process, performance, and life-cycle information needed to evaluate the sustainability of ferrite–carbon microwave absorbers. In particular, environmental comparisons require transparent process inventories, consistent electromagnetic performance metrics, and clearly defined functional units and system boundaries.

Saleem et al. (2025) investigated the life-cycle impacts of activated carbon production from coconut shells using potassium hydroxide and sodium hydroxide activation routes. Their analysis identified pyrolysis as a major contributor to energy consumption and associated carbon emissions. The study also showed that environmental conclusions can depend on whether impacts are expressed per unit mass of activated carbon or relative to functional performance. Zhang et al. (2025) compared preparation routes for corn-stover-derived activated carbon and reported differences in environmental impacts associated with processing technology. Although these studies do not directly establish the life-cycle performance of ferrite–carbon microwave absorbers, they identify processing factors relevant to evaluating biomass-derived carbon components.

Chemical activation introduces additional environmental considerations. Activating agents can promote pore development, but their consumption and removal may increase chemical demand and wastewater generation. Washing, neutralization, and high-temperature treatments also affect material yield and resource efficiency. Reporting reagent quantities, carbonization conditions, activation procedures, washing requirements, and final carbon yield would enable more transparent comparisons of biomass-derived carbon production (Saleem et al., 2025; Zhang et al., 2025).

Reproducibility represents a further challenge. Variations in biomass composition, pretreatment, and carbonization can affect pore structure, surface chemistry, and electrical conductivity. Ferrite properties are likewise influenced by precursor concentration, reaction pH, calcination conditions, crystallite size, and cation distribution. Because these variables can modify complex permittivity and permeability, differences in synthesis conditions may contribute to variation in measured microwave absorption performance. More consistent reporting of preparation procedures, material characteristics, and experimental repeatability would strengthen comparisons across studies (Meng et al., 2024; Ren et al., 2025).

The practical relevance of advanced ferrite–carbon architectures also depends on their manufacturing requirements. Complex synthesis procedures and high filler consumption may limit scalability and material efficiency. Combining electromagnetic characterization with life cycle assessment and techno-economic analysis would help identify formulations that balance absorption performance with resource demands (Saleem et al., 2025; Yang et al., 2025; Zhang et al., 2025).

7. Conclusions and Future Perspectives

Ferrite–carbon hybrid composites offer considerable potential for microwave absorption by combining the magnetic properties of spinel ferrites with the dielectric characteristics of carbon-based materials. Studies involving $CoFe_2O_4$, $NiFe_2O_4$, $MnFe_2O_4$, and $ZnFe_2O_4$ demonstrate that absorption performance depends on

ferrite composition, carbon structure, interfacial interactions, and absorber geometry rather than individual material properties alone.

The comparative findings reveal trade-offs among minimum reflection loss (RLmin), effective absorption bandwidth (EAB), and absorber thickness. A deeper RLmin does not necessarily indicate broader bandwidth or reduced thickness. Reliable comparisons therefore require fixed-thickness EAB, operating frequency, filler loading, and measurement conditions alongside RLmin (Yang et al., 2025).

Porous carbon frameworks, heterogeneous interfaces, core–shell structures, and multicomponent ferrites offer opportunities to regulate electromagnetic attenuation and impedance matching (Li et al., 2024; Mohapatra et al., 2025). However, structural complexity must be justified by measurable performance improvements and balanced against synthesis reproducibility and fabrication requirements.

Biomass-derived carbon provides opportunities for waste valorization, but renewable feedstock origin alone does not establish environmental superiority. Carbonization, chemical activation, washing, ferrite synthesis, and material yield influence the environmental profile of the final composite. Life cycle assessment and techno-economic evaluation are therefore important for establishing measurable sustainability benefits (Ren et al., 2025; Saleem et al., 2025; Zhang et al., 2025).

Future research should prioritize thin, lightweight, and reproducible absorber designs, supported by standardized reporting of electromagnetic parameters, filler concentrations, sample geometry, and experimental uncertainty. Long-term stability, scalable synthesis, and validated computational or data-driven optimization also warrant greater attention. Integrating electromagnetic characterization with environmental and economic assessment could support more efficient material development.

An important direction for future research is the evaluation of ferrite–carbon composites under application-relevant conditions. Most reported absorption characteristics are obtained from laboratory-scale specimens, whereas practical applications may involve different substrate geometries, coating thicknesses, environmental conditions, and mechanical requirements. Investigating adhesion, mechanical durability, thermal stability, and performance retention under repeated environmental exposure would help establish whether promising laboratory formulations can be translated into reliable functional coatings or structural composites. Ultimately, progress in ferrite–carbon microwave absorbers should be guided by performance–thickness–bandwidth–sustainability optimization, rather than increasingly negative reflection-loss minima alone. This integrated perspective offers a pathway toward practical, resource-efficient microwave-absorbing materials.

References

Cao, R., Qiu, Y., Zhao, X., Lan, D., Lu, Y., Wang, Z., Xu, H. & Liu, Y. (2025). Carbon-$CoFe_2O_4$ composite with hierarchical porous structure for efficient microwave absorption. Diamond and Related Materials, 157, 112542. DOI: 10.1016/j.diamond.2025.112542.

Chen, G., Feng, D. & Liu, R. (2025). In situ co-deposition-enabled hierarchical pores in Ni–Co–Zn ferrite/carbon derived from biomass composites with adaptive electromagnetic wave absorption. Carbon Letters, 35(6), 2931–2951. DOI: 10.1007/s42823-025-00967-7.

Ji, G., Ma, C., Jin, S., Song, N. & Li, W. (2026). Facile synthesis of $MnFe_2O_4$ nanoparticles/biomass-derived porous carbon composites with superior microwave absorption performance. Materials Today Communications, 50, 114165. DOI: 10.1016/j.mtcomm.2025.114165.

Li, J., Chen, S., Fan, R., Gong, X., Zhao, H., Yan, L. & Zhou, Y. (2024). Structural engineering on carbon materials for microwave absorption: From micro to macro to meta. Carbon, 224, 119058. DOI: 10.1016/j.carbon.2024.119058.

Lu, Y., Hong, B., Xu, J. C., Li, J., Zeng, Y. X., Peng, X. L., Qiu, S. & Wang, X. Q. (2025). Improved microwave absorption properties of $CoFe_2O_4$/AC nanocomposites from matching electromagnetic characteristics. Journal of Magnetism and Magnetic Materials, 614, 172688. DOI: 10.1016/j.jmmm.2024.172688.

Mehdizadeh, Y., Seyed-Yazdi, J., Jamadi, F., Ebrahimi-Tazangi, F., Seyyedyazdi, S. J., Hosseiny, S. M. & Teixeira, J. (2025). Ultra-broadband microwave absorption performance of multi-scale designed Fe_3O_4@$NiCo_2O_4$/PANI/NRGO aerogels. Journal of Materials Chemistry A, 13, 23766–23785. DOI: 10.1039/D5TA03371C.

Meng, X., Xu, W., Ren, X. & Zhu, M. (2024). Progress and challenges of ferrite matrix microwave absorption materials. Materials, 17(10), 2315. DOI: 10.3390/ma17102315.

Mohapatra, P. P., Singh, H. K. & Dobbidi, P. (2025). Advancements in electromagnetic microwave absorbers: Ferrites and carbonaceous materials. Advances in Colloid and Interface Science, 337, 103381. DOI: 10.1016/j.cis.2024.103381.

Ren, X., Zhen, M., Meng, F., Meng, X. & Zhu, M. (2025). Progress, challenges and prospects of biomass-derived lightweight carbon-based microwave-absorbing materials. Nanomaterials, 15(7), 553. DOI: 10.3390/nano15070553.

Saleem, J., Moghal, Z. K. B., Tahir, F., Al-Ansari, T., Osman, A. I. & McKay, G. (2025). Life cycle assessment of high value activated carbon production based on mass and functional performance metrics. Scientific Reports, 15, 32797. DOI: 10.1038/s41598-025-16300-1.

Shao, S., Xing, S., Bi, K., Guo, C., Tang, Y., Wu, L., Wang, Z., Liu, J. & Wang, F. (2025). Tailored multi-band microwave absorption performance via entropy engineering in spinel ferrite/carbon nanofiber composites. Small, 21(23), e2502349. DOI: 10.1002/smll.202502349.

Shen, X., Lu, X., Lan, C., Qi, J., Zhang, X., Gao, G. & Lv, Z. (2026). Integrated $MnFe_2O_4$ nanoparticles on waste-derived N-doped porous carbon for enhanced electromagnetic wave absorption. Ceramics International, 52(2), 2392–2402. DOI: 10.1016/j.ceramint.2025.12.057.

Si, L., Gao, J., Ma, Z., Liu, F. & Qian, M. (2026). Preparation and microwave absorption mechanism of cobalt ferrite/coal slime-based carbon composites. RSC Advances, 16(18), 16622–16630. DOI: 10.1039/D6RA00652C.

Tian, Y., Estevez, D., Peng, M., Li, C., Lv, X., Wei, H. & Qin, F. (2025). Trimodal pore engineering on biomass-derived carbon composites for efficient microwave absorption. Composites Communications, 57, 102474. DOI: 10.1016/j.coco.2025.102474.

Wang, Y., Ye, X., Yan, T., Zhang, R., Li, R., He, E. & Wu, H. (2025). Multi-mechanism synergy in graphene-(Fe_3O_4/FeO)@carbon core–shell structure composites for enhanced broadband microwave absorption. Polymer Composites, 46(18), 17167–17183. DOI: 10.1002/pc.70103.

Wen, J., Wang, K., Jin, S., Yang, J., Xu, S., Jiang, Y., Zhang, X. & Wu, X. (2025). Facile synthesis of tunable flower-like $NiFe_2O_4$/C composites for boosting electromagnetic wave absorption. Journal of Alloys and Compounds, 1044, 184319. DOI: 10.1016/j.jallcom.2025.184319.

Xu, J., Li, J., Ma, Y., Wang, M., Zhu, C., Zheng, G., Ding, W. & Sheng, Z. (2026). Microwave absorption performance of $ZnFe_2O_4$ nanoparticles coated with carbon and SiO_2. CrystEngComm, 28(3), 663–672. DOI: 10.1039/D5CE01000D.

Yang, S., Wu, P., Sheng, Y., Dong, Y., Li, Z., Wang, T., Qiao, L. & Li, F. (2025). On the quality criteria for microwave absorbing materials. Advanced Electronic Materials, 11(14), e00239. DOI: 10.1002/aelm.202500239.

Zhang, L., Qiao, W., Sun, T., Qian, Y. & Wu, Z. (2026). Cation-engineered Co–Fe spinel/rGO composites with tuned magnetocrystalline anisotropy for wideband microwave absorption. Composites Part B: Engineering, 324, 113794. DOI: 10.1016/j.compositesb.2026.113794.

Zhang, M., He, C., Shi, E., Bei, S., Zhao, Z. & Zhao, Y. (2025). Comparative life-cycle assessment for producing activated carbon from corn stover. Industrial Crops and Products, 231, 121176. DOI: 10.1016/j.indcrop.2025.121176.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

SENSITIVITY OF LiDAR-BASED POWER LINE RISK MAPS TO SEGMENTATION ERRORS AND CLEARANCE REGULATIONS

Mertcan Nazar
Umut Güneş Sefercik
0000-0002-3280-5685, Gebze Technical University, Faculty of Engineering, Department of Geomatics Engineering, Kocaeli, Türkiye.
0000-0003-2403-5956, Gebze Technical University, Faculty of Engineering, Department of Geomatics Engineering, Kocaeli, Türkiye.

Abstract

Clearance-risk maps derived from airborne light detection and ranging (LiDAR) point clouds identify the vegetation that breaches the minimum distances prescribed for overhead transmission lines and are used to plan pruning. Such a map is the end of a processing chain of semantic segmentation, power line reconstruction, and a clearance rule, and the breach counts it reports inherit the choices made at each stage. This study quantifies three of them on a 3.66 km section of a 220 kV transmission corridor in Türkiye: the label source (reference labels of the surveyed point cloud versus labels predicted by a graph neural network), the clearance values (a 19 × 19 sweep of horizontal and vertical clearance from 1 to 10 m, with the Turkish regulation at 4.5 m and 5.0 m as the reference point), and the breach criterion (independent horizontal and vertical limits versus a combined normalized distance). The analysis was run on two held-out corridor ends, one open and one under dense canopy. At the regulated clearances, predicted labels changed the breach count by 9.7 and 6.0 percent relative to reference labels, with a Jaccard agreement of the breaching point sets of 0.87 and 0.94 and identical span-level rankings. Under predicted labels, the clearance values changed the count by a factor of 37 to 44 across the 3 to 6 m window, and the count changed by 771 and 708 points per 0.5 m of horizontal clearance, 3.6 to 4.7 times the label-source effect. Reading the two clearances as a combined ellipsoid instead of independent limits reduced the count by a factor of 3.9. With a segmentation of this quality, the risk map is governed by the regulation and by how it is interpreted rather than by the network. Limitations include one corridor and reference labels taken from a pre-classification.

Keywords: Airborne LiDAR, Power Transmission Corridor, Clearance Risk, Sensitivity Analysis, Vegetation Management, Safety Regulation.

INTRODUCTION

Contact between an overhead transmission line and surrounding objects such as tree limbs can cause arcing, and power line failures under extreme wind conditions have caused catastrophic wildfires, including the 2007 fires in California and the 2009 Black Saturday fires in Australia (Mitchell, 2013). Grid operators are therefore required to keep vegetation outside a minimum horizontal and vertical distance from the line. The inspection that verifies this is still conducted by teams on foot or from helicopters, both of which depend on human visual observation, and the ground-based method is labor-intensive (Matikainen et al., 2016). Airborne laser scanning (ALS) has become an important acquisition approach for corridor surveys and, together with mobile laser scanning, is among the most promising bases for automated detection and three-dimensional reconstruction of power lines and pylons (Matikainen et al., 2016), and it reduces the labor of ground-based inspection (Shen et al., 2024). Turning a corridor point cloud into a clearance-risk map requires three steps. The power line points are first separated from the rest of the point cloud by rule-based detection (Nazar & Sefercik, 2025), by projection-based convolutional networks (Nazar & Sefercik, 2026), or by point-based deep networks that assign every point to a class (Shen et al., 2024). The power line points are then converted into continuous line geometry, and finally the distance from every vegetation point to the nearest line is compared with the clearance that the applicable regulation prescribes (Al-Najjar et al., 2024; Chen et al., 2018). The breach count

that results, and the map of where the breaches lie, is what an operator acts on. That count is not a measurement. It is the output of a chain in which the segmentation can be wrong, the clearance values differ between regulations, and the rule that turns two clearances into a breach decision can be read in more than one way. Published corridor studies report the accuracy of the segmentation in detail, and the clearance analysis as a single result under one fixed set of clearance thresholds (Al-Najjar et al., 2024; Chen et al., 2018), so the question of how much the final map depends on each choice remains open for a forested corridor. That question is addressed here on a forested 220 kV corridor in Türkiye with a three-stage processing chain: a graph neural network for semantic segmentation of the point cloud, a catenary reconstruction of the power lines, and a regulation-referenced clearance analysis. The segmentation, the reconstruction, and the present-state risk map are treated as fixed inputs. Three sources of variation are quantified on two spatially held-out corridor ends. The label source is varied by running the chain once from the reference labels of the surveyed point cloud and once from the labels predicted by the network. The clearance values are varied by sweeping the horizontal and vertical clearance over a wide range around the regulated values. The breach criterion is varied by comparing the independent-limit reading of the regulation with a combined normalized distance. The outcome is a statement of which of the three the operator should attend to first.

MATERIALS AND METHODS

Corridor dataset and test areas

The study area is a 3.66 km section of a 220 kV transmission corridor crossing forested and mountainous terrain in Türkiye and holding nine pylons. The corridor is extracted from an ALS survey that also served an earlier study of the same line (Nazar & Sefercik, 2026), clipped here to a slightly shorter extent and reduced by the class filtering described below. The survey recorded up to six returns per pulse and was pre-classified in TerraSolid into the standard classes of the American Society for Photogrammetry and Remote Sensing. All points within 50 m of the corridor axis were kept, and after removal of noise, low points, and low and medium vegetation, the dataset holds 7.84 million points in five classes: ground, high vegetation (hereafter vegetation), building, power line, and pylon. The pre-classification is the reference labeling throughout this study and was not edited. Two test areas are used: the two ends of the corridor that are held out for spatial cross-validation of the network. Area 1 is the first 20 percent of the corridor, the open end, with 2.08 million points, where the power lines run clear of the treetops. Area 2 is the last 20 percent, with 1.33 million points, where the canopy rises to the height of the lines and, in places, surrounds them. Each area holds two pylons. Figure 1 shows both areas in side view with their reference classes and the reconstructed lines.

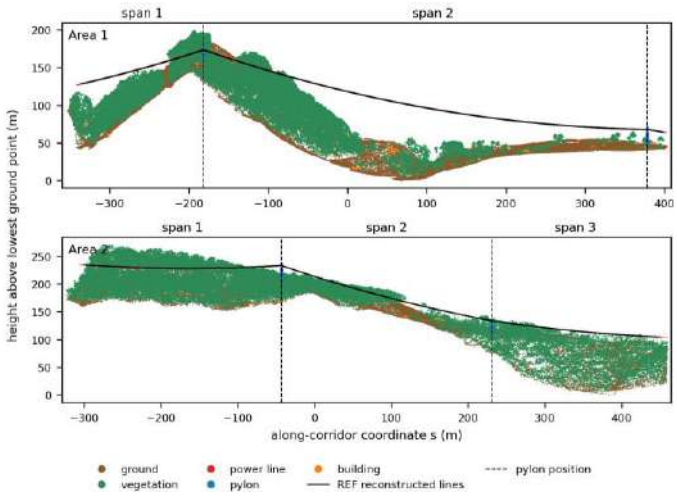


Figure 1. The two test areas in side view, colored by reference class, with the reconstructed lines from reference labels in black, pylon positions as dashed lines, and the span numbering used in the analysis. Heights are relative to the lowest ground point. (a) Area 1, open end. (b) Area 2, end under dense canopy

Segmentation and reconstruction as fixed inputs

Predicted labels come from a graph neural network for point cloud semantic segmentation, trained on the part of the corridor outside each test area so that no test point neighbors a training point. The map depends on two classes of this segmentation. The vegetation class supplies the points that are evaluated, and reaches an intersection-over-union (IoU) of 99.9 and 99.8 percent on Area 1 and Area 2. The power line class supplies the points from which the lines are reconstructed, and reaches 96.7 and 92.5 percent, with precision above 98.9 percent in both areas and recall of 97.0 and 93.5 percent, so that the predicted power line is nearly free of false points and misses part of the line under the canopy. Pylon labels enter the map only through the cluster positions that delimit the spans. The predicted labels are the operational case of this study: the map an operator would obtain without reference labels. The network itself is not modified or retrained here, and no other configuration is used. The power line points of each label source are converted into continuous geometry with a three-step reconstruction procedure: a piecewise-linear route in plan with vertices at the pylons, three parallel phases at fixed lateral offsets, and a least-squares catenary per span and phase in elevation. Pylon positions are found by clustering the pylon-labeled points of the same label source, so that under predicted labels both the lines and the span boundaries depend on the segmentation. A span is the segment of the reconstructed line between consecutive pylons that lie at least 20 m inside the line extent, and the pieces between the extent ends and the outermost such pylon count as spans. Under this rule, Area 1 has two spans, because its second pylon lies 19.5 to 19.6 m from the end of the line extent, inside the 20 m margin, and Area 2 has three. Reconstruction quality is measured against the reference power line points by the coverage (share of reference points within 1 m of a reconstructed line) and by the three-dimensional root-mean-square (RMS) distance of those points from the line.

Clearance rule and breach criterion

For a 220 kV line, the Turkish regulation on high-current electrical installations, hereafter EKAT, prescribes a horizontal clearance C_h of 4.5 m and a vertical clearance C_v of 5.0 m between a power line and vegetation (MENR, 2000). For every vegetation point, the horizontal distance dxy to the nearest reconstructed line and the absolute vertical offset dz from it are computed. Two readings of the regulation are compared. In the independent-limit reading, the two clearances are applied separately, and a point breaches when at least one point of the reconstructed line lies within both limits of it, Eq. (1). This is the rectangular envelope implied by stating the two clearances as independent limits. The envelope is evaluated in a frame aligned with the line, so that the horizontal limit is measured laterally. Evaluating the same envelope in map coordinates would give breach counts 40 to 75 percent higher than the line-aligned counts reported here. EKAT specifies the horizontal distance at the maximum swing of the line and the vertical distance at its maximum sag (MENR, 2000). The surveyed geometry is used here without those adjustments, which belong to a scenario analysis outside the scope of this study. In the combined reading, the two distances are scaled by their clearances and merged into a single normalized distance d_{norm} Eq. (2), and a point breaches when d_{norm} is below 1, which is the ellipsoid inscribed in the rectangle, and the difference between the two readings is quantified here. In both readings, d_{norm} provides the graded distance of the risk bands: 1 to 2 high, 2 to 3 medium, 3 to 4 low, 4 and above very low, and points farther than 50 m from the line carry no risk.

$$\max\left(\frac{d_{xy}}{C_h}, \frac{d_z}{C_v}\right) < 1 \tag{1}$$

$$d_{norm} = \sqrt{\left(\frac{d_{xy}}{C_h}\right)^2 + \left(\frac{d_z}{C_v}\right)^2} \tag{2}$$

Sensitivity design

Three factors are varied, one at a time, in both areas. The present state of the corridor is analyzed throughout: no sag, growth, or fall-in scenario is applied. Label source. The whole chain, from labels through reconstruction to breach set, is run once from the reference labels (REF) and once from the predicted labels

(PRED). The two runs are compared by the breach count under EKAT, by the agreement of the two breaching point sets over the vegetation points that both sources label as vegetation (confusion of breach against no breach, and the Jaccard index), and by the per-span counts. Breaches on points that only one source labels as vegetation are counted in the totals and reported separately. Clearance values. With the geometry of each label source fixed, the clearance pair (C_h, C_v) is varied on a 19 × 19 grid from 1.0 to 10.0 m in 0.5 m steps, 361 pairs per area and label source, and the breach count under Eq. (1) is recomputed exactly at every pair. EKAT is one point of this grid. The European overhead line standard EN 50341-1 (CENELEC, 2012) and the North American transmission vegetation management standard FAC-003-5 (NERC, 2024) were not evaluated as named points, because the standard texts were not available at the time of writing. Breach criterion. At EKAT and with the geometry fixed, the count under Eq. (1) is compared with the count under Eq. (2). The three factors are then placed on a common scale as the range of the breach count that each one produces: the difference between REF and PRED at EKAT, the difference between the smallest and the largest count over the 3.0 to 6.0 m window of the sweep around the EKAT values, and the difference between the two breach criteria at EKAT. Each range is also expressed as a percentage of the operational count (PRED, EKAT, Eq. (1)). The local sensitivity to the clearance values is reported as the change in count per 0.5 m of C_h and of C_v at the EKAT point, from central differences on the grid. All computations reuse the distance functions of the risk-mapping code. The envelope test was re-implemented in the line-aligned frame described above, after the code's original counts had been reproduced exactly, and the analysis adds no learned component.

RESULTS

Label source

Table 1 gives the two runs side by side. Under EKAT, the breach count rises from 1676 reference-label breaches to 1839 predicted-label breaches in Area 1, a change of 163 points or 9.7 percent, and from 3212 to 3406 in Area 2, a change of 194 points or 6.0 percent. In both areas, the breaching vegetation is a small fraction of all vegetation points, 0.14 to 0.16 percent in Area 1 and 0.32 to 0.34 percent in Area 2. The band populations above the breach line, high, medium, and low, differ by less than one percent between the two label sources.

Table 1. Breach counts and reconstruction quality under the EKAT clearances (C_h = 4.5 m, C_v = 5.0 m) for the two label sources: breaches under Eq. (1) and Eq. (2), band counts from dnorm, Eq. (2), and coverage and RMS against the reference power line points

	Area 1, REF	Area 1, PRED	Area 2, REF	Area 2, PRED
Vegetation points	1167893	1168168	1015813	1015173
Breaches, Eq. (1)	1676	1839	3212	3406
Breaches, Eq. (2)	274	474	694	867
Breach share, Eq. (1) (%)	0.14	0.16	0.32	0.34
High band (1 to 2)	15912	15850	33206	32901
Medium band (2 to 3)	37163	37478	80618	80639
Low band (3 to 4)	52301	52570	100392	100477
Line coverage (%)	98.9	97.5	88.7	86.5
Line RMS (m)	0.31	0.24	0.27	0.29

The agreement goes beyond the totals. Over the 1167246 vegetation points that both label sources share in Area 1, 1580 breach under both, 96 under reference labels only, and 132 under predicted labels only, a Jaccard index of 0.874. In Area 2, the shared set holds 1014438 points, of which 3109 breach under both, 102 under reference only, and 84 under predicted only, a Jaccard index of 0.944. A further 127 and 213 breaches lie on points that only the network labels as vegetation, which is where both areas gain most of their extra points. Figure 2 maps the disagreements: in Area 1, they cluster around the first pylon and at the far end of the line, in Area 2, along the first span and just beyond the first pylon, in both cases, next to the line rather than spread along the corridor.

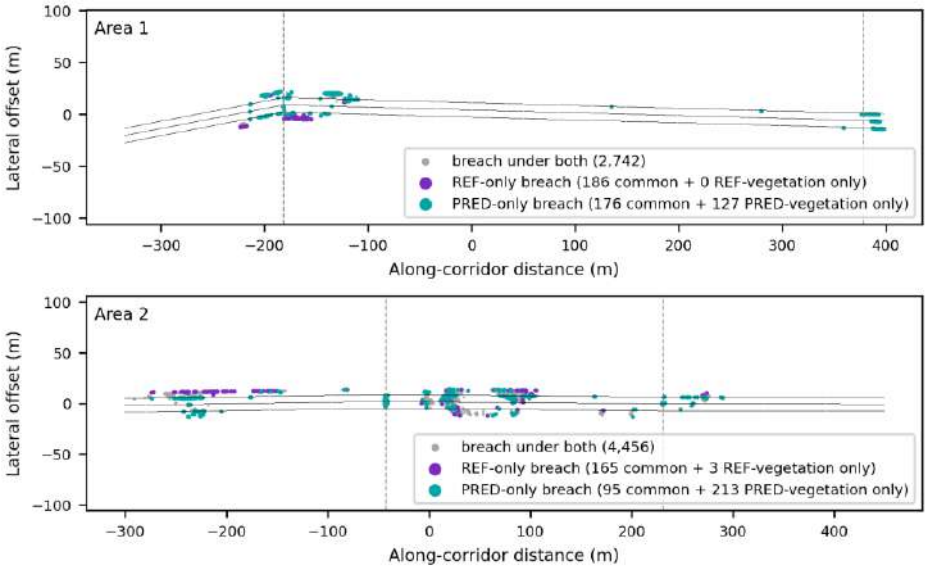


Figure 2. Plan view of the breaching vegetation points under EKAT that differ between the two label sources: breaches under both (grey), under reference labels only (purple), and under predicted labels only (teal), with the reconstructed lines in black and pylons as dashed lines. Legend counts are the shared-set and single-source numbers of Table 2

At span level, the two label sources agree completely. The pylon clusters found from predicted labels lie within 0.3 m along the corridor of those found from reference labels, the span partitions are identical, and the ranking of spans by breach count is the same (Table 2). The reconstruction from predicted labels covers 97.5 and 86.5 percent of the reference power line points, compared with 98.9 and 88.7 percent for the reconstruction from reference labels, at an RMS distance of 0.24 to 0.31 m in both cases. The lower coverage in Area 2 reflects the canopy, under which part of each span is not sampled by the scanner, and the catenary bridges those parts for both label sources alike.

Table 2. Agreement of the breaching point sets and the per-span breach counts between reference (REF) and predicted (PRED) labels under EKAT. Point agreement is computed over the vegetation points shared by both label sources

	Area 1	**Area 2**
Shared vegetation points	1167246	1014438
Breach under both	1580	3109
Breach under REF only	96	102
Breach under PRED only	132	84
Jaccard index	0.874	0.944
Breaches on single-source vegetation points, REF / PRED	0 / 127	1 / 213
Spans	2	3
Per-span breaches, REF	280 / 1396	710 / 2274 / 228
Per-span breaches, PRED	331 / 1508	794 / 2361 / 251

Clearance values

Figure 3 shows the breach count over the full clearance grid for predicted labels, and Figure 4 shows two slices of the same surface through the EKAT point. Three properties stand out. The surface is smooth and monotone, with no plateau anywhere in the range of regulatory interest. It is steep: at the EKAT point, the count changes by 771 breaches in Area 1 and 708 in Area 2 per 0.5 m of horizontal clearance, and by 485 and 1057 per 0.5 m of vertical clearance (central differences on the grid), so that a single step of the grid moves the count by 21

to 42 percent of its EKAT value. Over the 3.0 to 6.0 m window, the count under predicted labels ranges from 162 to 7161 in Area 1 and from 273 to 10091 in Area 2, factors of 44 and 37; under reference labels the window maxima are nearly the same, 7025 and 10012, but the minima are lower, 18 and 102, so the two surfaces separate only at the tightest clearances. And the two label sources trace nearly the same surface: in Figure 4, the REF and PRED curves of each area lie close together at the scale of the figure above a few hundred breaches, with the label-source difference staying below 300 points while the clearance effect runs into the thousands.

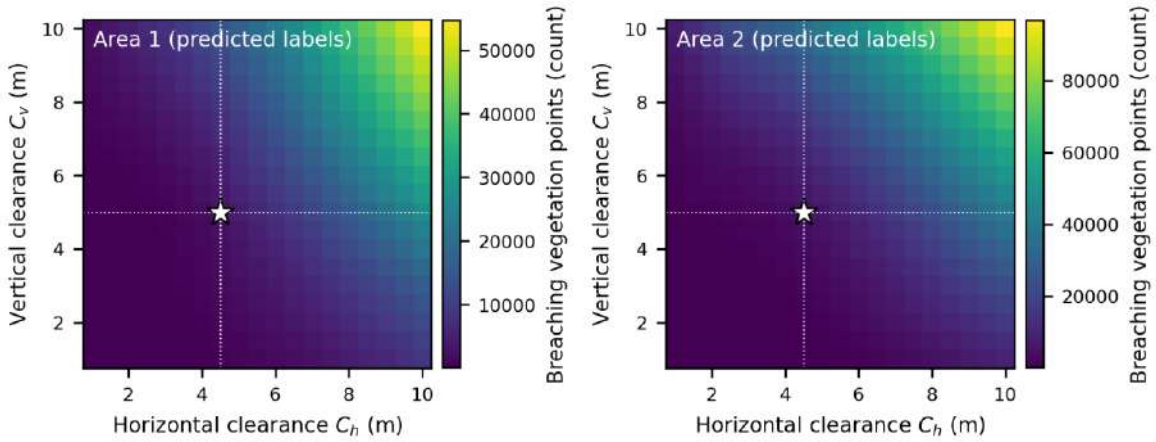


Figure 3. Breach count under Eq. (1) over the clearance grid for predicted labels, 1.0 to 10.0 m in 0.5 m steps. The star marks the EKAT values

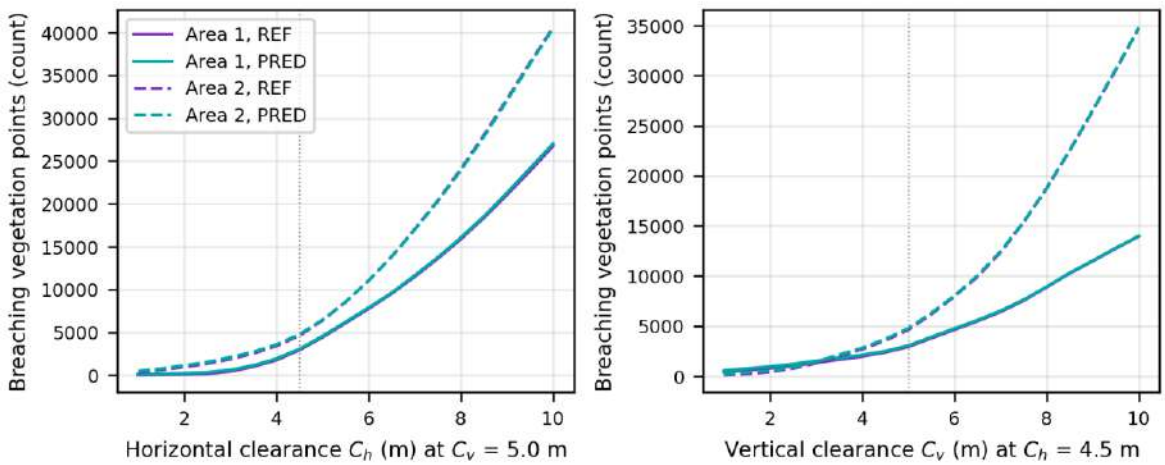


Figure 4. Two slices of the clearance surface through the EKAT point for both areas and both label sources: breach count against C_h at C_v = 5.0 m (left) and against C_v at C_h = 4.5 m (right). The dotted line marks the EKAT value

The vertical clearance matters more under the canopy. In Area 1, the horizontal slope exceeds the vertical one by about half, because the lines run well above the crowns and vegetation enters the envelope mostly from the side at the pylons. In Area 2, the vertical slope is the larger of the two, because crowns reach the height of the lines and a lowered vertical limit admits them from below more readily than from the side.

Breach criterion

Under the combined reading of Eq. (2), the EKAT breach count falls from 1839 to 474 in Area 1 and from 3406 to 867 in Area 2, a factor of 3.9 in both areas (Table 1). The reduction is due to the geometry of the two envelopes: the ellipsoid of Eq. (2) is inscribed in the rectangle of Eq. (1), and the corner region that only the

rectangle covers, where a crown is both beside and below a power line at distances just inside both limits, holds most of the breaching points in a forest corridor. Under reference labels, the factors are larger, 6.1 and 4.6 (1676 to 274 and 3212 to 694), because the few points inside the ellipsoid sit closest to the line, where the two label sources differ most: the combined criterion changes its count by 73 and 25 percent between label sources, whereas the independent-limit criterion changes by 9.7 and 6.0 percent.

The three factors on one scale

Table 3 places the three ranges side by side with the operational count as the denominator. The label source accounts for 163 and 194 points, 8.9 and 5.7 percent. The breach criterion accounts for 1365 and 2539 points, 74 and 75 percent. The clearance values account for 6999 and 9818 points over the 3.0 to 6.0 m window, 381 and 288 percent, and the count changes by 771 and 708 points per 0.5 m of horizontal clearance at the regulated values. The order is the same in both areas and does not depend on whether the operational or the reference labels are used as the base.

Table 3. Range of the breach count produced by each factor, in points and as a percentage of the operational count (PRED labels, EKAT, Eq. (1)), and the local sensitivity to the clearance values at the EKAT point

Area	Factor	Range (points)	Range (%)	Per 0.5 m of C_h	Per 0.5 m of C_v
Area 1	Label source (REF vs PRED)	163	8.9		
Area 1	Breach criterion (Eq. 1 vs Eq. 2)	1365	74.2		
Area 1	Clearance values, 3.0 to 6.0 m window	6999	380.6	771	485
Area 2	Label source (REF vs PRED)	194	5.7		
Area 2	Breach criterion (Eq. 1 vs Eq. 2)	2539	74.5		
Area 2	Clearance values, 3.0 to 6.0 m window	9818	288.3	708	1057

DISCUSSION

The three factors sit on three different scales, and that is the main result. A segmentation with a power line IoU in the nineties changes the breach count of a 220 kV corridor by six to ten percent and leaves the ranking of spans untouched, so a pruning plan derived from the predicted map would send the crew to the same spans in the same order as a plan derived from the reference labels. The disagreements that remain lie beside the line at the pylons and along the first span of the occluded end, which is where the reconstruction is most sensitive to the few power line points it is given. Reading the regulation as a combined distance instead of two independent limits changes the count by a factor of about four, and shifting either clearance by half a meter changes it by a fifth to two fifths. For an operator, the practical order of attention is therefore the clearance table and its interpretation first, the segmentation last. The breach-criterion result is a matter of definition rather than of measurement, and it is the one factor that an operator controls completely. The two readings answer different questions: the independent-limit reading asks whether a point lies within both clearances that the regulation states, the combined reading asks how far a point lies from the line in a normalized sense, which is what the graded risk bands need. A corridor report should use the first for the breach count and the second for the bands, and state so, because the factor of about four between them is larger than any difference a segmentation method is likely to make. Any comparison of breach counts between studies, or between a study and an operator's own inventory, must state which envelope was used. The steepness of the clearance surface has a second consequence. The sweep shows that, at the regulated values, a difference of one meter in either clearance changes the breach count of the same corridor by a factor of 1.5 to 2.6. A risk map is therefore not transferable between jurisdictions as a count of breaches. It is transferable as the per-point distances d_{xy} and d_z, from which any clearance table can be applied, and the sweep of Figure 3 is the form in which the result of a corridor survey should be stored. Five limitations bound these results. One corridor, one voltage, and one survey were analyzed, so the relative size of the three effects is established for this corridor and not in general, although the geometric argument for the breach criterion does not depend on the site. The two test areas hold two pylons each, so the span-level agreement rests on two and three spans. The reference labels are a pre-classification to the standard classes rather than a field-checked ground truth, so the label-source effect is the

difference between two labelings, not the error against reality. The European and North American tables were not evaluated as named points, so the regulatory comparison is made through the sweep rather than between specific standards. The segmentation error measured here also includes its effect on the reconstruction, since both the lines and the span boundaries were rebuilt from each label source. Separating the two contributions is a short extension of the same design.

CONCLUSION

On a forested 220 kV corridor, the clearance-risk map produced from airborne laser scanning is governed by the regulation and by how it is read, not by the segmentation network. Predicted labels changed the EKAT breach count by 6.0 to 9.7 percent relative to reference labels, with Jaccard agreement of 0.87 to 0.94 between the breaching point sets and identical span rankings. The count changed by 708 to 771 points per half meter of horizontal clearance, and the choice between an independent-limit and a combined reading of the two clearances changed it by a factor of 3.9. Corridor surveys should therefore deliver the per-point clearance distances rather than a breach count under one table, state the breach envelope explicitly, and treat segmentation accuracy at the level reached here as sufficient for regulation-referenced clearance mapping.

REFERENCES

Al-Najjar, A., Amini, M., Rajan, S., & Green, J. R. (2024). Identifying areas of high-risk vegetation encroachment on electrical powerlines using mobile and airborne laser scanned point clouds. IEEE Sensors Journal, 24(14), 22129-22143. https://doi.org/10.1109/JSEN.2023.3348785

CENELEC (European Committee for Electrotechnical Standardization). (2012). Overhead electrical lines exceeding AC 1 kV, Part 1: General requirements, common specifications (EN 50341-1:2012). Brussels.

Chen, C., Yang, B., Song, S., Peng, X., & Huang, R. (2018). Automatic clearance anomaly detection for transmission line corridors utilizing UAV-Borne LIDAR data. Remote Sensing, 10(4), 613. https://doi.org/10.3390/rs10040613

Matikainen, L., Lehtomäki, M., Ahokas, E., Hyyppä, J., Karjalainen, M., Jaakkola, A., Kukko, A., & Heinonen, T. (2016). Remote sensing methods for power line corridor surveys. ISPRS Journal of Photogrammetry and Remote Sensing, 119, 10-31. https://doi.org/10.1016/j.isprsjprs.2016.04.011

MENR (Ministry of Energy and Natural Resources of Türkiye). (2000). Elektrik kuvvetli akım tesisleri yönetmeliği (Regulation on high-current electrical installations). Resmî Gazete, No. 24246, 30 November 2000.

Mitchell, J. W. (2013). Power line failures and catastrophic wildfires under extreme weather conditions. Engineering Failure Analysis, 35, 726-735. https://doi.org/10.1016/j.engfailanal.2013.07.006

Nazar, M., & Sefercik, U. G. (2025). Assessment of algorithms utilized in automatic power line detection from LiDAR point clouds. Proceedings of the 1st International Cyprus Congress of Scientific Research, Kyrenia, 21-23 March 2025, 349-354.

Nazar, M., & Sefercik, U. G. (2026). Semantic segmentation of power lines from airborne laser scanning point clouds using projection-based deep learning methods. Proceedings of the 12th International Asian Congress on Contemporary Sciences, Dubai, 25-29 March 2026, 393-405.

NERC (North American Electric Reliability Corporation). (2024). Reliability standard FAC-003-5: Transmission vegetation management. Atlanta.

Shen, Y., Huang, J., Wang, J., Jiang, J., Li, J., & Ferreira, V. (2024). A review and future directions of techniques for extracting powerlines and pylons from LiDAR point clouds. International Journal of Applied Earth Observation and Geoinformation, 132, 104056. https://doi.org/10.1016/j.jag.2024.104056

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THREE-DIMENSIONAL MONITORING OF FOREST LOSS CAUSED BY FIRES USING RADAR SATELLITE IMAGERY, CASE STUDY: 2021 MANAVGAT FIRE, TÜRKİYE

Umut Güneş Sefercik
Mertcan Nazar
0000-0003-2403-5956, Gebze Technical University, Engineering Faculty, Geomatics Engineering Department, Kocaeli, Türkiye.
0000-0002-3280-5685, Gebze Technical University, Engineering Faculty, Geomatics Engineering Department, Kocaeli, Türkiye.

Abstract

Forests cover 31% of the Earth's land surface, and every year, several hundred million hectares of forest are lost globally due to wildfires. In Türkiye, the summer of 2021 saw numerous large-scale forest fires, particularly within the Mediterranean basin. Assessing forest loss caused by wildfires through ground-based methods is highly challenging, dangerous, time-consuming, and costly. Consequently, satellite-based remote sensing technologies have gained prominence as an effective means of monitoring the damage inflicted by forest fires. Among satellite-based approaches, optical satellites equipped with camera systems that capture imagery in the visible and near-infrared regions of the electromagnetic spectrum are frequently preferred. However, when using optical satellite data to assess damage over extensive fire-affected areas, the reliance on medium-to-low-resolution imagery (rather than high-resolution data) significantly limits the effectiveness of three-dimensional (3D) modeling. In this study, synthetic aperture radar (SAR) satellite data, which enables the generation of high-quality 3D digital models via interferometry, were used to analyze forest loss during the 2021 Manavgat (Antalya) wildfire in Türkiye, yielding compelling results. The analysis utilized four images (comprising two independent pairs) provided by the European Space Agency's SAR satellite, Sentinel-1: two captured before the fire and two after. By employing these satellite image pairs, digital surface models (DSMs) of the forested area were generated for both the pre-fire and post-fire periods. By generating a differential DSM, which serves as a difference map of forest visible surfaces, the necessary calculations and visual interpretations were completed, clearly revealing the metric changes in forest cover.

Keywords: Forest Loss, Fire, Radar, Satellite Imagery, Three-dimensional Monitoring, DSM.

INTRODUCTION

Forest fires, which occur globally, most notably in Canada, the United States, Australia, Russia, and countries around the Mediterranean, destroy millions of hectares of natural habitat each year and lead to the deaths of more than a thousand people directly, while causing over 1.5 million indirect deaths linked to smoke and harmful fire-related particles (Xu et al., 2024). These fires also cause an average of $10 billion in annual financial losses, while a single fire can result in the deaths of millions of animals. For instance, it is known that 17 million vertebrate animals perished in the 2020 Pantanal fires in Brazil (Tomas et al., 2021). Given these significant impacts of forest fires, numerous remote sensing strategies focused particularly on early warning, detection, monitoring, and response are currently being implemented (Sefercik and Kavzoglu, 2021). Synthetic Aperture Radar (SAR) technology is one of the methods used for data acquisition and processing within remote sensing strategies. By providing data 24 hours a day regardless of weather conditions, season, or time of day, SAR satellite imagery plays a significant role in the detection and monitoring of forest fires.

Another advantage of SAR satellite data is the potential to image much larger areas at once, compared to airborne systems and optical satellites that rely on passive sensing principles. This facilitates more rapid monitoring and management of disasters that span extensive regions. In particular, Sentinel-1, operated by the European Space Agency (ESA) and providing data since 2016 has become the most frequently utilized SAR

mission for global disasters such as earthquakes, land subsidence, landslides (erosion), floods, marine mucilage and volcanic eruptions, thanks to the Interferometric Wide Swath (IW) imagery it produces, which covers areas of approximately 200 × 250 km (Uddin et al., 2019; Li et al., 2021; Sefercik et al., 2024).

This study aims to assess the damage caused to forested areas by the Manavgat wildfire, which occurred in Türkiye in 2021 and was the largest wildfire recorded in the country up to that date, using SAR satellite data. To this end, three-dimensional (3D) digital surface models (DSMs) of forest areas were generated using SAR imagery with appropriate characteristics, acquired both before and after the onset of the Manavgat fire. By calculating the difference between these DSMs, a color-scaled "DIFFDSM", a map that allows for the visual interpretation of the forest areas lost, was produced. Furthermore, based on this map, 3D metric analyses were conducted to quantitatively assess the impacts of the fire.

MATERIALS AND METHODS

The study area selected within the region affected by the Manavgat fire is shown in Figure 1. As can be seen from the figure, the fire had a major impact across an area of approximately 40 × 30 km (W × H), resulting in significant forest loss. Four Sentinel-1 satellite images were used to generate DSMs for the purpose of modeling the state of the forest in 3D both before and after the fire. Each DSM was produced using a pair, that is, two of these images. The technical specifications for these images are presented in Table 1.

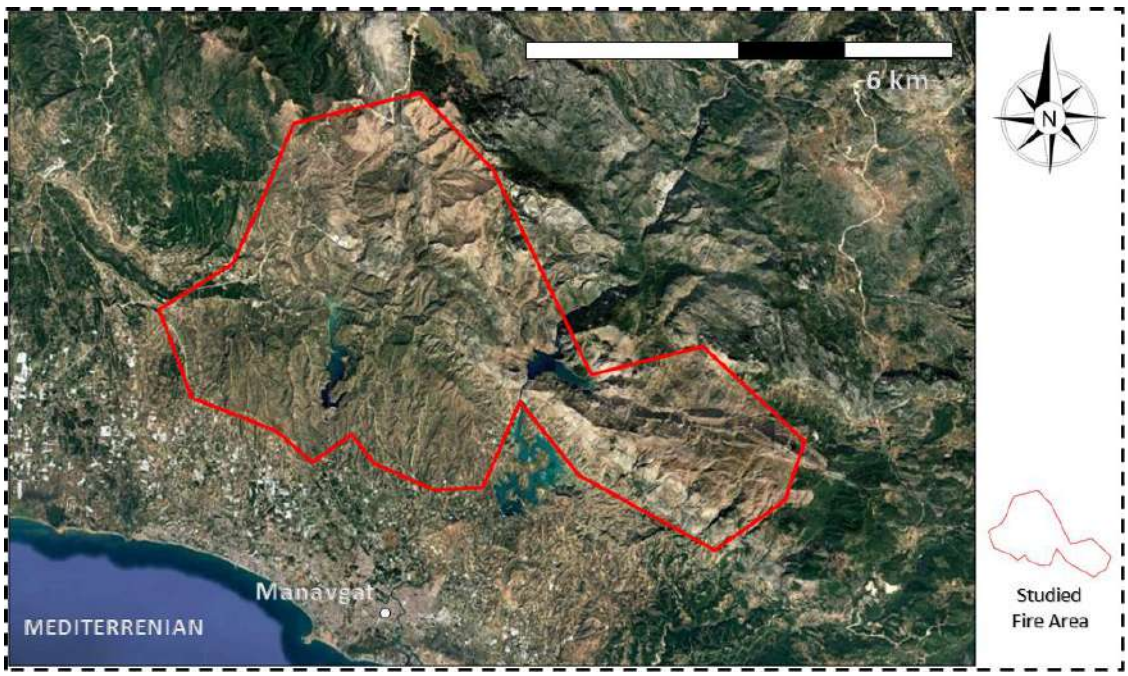
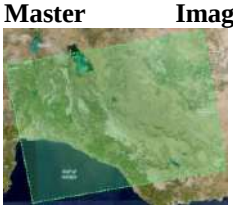


Figure 1. Studied fire area

To obtain the highest-quality DSMs from SAR imagery, images acquired from the same relative orbit sharing the same pass direction (ascending or descending) and the same side-looking orientation were paired. Additionally, the temporal and perpendicular baselines of the images were taken into account as key parameters. The data search interface of the Alaska Satellite Facility (ASF) at the University of Alaska was utilized to select the image pairs that best met the established criteria. In the selection of the Sentinel-1 image pairs, the perpendicular baseline should be between 150 m and 300 m to generate a qualified Sentinel-1 DSM (Hidayatulloh et al., 2022; Sefercik and Jacobsen, 2025). Too short perpendicular baseline decreases signal-to-noise ratio (SNR), sensitive to atmospheric artefacts. In DSM generation, VV polarization images were preferred due to having more energy and lower noise (i.e., high SNR).

Table 1. Properties of Sentinel-1 image pairs used for DSM generation

Properties	Image-pair 1		Image-pair 2	
	Master Image	**Slave Image**	**Master Image** 	**Slave Image**
Mission	Sentinel-1A	Sentinel-1A	Sentinel-1A	Sentinel-1A
Product Type	SLC	SLC	SLC	SLC
Operational Mode	IW	IW	IW	IW
Date and Time	30/04/2021 T18:20:33.415	17/06/2021 T18:30:34.102	28/08/2021 T17:11:02.419	21/09/2021
Relative Orbit	160	160	160	160
Orbit Direction	Ascending	Ascending	Ascending	Ascending
Antenna Pointing	Right	Right	Right	Right
Polarization	VV/VH Used: VV	VV/VH Used: VV	VV/VH Used: VV	VV/VH Used: VV
Resolution Azimuth (m)	13.94	13.94	13.94	13.94
Resolution Range (m)	2.33	2.33	2.33	2.33
Temporal Baseline (day)	48		24	
Perpendicular Baseline (m)	-155		120	

In the production of DSMs, the required interferometric processing steps were applied in the ESA SNAP tool. Figure 2 shows the interferometric processing workflow used in Sentinel-1 DSM generation. The DSMs were generated with a 15 m grid spacing to clearly describe affected tree canopies due to the wildfire.

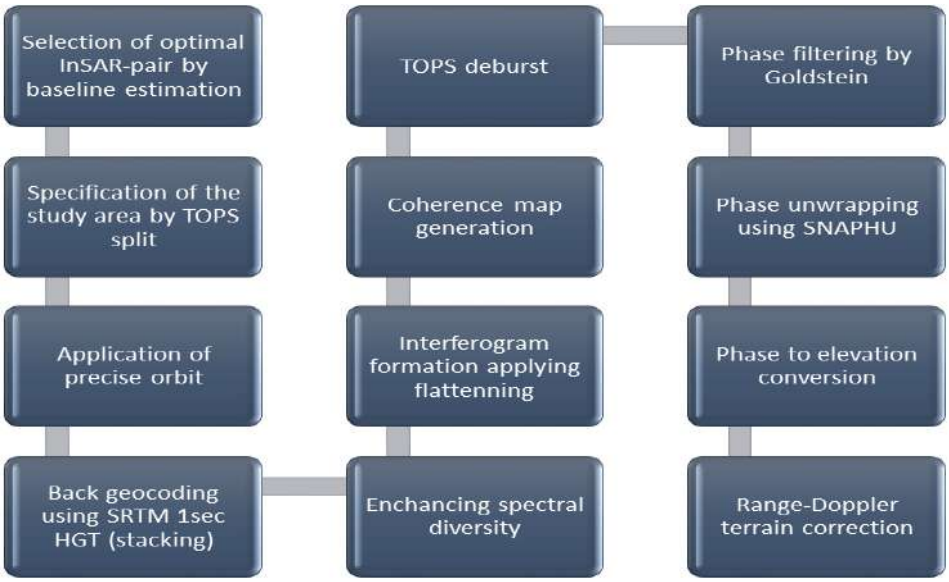


Figure 2. Interferometric processing workflow used in DSM generation

According to the interferometric processing workflow employed, the pre-fire and post-fire DSMs must be perfectly aligned (100% horizontal positional agreement) before generating the "DIFFDSM," a product that provides highly valuable metric information regarding the affected trees. Otherwise, the height differences calculated in the DIFFDSM would be based on pixels at mismatched horizontal positions, leading to misleading results. To address this, an area-based cross-correlation approach was used: the pre-fire DSM was taken as the reference, and the post-fire DSM was shifted to ensure it perfectly aligns horizontally with that reference.

RESULTS

Figure 3 shows DSMs with a 15 m grid, generated from Sentinel-1 SAR imagery for the periods before and after the forest fire. When the DSMs are examined in detail, it becomes clearly evident that the pre-fire DSM exhibits a smoother structure owing to the harmonious canopy surfaces of the tree communities whereas the post-fire DSM appears rougher, characterized by highly variable surfaces created by trees that have burned to varying degrees.

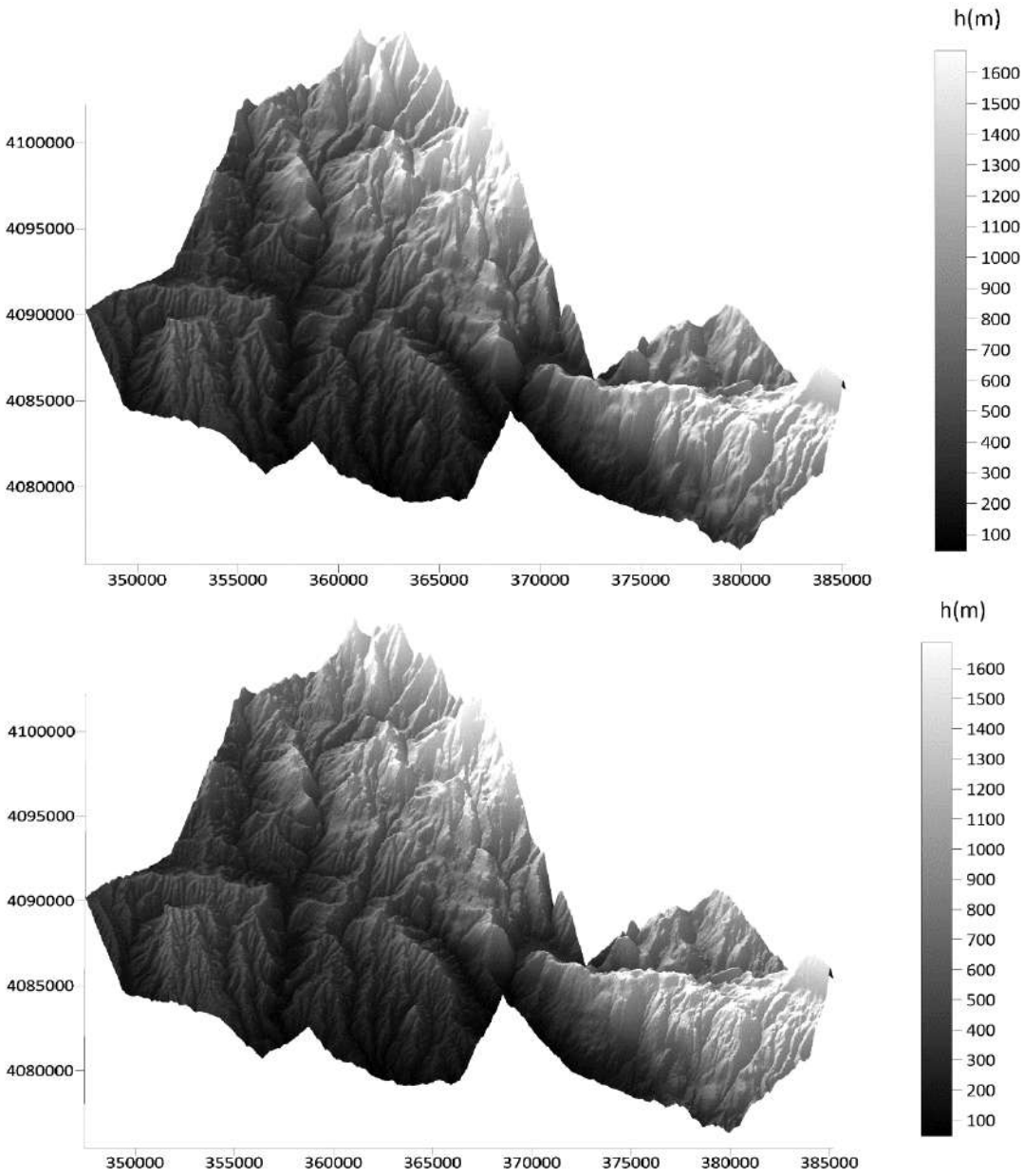


Figure 3. Generated DSMs before (top) and after (below) forest fire

Table 2 shows the horizontal positional offsets between the DSMs generated using pre-fire and post-fire data. The primary cause of these shifts lies in the varying effects of parameters selected during the interferometric processing steps used to derive DSMs from SAR imagery, as well as the distorting influence of interpolation. These detected offsets were corrected by applying a horizontal translation in the opposite direction, ensuring precise horizontal alignment between the DSMs.

Table 2. The horizontal positional offsets between the DSMs generated using pre-fire and post-fire data

Reference DSM	**Shifted DSM**	**Offset in X direction (m)**	**Offset in Y direction (m)**
Pre-fire DSM	Post-fire DSM	1.107	93.133

Figure 4 displays the "DIFFDSM" obtained by subtracting the post-fire DSM from the DSM generated using pre-fire Sentinel-1 satellite imagery. This map shows the distribution of the forest trees that burned, as well as the heights of the sections destroyed by the fire. In other words, every single detail visible on the map has been obliterated. A careful examination of DIFFDSM reveals that the forest fire was particularly intense in the northern and eastern parts of the area, with forest stands experiencing losses of more than 20 m in some places.

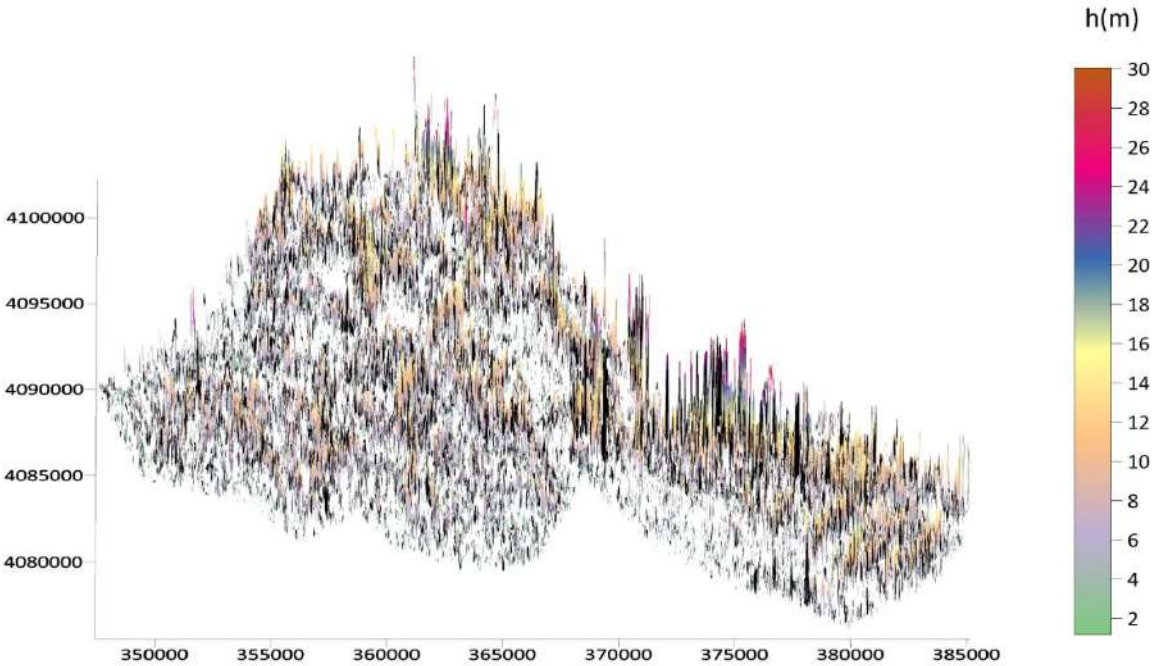


Figure 4. Generated DIFFDSM

Figure 5 presents the metric values for the loss of forested areas as determined by DIFFDSM. An examination of these values reveals that the highest proportion of loss is associated with burning up to a height of 6 m; 68% of the total loss of forested area occurred within this range. This is followed by burning at a height of 6-12 m, which accounts for 22% of the loss. The remaining 10% corresponds to highly intense fire activity that destroyed tree stands at heights between 12 and 30 m.

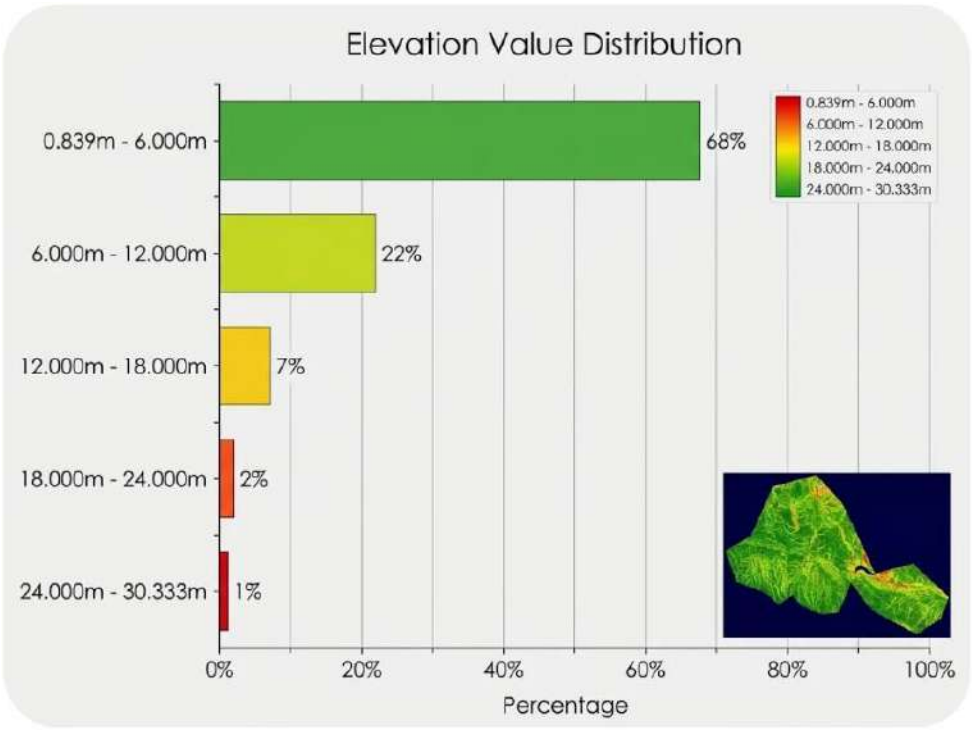


Figure 5. The metric values for the loss of forested areas as determined by DIFFDSM

CONCLUSION

This study presents a case study on the effective use of synthetic aperture radar (SAR) satellite data, which enables active detection 24/7, regardless of the season, day, or night, for monitoring forest fire disasters. It clearly demonstrates the extent and location of the damage caused by the major forest fire that occurred in the Manavgat district of Antalya, Türkiye, in 2021. Türkiye is currently developing its own SAR satellite, Göktürk-3, and our future objective is to conduct the analyses presented in this study and to leverage the experience gained by utilizing data from this domestically produced satellite.

REFERENCES

Hidayatulloh, A., Chaabani, A., Zhang, L., & Elhag, M. (2022). DEM study on hydrological response in Makkah City, Saudi Arabia. Sustainability, 14(20), 13369. https://doi.org/10.3390/su142013369

Li, Y., Jiang, W., Zhang, J., Li, B., Yan, R., & Wang, X. (2021). Sentinel-1 SAR-Based coseismic deformation monitoring service for rapid geodetic imaging of global earthquakes. Natural Hazards Research, 1(1), 11-19. https://doi.org/10.1016/j.nhres.2020.12.001

Sefercik, U. G., Colkesen, I., Kavzoglu, T., Ozdogan, N., & Ozturk, M. Y. (2024). Assessing the physical and chemical characteristics of marine mucilage utilizing in-situ and remote sensing data (Sentinel-1,-2,-3). PFG–Journal of Photogrammetry, Remote Sensing and Geoinformation Science, 92(4), 415-430. https://doi.org/10.1007/s41064-023-00254-y

Sefercik, U. G., & Jacobsen, K. (2025). Quality Comparison of Free-of-Charge Global DSMs: ALOS AW3D30, TanDEM-X 12 m, TanDEM-X EDEM, TanDEM-X 90 m, and Sentinel-1. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 48, 265-272. https://doi.org/10.5194/isprs-archives-XLVIII-M-6-2025-265-2025

Sefercik, U. G., & Kavzoglu, T. (2021). Orman yangınlarında uzaktan algılama teknolojileri ile erken uyarı, tespit, izleme ve müdahale stratejileri. Orman yangınları: sebepleri, etkileri, izlenmesi, alınması gereken önlemler ve rehabilitasyon faaliyetleri, 111-135, Türkiye Bilimler Akademisi (TÜBA).

Tomas, W. M., Berlinck, C. N., Chiaravalloti, R. M., Faggioni, G. P., Strüssmann, C., Libonati, R., ... & Morato, R. (2021). Distance sampling surveys reveal 17 million vertebrates directly killed by the 2020's wildfires in the Pantanal, Brazil. Scientific Reports, 11(1), 23547. https://doi.org/10.1038/s41598-021-02844-5

Uddin, K., Matin, M. A., & Meyer, F. J. (2019). Operational flood mapping using multi-temporal Sentinel-1 SAR images: A case study from Bangladesh. Remote Sensing, 11(13), 1581. https://doi.org/10.3390/rs11131581

Xu, R., Ye, T., Huang, W., Yue, X., Morawska, L., Abramson, M. J., ... & Li, S. (2024). Global, regional, and national mortality burden attributable to air pollution from landscape fires: a health impact assessment study. The Lancet, 404(10470), 2447-2459. https://doi.org/10.1016/S0140-6736(24)02251-7

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE RELATIONSHIP BETWEEN THE USE OF SOCIAL INTERACTION ELEMENTS IN LEARNING MANAGEMENT SYSTEMS AND STUDENT ENGAGEMENT AND MOTIVATION

Aysun Yesilgul
Celebi Uluyol
0009-0006-6845-1643, Gazi University, Gazi Faculty of Education, Department of Computer Education and Instructional Technology, Ankara, Türkiye.
0000-0001-9774-0547, Gazi University, Gazi Faculty of Education, Department of Computer Education and Instructional Technology, Ankara, Türkiye.

Abstract

This study examines the relationship between the use of social interaction elements in Learning Management Systems and students' engagement and motivation. The study group consists of 27 students enrolled in a hybrid Computer Networks class at Gazi University in the spring term of the 2025-2026 academic year. The research used a relational survey model. Moodle was used without social interaction elements in the first six weeks. During the second six weeks, peer assessment, mutual feedback, topic focused forum discussions and commenting activities were added. Moodle logs and the "Online Learning Motivation Scale" (Chen & Jang, 2010; Özbaşı et al., 2018) were used. Two scores were calculated per student, one for social interaction and one for engagement. A one-sample t-test was used to determine motivation levels. Pretest and posttest scores were compared with a paired-samples t-test and the Wilcoxon signed-rank test. Spearman correlation was used for the relationship between social interaction and engagement. Intrinsic motivation to know was the highest dimension. The scores for identified regulation and external regulation were also above the midpoint. Intrinsic motivation toward accomplishment and stimulation was above the midpoint as well, whereas introjected regulation did not differ from it. No subdimension changed significantly between pretest and posttest. A significant positive correlation was found between social interaction and engagement. This relationship was strongest for the number of active weeks. It was weaker for session count and active days. The results suggest that social interaction is related to engagement spread across weeks. Social interaction was not significantly related to the change in motivation after correction. Besides the frequency of interactions, the continuity of engagement and the distribution of interaction among students should be monitored. Since the correlational design does not allow causal inference, future studies with control groups and larger samples may help to clarify the direction.

Keywords: Learning management system, social interaction, student engagement, online learning motivation, learning analytics.

ÖĞRENME YÖNETİM SİSTEMLERİNDE SOSYAL ETKİLEŞİM UNSURLARININ KULLANIMI İLE ÖĞRENCİ KATILIMI VE MOTİVASYONU ARASINDAKİ İLİŞKİ

Özet

Bu araştırmanın amacı, öğrenme yönetim sistemlerindeki (ÖYS) sosyal etkileşim unsurlarının kullanımı ile öğrencilerin katılım ve motivasyon düzeyleri arasındaki ilişkiyi incelemektir. Çalışma grubunda 27 öğrenci vardır. Öğrenciler, 2025-2026 eğitim yılı bahar döneminde Gazi Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü'nde hibrit olarak yürütülen Bilgisayar Ağları dersine kayıtlıdır. Araştırma, nicel araştırma yöntemlerinden ilişkisel tarama modeliyle yürütülmüştür. Uygulama on iki hafta sürmüştür. İlk altı haftada Moodle, sosyal etkileşim unsurları olmadan kullanılmıştır. İkinci altı haftada sürece akran değerlendirmesi, karşılıklı geri bildirim, konu odaklı forum tartışmaları ve paylaşımlara yorum yapma etkinlikleri eklenmiştir. Motivasyon, Chen ve Jang (2010) tarafından geliştirilen, Özbaşı vd. (2018) tarafından Türkçeye uyarlanan "Çevrimiçi Öğrenme Motivasyon Ölçeği" ile ölçülmüştür. Katılım ve sosyal etkileşim

için Moodle günlük kayıtlarından yararlanılmıştır. Bu kayıtlardan her öğrenci için iki puan hesaplanmıştır: sosyal etkileşim ve katılım. Motivasyon düzeyi tek örneklem t-testiyle incelenmiştir. Ön test ile son test arasındaki fark eşleştirilmiş örneklem t-testi ve Wilcoxon işaretli sıralar testiyle incelenmiştir. Sosyal etkileşim ile katılım arasındaki ilişki için Spearman korelasyonu kullanılmıştır. Bulgulara göre bilmeye yönelik içsel motivasyon en yüksek düzeydedir. Belirlenmiş düzenleme, dışsal düzenleme, başarmaya yönelik ve uyarım yaşamaya yönelik içsel motivasyon puanları da orta noktanın üzerindedir. İçe atım düzenleme puanı orta noktadan anlamlı biçimde ayrışmamıştır. Ön test ile son test arasında hiçbir alt boyutta anlamlı fark bulunamamıştır. Sosyal etkileşim ile katılım arasında pozitif yönde anlamlı bir ilişki bulunmuştur. Bu ilişki en çok etkin hafta sayısında görülmüştür. Sonuçlar, sosyal etkileşimin katılımın dönem boyunca farklı haftalara yayılmasıyla ilişkili olduğuna işaret eder. Oturum ve etkin gün sayısıyla ilişki daha zayıftır. Sosyal etkileşim ile motivasyondaki değişim arasında düzeltme sonrası anlamlı ilişki bulunmamıştır. ÖYS'lerde sosyal etkileşim tasarlanırken etkinlik sıklığı kadar katılımın sürekliliğinin de izlenmesi önerilir. Etkileşimin öğrenciler arasında nasıl dağıldığına da bakılmalıdır. İlişkisel desen neden-sonuç yorumuna izin vermez. Bu yüzden sonraki araştırmalarda kontrol gruplu desenler ve daha geniş örneklemler ilişkinin yönünü daha açık gösterebilir.

Anahtar sözcükler: Öğrenme yönetim sistemi, sosyal etkileşim, öğrenci katılımı, çevrim içi öğrenme motivasyonu, öğrenme analitiği.

Giriş

Öğrenme yönetim sistemleri (ÖYS), yükseköğretimde ders içeriğinin sunulduğu, ödevlerin toplandığı ve değerlendirmenin yürütüldüğü ortamlardır. Salgın döneminde ÖYS'ler, üniversitelerde ders anlatımının ve öğrenmenin ana kanalı olmuştur (Kim vd., 2021). İçerik aktarımına ağırlık veren bir ÖYS, öğrencilere birbirleriyle konuşacakları bir alan sunmuyorsa katılım zayıf kalabilir. Akranlarla etkileşimin eksikliği, MOOC'larda düşük tamamlama oranının başlıca nedenleri arasında gösterilir (Loh vd., 2024). Zhu vd. (2025) de sosyal etkileşimin yokluğunun çevrim içi ortamlarda yüksek bırakma oranına yol açabileceğini belirtir.

ÖYS'lere bu amaçla forum, yorum ve akran değerlendirmesi gibi sosyal etkileşim unsurları eklenmektedir. Demmans Epp vd. (2020), tartışma forumlarını öne çıkaran bir sistemi kullanan öğrencilerin daha fazla öğrenme desteği algıladığını bildirmiştir. Aynı ilişki her ders türünde görülmemiştir. Tsai vd. (2026) 577 öğrenciyle yürüttükleri çalışmada, öğrenci-öğrenci, öğrenci-içerik ve öğrenci-öğretici etkileşimini dengeli biçimde bütünleştiren derslerdeki öğrencilerin daha yüksek katılım ve öğrenme algısı bildirdiğini bulmuştur. Gao vd. (2024) ortaokul öğrencilerinde, Shen vd. (2024) ise üniversite öğrencilerinde sosyal etkileşim ve sosyal buradalığın katılımla ilişkili olduğunu göstermiştir. İkisi de öz bildirim ölçekleriyle veri toplamıştır.

ÖYS günlük kayıtları, öğrencinin sistemde ne yaptığını öz bildirimden bağımsız olarak verir. Ahmadi vd. (2023), günlük verisinden türetilen 27 katılım göstergesini derlemiş ve bunları giriş ve kullanım, öğrenci performansı ve iletişim başlıkları altında toplamıştır. Paik vd. (2024) ÖYS'den alınan 13 davranış göstergesinin davranışsal, sosyal ve bilişsel katılım olmak üzere üç boyut verdiğini bulmuştur. Kayıtlara dayanan göstergelerde etkinliğin hacmi ile zamana yayılımı ayrı şeylerdir. Lyu vd. (2024), çevrim içi bir tartışma panosunda katılımın zamanla azaldığını, sosyal etkileşimin ise sürdürülen katılımı etkilediğini bildirmiştir. Lee ve Sharma (2026) yazı sıklığının daha geniş bir katılımla güçlü biçimde ilişkili olmadığını, yanıt alan öğrencilerin ağda daha merkezi bir konumda bulunduğunu saptamıştır.

Araştırmada iki yaklaşım birlikte kullanılmıştır. Katılım ve sosyal etkileşim, Moodle günlük kayıtlarından hesaplanmış, motivasyon ise ölçekle belirlenmiştir. Araştırma şu sorulara yanıt aramıştır:

1. Öğrencilerin çevrim içi öğrenme motivasyonu hangi düzeydedir ve uygulama boyunca değişmiş midir?

2. ÖYS'deki sosyal etkileşim unsurlarının kullanımı ile öğrencilerin katılımı arasında ilişki var mıdır?

3. ÖYS'deki sosyal etkileşim unsurlarının kullanımı ile öğrencilerin motivasyonundaki değişim arasında ilişki var mıdır?

Kuramsal Çerçeve ve İlgili Çalışmalar

Öğrenme Yönetim Sistemlerinde Sosyal Etkileşim

Thommadurage vd. (2026), çevrim içi sosyal öğrenmede karşılaşılan güçlükleri inceledikleri 36 çalışmalık sistematik derlemede, bu güçlüklerin bilişsel, sosyal ve öğretimsel buradalığı birlikte etkilediğini göstermiştir. Yazarlara göre öğrenme tasarımı da sosyal etkileşimi sınırlayabilir. Bu bulgu, sosyal etkileşimin tasarım kararlarına da bağlı olduğunu düşündürür. Llantos ve Estuar (2021), sosyal bir ÖYS'nin etkileşim kayıtlarına sosyal ağ analizi uygulamış, işbirliğinin zamanla arttığını ve kurumsal hiyerarşinin ağ yoğunluğunu düşürdüğünü bildirmiştir. Bayrak Karslı ve Karaman (2024) Türkiye'de uzaktan eğitim alan 80 lisans ve 31 lisansüstü öğrencisiyle, içerikle bütünleşik sosyal etkileşim olanaklarına ilişkin deneyimleri incelemiştir.

Müdahale çalışmaları sosyal etkileşimin sonuçlarını daha doğrudan sınamıştır. Gharbaoui vd. (2024), Moodle'da yürütülen bir programlama dersinde 49 mühendislik öğrencisini iki gruba ayırmış, ikinci gruba forum ve sohbet etkinlikleri eklemiştir. İkinci grup daha yüksek memnuniyet bildirmiş ve daha iyi başarı göstermiştir. Xu ve Rahim (2025), 122 öğrenciyle yürüttükleri kontrol gruplu çalışmada akran geri bildiriminin ve sosyal desteğin motivasyonu, görev katılımını ve dil başarısını anlamlı biçimde artırdığını bulmuştur.

Katılım ve Motivasyon

Öz-belirleme kuramı motivasyonu özerklik, yetkinlik ve ilişkisellik ihtiyaçlarının karşılanması üzerinden ele alır. He vd. (2025) 408 üniversite öğrencisiyle yaptıkları çalışmada öğretmen desteğinin içsel motivasyonu güçlendirdiğini, bunun da etkileşimi ve katılımı desteklediğini bildirmiştir. Katılım üzerinde en güçlü etkiyi özerklik göstermiştir. Catapang vd. (2025) 510 öğrencilik örneklemde ÖYS kabulünün akademik motivasyon üzerinde doğrudan olumlu etkisi olduğunu saptamıştır. Araştırmada kullanılan ölçek de öz-belirleme kuramına dayanır. Ölçek içsel motivasyonu, dışsal düzenleme biçimlerini ve motivasyonsuzluğu ayrı alt boyutlarda ölçer (Chen & Jang, 2010; Özbaşı vd., 2018).

Katılımın günlük kayıtlarıyla ölçülmesi yerleşik bir uygulamadır (Ahmadi vd., 2023). Van Wyk vd. (2026), tam çevrim içi bir lisansüstü modülde 773 öğrencinin ÖYS izlerinden dört davranış göstergesi türetmiş ve öğrencilerin dört farklı katılım profiline ayrıldığını bulmuştur. Sonuç, öğrenciler arasındaki farkların ayrıca incelenmesinin yararlı olduğunu düşündürür. Araştırmada da sosyal etkileşimin öğrenciler arasındaki dağılımına bakılmıştır.

Yöntem

Araştırma Deseni

Araştırma nicel yaklaşımla ve ilişkisel tarama modeliyle yürütülmüştür. Muslem vd. (2024) de çevrim içi platform etkinliklerinin kullanımı ile öğrenci özellikleri arasındaki ilişkiyi korelasyonel bir desenle incelemiştir. Kontrol grubu ve seçkisiz atama yoktur. Aynı öğrenciler uygulamanın başında ve sonunda ölçülmüştür. Altıncı haftada ara ölçüm alınmamıştır. Bu nedenle ön test ile son test arasındaki fark yalnızca betimsel bir değişim olarak yorumlanır. Değişimin hangi döneme ait olduğu ve uygulamadan mı yoksa dönemin ilerlemesinden mi kaynaklandığı ayırt edilemez.

Çalışma Grubu ve Uygulama

Çalışma grubunu, 2025-2026 eğitim öğretim yılı bahar döneminde Gazi Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü'nde hibrit olarak yürütülen Bilgisayar Ağları dersine kayıtlı 27 öğrenci oluşturmuştur. Öğrencilerin hepsi için hem günlük verisi hem de iki ölçüme ait ölçek yanıtları elde edilmiş, kayıp veri kalmamıştır. Araştırma için Gazi Üniversitesi'nden etik onay alınmıştır. Öğrenci kimliğine ait değerler bu bildiride yer almamaktadır.

Uygulama on iki hafta sürmüş ve iki bölümden oluşmuştur. İlk altı haftada Moodle, sosyal etkileşim unsurları olmadan kullanılmıştır. İkinci altı haftada akran değerlendirmesi, karşılıklı geri bildirim, konu odaklı forum tartışmaları ve paylaşımlara yorum yapma etkinlikleri sürece eklenmiştir. Etkinlikler Moodle'ın forum, yapışkan not, yorum bloğu ve atölye (akran değerlendirmesi) araçlarıyla yürütülmüştür. Forum ve yapışkan

not etkinlikleri ilk dönemde hiç kullanılmamıştır. Motivasyon ölçeği uygulamanın başında ve sonunda çevrim içi form ile uygulanmıştır.

Veri Toplama Araçları

Motivasyon ölçeği. Motivasyon, Chen ve Jang (2010) tarafından geliştirilen ve Özbaşı vd. (2018) tarafından Türkçeye uyarlanan Çevrimiçi Öğrenme Motivasyon Ölçeği ile ölçülmüştür. Ölçek 28 madde ve yedi alt boyuttan oluşur. Her alt boyut dört maddedir. Üç alt boyut içsel motivasyonu (bilmeye, başarmaya ve uyarım yaşamaya yönelik), üç alt boyut dışsal düzenleme biçimlerini (belirlenmiş, içe atım ve dışsal düzenleme) ölçer. Yedinci alt boyut motivasyonsuzluktur. Yanıtlar yedili derecelendirmeyle alınmış, alt boyut puanları madde ortalaması olarak hesaplanmıştır. Ölçeğin uyarlama çalışmasında alt boyutların iç tutarlılık katsayıları ,60 ile ,90 arasında bulunmuştur (Özbaşı vd., 2018). Çalışma grubunda ölçek geneli için Cronbach alfa ön testte ,85, son testte ,91 çıkmıştır. Alt boyutlarda katsayılar ön testte ,31 ile ,77, son testte ,61 ile ,86 arasında değişmiştir (Tablo 1). En düşük katsayılar ön testteki içe atım düzenleme (,31) ve uyarım yaşamaya yönelik içsel motivasyon (,43) boyutlarında görülmüştür. İki boyutun ön test bulguları ihtiyatla yorumlanmalıdır. Ölçekten madde çıkarılmamıştır.

Tablo 1. Motivasyon Ölçeğinin Alt Boyutlarına İlişkin Cronbach Alfa Katsayıları

Alt boyut	Madde sayısı	Ön test	Son test
Bilmeye yönelik içsel motivasyon	4	,71	,77
Başarmaya yönelik içsel motivasyon	4	,55	,72
Uyarım yaşamaya yönelik içsel motivasyon	4	,43	,67
Belirlenmiş düzenleme	4	,74	,86
İçe atım düzenleme	4	,31	,83
Dışsal düzenleme	4	,77	,79
Motivasyonsuzluk	4	,56	,61
Ölçek geneli	28	,85	,91

Not. N = 27.

Moodle günlük kayıtları. Sosyal etkileşim ve katılım, dersin Moodle olay günlüğünden ve etkinlik tablolarından hesaplanmıştır. Sosyal etkileşim göstergeleri, öğrencinin kendi isteğiyle yaptığı akran yönelimli eylemlerdir. Bunlar başka bir öğrencinin iletisine forum yanıtı, forum konusu açma, yapışkan not yazma, yapışkan nota oy verme, sosyal yorum ve tartışma aboneliğidir. Katılım göstergeleri oturum sayısı, etkin gün sayısı, etkin hafta sayısı ve ödev etkinliğidir. Oturum, aynı öğrencinin otuz dakikadan uzun bir boşlukla ayrılan olay kümesidir. Etkin gün ve etkin hafta, öğrencinin en az bir kayıt ürettiği gün ve takvim haftasıdır. Ödev etkinliği, ödev bileşenlerinden gelen kayıt sayısıdır. Katılım göstergeleri hesaplanırken forum, yapışkan not ve yorum bloğundan gelen olaylar dışarıda bırakılmıştır. Aksi hâlde bir forum iletisi hem sosyal etkileşim hem katılım sayılır ve iki puan arasındaki ilişki kısmen değişkenin kendisiyle ilişkisini yansıtırdı.

Göstergeler standart puana çevrilmiş ve ortalamaları alınarak iki bileşik puan oluşturulmuştur. Bileşik puanların iç tutarlılığı sosyal etkileşim için ,93, katılım için ,90 bulunmuştur. Akran değerlendirmesi sayısı sosyal etkileşim puanına alınmamıştır. Her gönderim tam olarak bir akran tarafından değerlendirildiğinden bu sayı gönderim sayısıyla aynı bilgiyi taşımaktadır. Forum iletilerinin yanıt ilişkisinden ayrıca yönlü bir ağ kurulmuş, öğrenci başına giriş derecesi, çıkış derecesi, karşılıklı bağ sayısı ve arasındalık merkeziliği hesaplanmıştır. Günlük verisinden yalnızca davranışsal katılım ölçülebilmiştir. Bilişsel ve duyuşsal katılım boyutları kabul edilebilir bir iç tutarlılıkla kurulamamıştır.

Verilerin Analizi

Betimsel düzeyde ortalama, standart sapma, ortanca ve en küçük ile en büyük değerler verilmiştir. Günlük göstergelerinin dağılımı sağa çarpıktır ve bir öğrenci forum yanıtlarının üçte birinden fazlasını tek başına üretmiştir. Göstergelerde ortanca da raporlanmıştır. Motivasyon düzeyi için her alt boyutun son test ortalaması ölçeğin orta noktası olan 4 değerine karşı tek örneklem t-testiyle sınanmıştır. Ön test ile son test arasındaki farklar eşleştirilmiş örneklem t-testiyle sınanmış ve Wilcoxon işaretli sıralar testiyle yinelenmiştir. Ortalama farkları için Cohen d hesaplanmıştır. Fark puanlarının normalliği çarpıklık ve basıklık katsayılarıyla değerlendirilmiş, ±2 aralığı kabul edilebilir sayılmıştır.

Sosyal etkileşim ile katılım arasındaki ilişki Spearman sıra korelasyonuyla incelenmiştir. Göstergeler sayım verisidir, sağa çarpıktır ve uç değer içerir. Sıralamaya dayalı katsayı yeğlenmiştir. Çoklu karşılaştırmalarda birinci tür hata olasılığını denetlemek için her test ailesinde Holm düzeltmesi uygulanmıştır. Yedi motivasyon alt boyutu, 24 gösterge karşılaştırması ve sekiz fark puanı karşılaştırması (yedi alt boyut ile özerk motivasyon) ayrı aileler olarak ele alınmıştır. Bildiride verilen "Holm p" değerleri düzeltilmiş değerlerdir. 27 kişilik örneklemde ,05 düzeyinde yaklaşık ,38 ve üzerindeki korelasyonlar saptanabilir. Bunun altındaki ilişkiler gözden kaçabilir. Örneklem büyüklüğü çoklu regresyon için de yetersiz olduğundan yordama çözümlemesi yapılmamıştır. Çözümlemeler Python ortamında yazılmış betiklerle yürütülmüştür.

Bulgular

Motivasyon Düzeyi

Son test alt boyut ortalamaları ölçeğin orta noktasıyla karşılaştırılmış ve sonuçlar Tablo 2'de verilmiştir. Bilmeye yönelik içsel motivasyon hem en yüksek ortalamaya (M = 5,23) hem de en büyük etki büyüklüğüne (d = 1,29) sahiptir. Belirlenmiş düzenleme (M = 4,81; d = 0,59) ve dışsal düzenleme (M = 4,70; d = 0,52) orta noktanın üzerindedir. Başarmaya yönelik (M = 4,48; d = 0,48) ve uyarım yaşamaya yönelik içsel motivasyon (M = 4,52; d = 0,50) da orta noktanın üzerindedir. Başarmaya ve uyarım yaşamaya yönelik boyutlarda ve dışsal düzenlemede Holm düzeltmeli p değeri ,047'dir. Fark ,05 düzeyinin hemen altında kalmıştır. İçe atım düzenleme orta noktadan anlamlı biçimde ayrışmamıştır (M = 4,21; Holm p = ,374). Motivasyonsuzluk puanı orta noktanın anlamlı biçimde altındadır (M = 3,25; d = −0,76).

Tablo 2. Motivasyon Alt Boyutlarının Ölçek Orta Noktasıyla (4) Karşılaştırılması (Son Test)

Alt boyut	M	SS	t(26)	p	Holm p	d
Bilmeye yönelik içsel motivasyon	5,23	0,96	6,68	< ,001	< ,001	1,29
Başarmaya yönelik içsel motivasyon	4,48	1,01	2,48	,020	,047	0,48
Uyarım yaşamaya yönelik içsel motivasyon	4,52	1,03	2,61	,015	,047	0,50
Belirlenmiş düzenleme	4,81	1,37	3,09	,005	,024	0,59
İçe atım düzenleme	4,21	1,22	0,90	,374	,374	0,17
Dışsal düzenleme	4,70	1,35	2,71	,012	,047	0,52
Motivasyonsuzluk	3,25	0,98	−3,96	,001	,003	−0,76

Not. N = 27. Holm p, yedi karşılaştırma için Holm düzeltmesi uygulanmış anlamlılık değeridir.

Ön Test ile Son Test Arasındaki Değişim

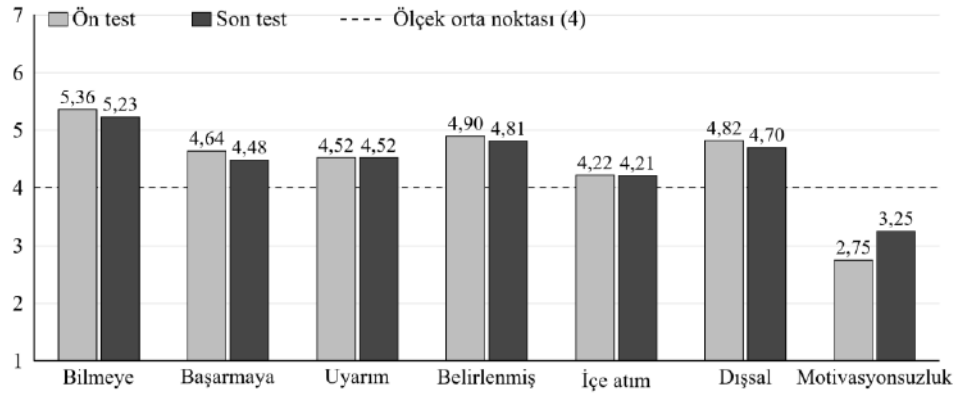
Yedi alt boyutun hiçbirinde ön test ile son test arasında anlamlı fark bulunmamıştır (Tablo 3). Etki büyüklükleri küçüktür. Uyarım yaşamaya yönelik içsel motivasyonda ön test ve son test ortalaması aynıdır (M = 4,52). Bilmeye yönelik ve başarmaya yönelik içsel motivasyon boyutlarında fark puanlarının basıklığı ±2 aralığının

dışındadır. Wilcoxon sonuçları esas alınmıştır. İki test de aynı yönde ve anlamsız sonuç vermiştir. Motivasyonsuzluk puanı 2,75'ten 3,25'e çıkmıştır. Artış eşleştirilmiş t-testinde sınırda kalmıştır ($t(26) = 2,03$; $p = ,053$; $d = 0,39$). Wilcoxon testinde ,05'in hemen altına inmiştir ($p = ,046$). Holm düzeltmesinden sonra ise anlamlılığını yitirmiştir (Holm $p = ,372$). Artış bu nedenle doğrulanmış bir bulgu olarak değil, izlenmesi gereken bir eğilim olarak değerlendirilmiştir. Alt boyut ortalamalarının iki ölçümdeki konumu Şekil 1'de gösterilmiştir.

Tablo 3. Motivasyon Alt Boyutlarında Ön Test ve Son Test Karşılaştırması

Alt boyut	Ön test	Son test	Fark	t(26)	p	Wilcoxon p	d
Bilmeye yönelik içsel motivasyon	5,36 (0,93)	5,23 (0,96)	−0,13	−0,58	,565	,961	−0,11
Başarmaya yönelik içsel motivasyon	4,64 (1,01)	4,48 (1,01)	−0,16	−0,60	,553	,819	−0,12
Uyarım yaşamaya yönelik içsel motivasyon	4,52 (0,98)	4,52 (1,03)	0,00	0,00	1,000	,966	0,00
Belirlenmiş düzenleme	4,90 (1,20)	4,81 (1,37)	−0,08	−0,33	,744	,635	−0,06
İçe atım düzenleme	4,22 (0,93)	4,21 (1,22)	−0,01	−0,04	,970	,896	−0,01
Dışsal düzenleme	4,82 (1,32)	4,70 (1,35)	−0,12	−0,61	,549	,405	−0,12
Motivasyonsuzluk	2,75 (1,01)	3,25 (0,98)	0,50	2,03	,053	,046	0,39

Not. N = 27. Ön test ve son test sütunlarında ortalama (standart sapma) verilmiştir. Holm düzeltmesinden sonra hiçbir karşılaştırma ,05 düzeyinde anlamlı kalmamıştır.



Şekil 1. Motivasyon Alt Boyutlarında Ön Test ve Son Test Ortalamaları

Not. N = 27. Değerler yedili derecelendirme üzerinden madde ortalamalarıdır. Kesik çizgi ölçeğin orta noktasını gösterir.

Sosyal Etkileşim ve Katılım Göstergelerinin Dağılımı

Göstergelerin betimsel değerleri Tablo 4'te verilmiştir. Sosyal etkileşim göstergelerinin hepsinde dağılım sağa çarpıktır ve ortalamalar ortancaların belirgin biçimde üzerindedir. Fark en çok forum yanıtında görülür: ortanca

4, ortalama 17,00'dir. Bir öğrenci 168 yanıt üretmiştir. Sosyal yorumun ortancası sıfırdır. Katılım göstergelerinde dağılım daha dengelidir. Ortalama ile ortanca birbirine yakındır ve hiçbir öğrencinin değeri sıfır değildir. Öğrenciler dönem boyunca ortalama 7,19 haftada sistemde etkin olmuştur (en az 3, en fazla 11 hafta).

Tablo 4. Sosyal Etkileşim ve Katılım Göstergelerinin Betimsel Değerleri

Gösterge	M	SS	Ortanca	En düşük	En yüksek
Sosyal etkileşim					
Forum yanıtı	17,00	35,77	4,0	0	168
Forum konusu açma	3,89	4,64	1,0	0	15
Yapışkan not	3,70	3,98	2,0	0	13
Yapışkan nota oy	6,74	5,71	5,0	0	22
Sosyal yorum	4,11	8,71	0,0	0	38
Tartışma aboneliği	11,48	14,74	5,0	0	42
Katılım					
Oturum sayısı	11,96	6,25	10,0	4	28
Etkin gün sayısı	9,15	3,60	8,0	3	18
Etkin hafta sayısı	7,19	1,96	7,0	3	11
Ödev etkinliği	27,07	11,73	26,0	2	61

Not. N = 27. Katılım göstergeleri hesaplanırken forum, yapışkan not ve yorum bloğundan gelen olaylar dışarıda bırakılmıştır.

Forum yanıt ağında, bir öğrencinin başka bir öğrencinin iletisine yanıt vermesi bir bağ sayılmıştır. Ağ 20 öğrenciden ve 108 yönlü bağdan oluşmuş, yoğunluğu ,154 bulunmuştur (Tablo 5). Yedi öğrenci hiçbir yanıt alışverişine girmediği için ağın dışında kalmıştır. Öğrenci başına ortalama giriş ve çıkış derecesi 4,00'dir. Arasındalık merkeziliğinin ortancası sıfırdır. Öğrencilerin çoğu ağda iki grup arasında köprü konumunda değildir. Etkileşim sınırlı sayıda öğrencinin çevresinde toplanmış olabilir.

Tablo 5. Forum Yanıt Ağı Ölçütlerinin Betimsel Değerleri

Ölçüt	M	SS	Ortanca	En düşük	En yüksek
Çıkış derecesi	4,00	4,78	3,0	0,0	15,0
Giriş derecesi	4,00	3,49	4,0	0,0	12,0
Karşılıklı bağ	2,52	3,03	2,0	0,0	12,0
Arasındalık merkeziliği	0,02	0,04	0,0	0,0	0,17

Not. N = 27. Ağ dışında kalan yedi öğrenci sıfır değeriyle hesaba katılmıştır.

Sosyal Etkileşim ile Katılım Arasındaki İlişki

Sosyal etkileşim ve katılım bileşik puanları arasında pozitif ve anlamlı bir ilişki bulunmuştur (ρ = ,66; $p <$,001). Forum etkinliğinin en yoğun olduğu öğrenci analizden çıkarıldığında katsayı ,63 olarak kalmıştır. İki puan ayrı göstergelerden ve birbirini içermeyen olaylardan kurulduğu için ilişkinin değişkenlerin örtüşmesinden kaynaklanmadığı düşünülebilir. Gösterge düzeyindeki katsayılar Tablo 6'da verilmiştir. 24 karşılaştırmanın altısı Holm düzeltmesinden sonra anlamlı kalmıştır. Bunların beşi etkin hafta sayısıyla kurulmuştur. Etkin hafta sayısıyla en yüksek katsayıyı yapışkan not (ρ = ,80) ve tartışma aboneliği (ρ = ,79)

vermiştir. Forum yanıtı (ρ = ,74), forum konusu açma (ρ = ,64) ve yapışkan nota oy verme (ρ = ,62) bunları izlemiştir. Altıncı anlamlı katsayı tartışma aboneliği ile ödev etkinliği arasındadır (ρ = ,57). Oturum sayısı ve etkin gün sayısıyla kurulan katsayıların hiçbiri düzeltmeden sonra anlamlı kalmamıştır.

Tablo 6. Sosyal Etkileşim ve Katılım Göstergeleri Arasındaki Spearman Korelasyonları

Sosyal etkileşim göstergesi	Oturum sayısı	Etkin gün sayısı	Etkin hafta sayısı	Ödev etkinliği
Forum yanıtı	,37	,32	,74**	,46
Forum konusu açma	,40	,42	,64**	,44
Yapışkan not	,52	,49	,80**	,54
Yapışkan nota oy	,26	,19	,62*	,29
Sosyal yorum	,31	,31	,51	,22
Tartışma aboneliği	,46	,44	,79**	,57*

Not. N = 27. Anlamlılık değerleri 24 karşılaştırma için Holm düzeltmesinden geçirilmiştir. * p < ,05. ** p < ,01.

Sosyal etkileşim en çok katılımın döneme yayılmasıyla ilişkili görünmektedir. Oturum sayısı, etkin gün sayısı ve ödev etkinliğiyle ilişkiler daha zayıftır. Sosyal araçları çok kullanan öğrenciler, dönem boyunca daha fazla haftada sisteme girmiştir.

Sosyal Etkileşim ile Motivasyondaki Değişim Arasındaki İlişki

Sosyal etkileşim bileşik puanı ile yedi alt boyuttaki ve özerk motivasyondaki fark puanları (son test eksi ön test) arasında Holm düzeltmesinden sonra anlamlı bir ilişki bulunmamıştır. En güçlü katsayı, dört içsel ve belirlenmiş düzenleme alt boyutunun ortalamasından oluşan özerk motivasyondaki değişimle kurulmuştur. Katsayı negatiftir ve düzeltmeden sonra anlamlı değildir (ρ = −,41; ham p = ,034; Holm p = ,270). Sosyal etkileşimin motivasyonsuzluktaki değişimle ilişkisi de anlamsızdır (ρ = ,07). Örneklem küçük olduğundan ,38'in altındaki ilişkiler bu çözümlemede saptanamaz.

Tartışma

Öğrencilerin motivasyonu, altı alt boyutun beşinde ölçeğin orta noktasının üzerinde bulunmuştur. Bilmeye yönelik içsel motivasyon en yüksek düzeydedir. Motivasyonsuzluk ise orta noktanın altındadır. Düzeyler uygulamanın sonunda ölçülmüştür. Ön testte de bilmeye yönelik içsel motivasyon en yüksek alt boyut olduğu için (M = 5,36) bu düzeyin sosyal etkileşim unsurlarından kaynaklandığı söylenemez. Catapang vd. (2025) ÖYS kabulünün motivasyonu olumlu etkilediğini bildirmiştir. Araştırmanın deseni, ÖYS'nin kendisinin mi yoksa eklenen etkileşim unsurlarının mı rol oynadığını ayırt etmeye elverişli değildir.

Ön test ile son test arasında hiçbir alt boyutta anlamlı fark çıkmamıştır. Xu ve Rahim (2025) akran geri bildirimi ve sosyal destek uygulanan gruplarda motivasyonun anlamlı biçimde arttığını bulmuştur. Gharbaoui vd. (2024) de sosyal öğrenme etkinliklerinin eklendiği grupta daha yüksek memnuniyet saptamıştır. Fark çıkmamasının olası nedenleri şunlardır: ön test puanları zaten orta noktanın üzerindedir, örneklem 27 kişidir ve ara ölçüm alınmamıştır. Xu ve Rahim'in çalışmasında kontrol grubu vardır, bu araştırmada yoktur. Eşleştirilmiş karşılaştırmada ,80 güçle ancak yaklaşık 0,56 ve üzerindeki etkiler saptanabilir. Gözlenen etki büyüklükleri bunun altındadır. Motivasyonsuzluktaki artış da düzeltmeden sonra anlamlı değildir. Dönemin sonuna yaklaşılmasının etkisi ve uygulamanın etkisi bu desenle ayrılamaz.

Sosyal etkileşim ile katılım arasındaki ilişki Gao vd. (2024) ve Shen vd. (2024) ile aynı yöndedir. Gao vd. ve Shen vd. ilişkiyi öz bildirimle göstermiştir. Bu araştırmada ilişki sistem kayıtlarından hesaplanan göstergelerle bulunmuştur. Altı anlamlı katsayının beşi etkin hafta sayısıyla kurulmuştur. Oturum ve etkin gün sayısıyla ilişki zayıftır. Lyu vd. (2024) katılımın zamanla azaldığını ve sosyal etkileşimin sürdürülen katılımla ilişkili olduğunu bildirmiştir. Bulgu bu sonuçla örtüşür. Lee ve Sharma (2026) yazı sıklığının katılımla güçlü biçimde

ilişkili olmadığını, yanıt alan öğrencilerin ağda daha merkezi konumda bulunduğunu göstermiştir. Forum etkinliğinin en yoğun olduğu öğrenci çıkarıldığında da ilişki sürmüştür (ρ = ,63).

Tsai vd. (2026), etkileşim açısından zengin derslerdeki öğrencilerin daha yüksek katılım bildirdiğini göstermiştir. O çalışmada etkileşim dersler arasında değişmiştir. Burada tek bir ders vardır ve etkileşim öğrenciden öğrenciye değişmiştir. Demmans Epp vd. (2020) forumları öne çıkaran sistemde öğrencilerin daha fazla destek algıladığını, ancak bunun her derste görülmediğini bildirmiştir. Bulguların başka ders türlerine genellenmesi bu yüzden sınırlıdır.

İlişki için birden fazla açıklama olabilir. Foruma yazılan bir yanıt, yazarı ya da yanıt verilen öğrenciyi sonraki haftalarda sisteme döndürüyor olabilir. Tersi de mümkündür: dönem boyunca derse düzenli devam eden öğrenciler sosyal araçlara da daha çok başvuruyor olabilir. Katılım göstergesi sosyal araçların sunulmadığı ilk altı haftayı da kapsadığı için iki açıklama arasında bu verilerle seçim yapılamaz. Foruma yazmak için sisteme girmek gerektiğinden iki puanın aynı oturumlarda birlikte üretilmiş olması da ilişkiyi kısmen açıklayabilir. İlişkisel desen nedensel bir yorum için yeterli değildir.

Etkileşim öğrenciler arasında eşit dağılmamıştır. Forum yanıtlarında ortanca 4, ortalama 17'dir. Yedi öğrenci yanıt ağının dışında kalmıştır ve arasındalık ortancası sıfırdır. Etkileşim, az sayıda öğrencinin çevresinde toplanmış görünmektedir. Thommadurage vd. (2026) öğrenme tasarımının sosyal etkileşimi kısıtlayabildiğini belirtmiştir. Ağın dışında kalan öğrencilerin katılımının düşük mü, yoksa sisteme giren ama etkileşime girmeyen bir grup mu olduğu ayrıca incelenmemiştir. Sosyal etkileşim ile motivasyondaki değişim arasında anlamlı bir ilişki bulunmamıştır. En güçlü katsayı negatiftir. Ön testte yüksek puan alan öğrencilerin son testte daha düşük puan almasından kaynaklanıyor olabilir. Açıklama bu verilerle sınanmamıştır.

Etkin hafta sayısı, ÖYS'lerin standart günlüklerinden hesaplanabilen bir göstergedir (Ahmadi vd., 2023). Öğretim elemanı, haftalarca sisteme girmeyen öğrencileri bu göstergeyle fark edebilir. Böyle bir izlemenin katılımı ya da başarıyı artırıp artırmadığı bu araştırmada sınanmamıştır. Etkileşimin dağılımı için yanıt ağı kullanılabilir. Lee ve Sharma (2026), yanıt alan öğrencilerin ağda daha merkezi konumda bulunduğunu bildirmiştir. Ağın dışında kalan öğrenciler, öğretim elemanının doğrudan yönlendirebileceği bir grup olabilir. Öz-belirleme kuramı açısından bakıldığında, akran etkileşiminin ilişkisellik ihtiyacını karşılaması beklenir (He vd., 2025). İlişkisellik ayrıca ölçülmemiştir. Kuramsal yorum bu yüzden bir varsayım olarak kalır.

Sonuç ve Öneriler

Araştırmada, sosyal etkileşim unsurlarının kullanımı ile öğrenci katılımı arasında pozitif ve anlamlı bir ilişki bulunmuştur. İlişki en çok katılımın döneme yayılmasında, yani etkin hafta sayısında görülmüştür. Oturum ve etkin gün sayısıyla ilişki zayıf kalmıştır. Öğrencilerin motivasyonu çoğu alt boyutta orta noktanın üzerindedir. Ön test ile son test arasında anlamlı bir değişim bulunmamıştır. Sosyal etkileşim ile motivasyondaki değişim arasında düzeltme sonrası anlamlı ilişki saptanmamıştır.

ÖYS'lerde sosyal etkileşim tasarlayanlar, etkinlik sıklığıyla birlikte katılımın sürekliliğini de izleyebilir. Etkin hafta sayısı bunun için basit bir göstergedir. Etkileşimin öğrenciler arasında nasıl dağıldığına da bakılmalıdır. Yanıt ağındaki bağlar ve ağın dışında kalan öğrenciler izlenebilir. Sosyal etkileşimin motivasyona katkısı varsayılmamalı, ölçülmelidir.

Araştırmanın sınırlılıkları şunlardır. Çalışma grubu tek bir dersten 27 öğrenciden oluşur. Kontrol grubu ve ara ölçüm yoktur. Katılım yalnızca davranışsal boyutuyla ve günlük kayıtlarıyla ölçülmüştür. Akran geri bildiriminin içeriği ve niteliği çözümlenmemiştir. Sonraki araştırmalarda kontrol gruplu desenler, ara ölçümler ve daha geniş örneklemler kullanılabilir. Bu desenler ilişkinin yönünü daha açık gösterebilir.

Kaynakça

Ahmadi, G., Mohammadi, A., Asadzandi, S., Shah, M., & Mojtahedzadeh, R. (2023). What are the indicators of student engagement in learning management systems? A systematized review of the literature. *International*

Review of Research in Open and Distributed Learning, 24(1), 117–136. https://doi.org/10.19173/irrodl.v24i1.6453

Bayrak Karslı, M., & Karaman, S. (2024). Investigation of distance education students' experiences on content-integrated social interactions. *Education and Information Technologies, 29*, 1617–1646. https://doi.org/10.1007/s10639-023-11867-6

Catapang, R. C., Repollo, N. A. M., Redondo, J. R., & Buenafe, M. L. (2025). Examining learning management system (LMS) acceptance effect on student academic motivation (SAM) in tertiary level. In *2025 International Conference on Educational Technology (ICET)* (pp. 593–598). IEEE. https://doi.org/10.1109/ICET67421.2025.11380768

Chen, K., & Jang, S. (2010). Motivation in online learning: Testing a model of self-determination theory. *Computers in Human Behavior, 26*, 741–752.

Demmans Epp, C., Phirangee, K., Hewitt, J., & Perfetti, C. A. (2020). Learning management system and course influences on student actions and learning experiences. *Educational Technology Research and Development, 68*, 3263–3297. https://doi.org/10.1007/s11423-020-09821-1

Gao, F., Wang, C., Xie, H., & Hong, J. (2024). Social interaction and online learning efficiency for middle school students: The mediating role of social presence and learning engagement. *Behavioral Sciences, 14*(10), Article 896. https://doi.org/10.3390/bs14100896

Gharbaoui, H., Mansouri, K., & Poirier, F. (2024). Improving student engagement and success in computer programming courses through social learning in online environments. *International Journal of Engineering Pedagogy, 14*(6), 54–68. https://doi.org/10.3991/ijep.v14i6.48705

He, J., Wang, Q., & Lee, H. (2025). Enhancing online learning engagement: Teacher support, psychological needs satisfaction and interaction. *BMC Psychology, 13*, Article 696. https://doi.org/10.1186/s40359-025-03016-0

Kim, J. J., Yoon, Y., & Kim, E.-J. (2021). A comparison of faculty and student acceptance behavior toward learning management systems. *International Journal of Environmental Research and Public Health, 18*(16), Article 8570. https://doi.org/10.3390/ijerph18168570

Lee, M., & Sharma, P. (2026). Beyond posting frequency: How network metrics and textual readability relate to engagement in online discussion. *Interactive Learning Environments, 34*(4), 2661–2675. https://doi.org/10.1080/10494820.2025.2550035

Llantos, O. E., & Estuar, M. R. J. E. (2021). Learning interactions as it evolves in a social learning management system. In *2021 Eighth International Conference on Social Network Analysis, Management and Security (SNAMS)*. IEEE. https://doi.org/10.1109/SNAMS53716.2021.9732106

Loh, H. S., van Jaarsveld, G. M., Mesutoglu, C., & Baars, M. (2024). Supporting social interactions to improve MOOC participants' learning outcomes: A literature review. *Frontiers in Education, 9*, Article 1345205. https://doi.org/10.3389/feduc.2024.1345205

Lyu, B., Li, C., Li, H., & Xing, W. (2024). Roles of joining time, technology use, and social interaction in sustaining student participation in an online mathematics discussion board. In *Proceedings of the Eleventh ACM Conference on Learning @ Scale (L@S '24)*. ACM. https://doi.org/10.1145/3657604.3664672

Muslem, A., Kasim, U., Mustafa, F., Fitriani, S. S., & Rahmi, M. (2024). The correlation between the use of online learning platforms and undergraduate students' self-efficacy. *Journal of Language and Education, 10*(1), 83–100. https://doi.org/10.17323/jle.2024.17606

Özbaşı, D., Cevahir, H., & Özdemir, M. (2018). Çevrimiçi Öğrenme Motivasyon Ölçeği'nin Türkçe'ye uyarlanması: Geçerlik ve güvenirlik çalışması. *Trakya Üniversitesi Eğitim Fakültesi Dergisi, 8*(2), 352–368. https://doi.org/10.24315/trkefd.331973

Paik, J. H., Himelfarb, I., Yoo, S. H., Yoo, K., & Ha, H. (2024). The relationships among school engagement, students' emotions, and academic performance in an elementary online learning. In *The 14th Learning Analytics and Knowledge Conference (LAK '24)*. ACM. https://doi.org/10.1145/3636555.3636871

Shen, Q., Gao, B., Lu, J., Ge, Q., Yan, X., & Chen, B. (2024). Overcoming the "screen dilemma": The psychological mechanisms of social presence promoting college students' online learning engagement. *Education and Information Technologies, 29*, 21095–21114. https://doi.org/10.1007/s10639-024-12706-y

Thommadurage, W., Pham, P. T. M., Mirriahi, N., Joksimovic, S., & De Laat, M. (2026). Barriers to social learning in online higher education: A systematic review to improve learning design. *Review of Education, 14*, Article e70144. https://doi.org/10.1002/rev3.70144

Tsai, C.-L., Brown, C., Estrada, S., & Ku, H.-Y. (2026). Course interactivity, college generation status, and learning experiences in online asynchronous courses. *Distance Education, 47*(2), 210–236. https://doi.org/10.1080/01587919.2025.2591634

Van Wyk, M., Patrick, S. M., & Wolvaardt, J. E. (2026). Exploring performance engagement in online postgraduate learning: Utilisation of digital activities. *Journal of Computer Assisted Learning, 42*, Article e70254. https://doi.org/10.1002/jcal.70254

Xu, B., & Rahim, N. (2025). Peer feedback and social support in online learning: Examining motivation, task engagement, and language mastery through an activity theory perspective. *Learning and Motivation, 90*, Article 102126. https://doi.org/10.1016/j.lmot.2025.102126

Zhu, Y., Lin, X., Kim, J., Al-Adwan, A. S., & Li, N. (2025). Exploring human interaction in online self-regulated learning through Danmaku comments. *International Journal of Human–Computer Interaction, 41*(22), 13964–13977. https://doi.org/10.1080/10447318.2025.2480826

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

TIME PERSPECTIVE PROFILES AND INTOLERANCE OF UNCERTAINTY: A COMPARATIVE STUDY BETWEEN YOUNG AND MIDDLE-AGED ADULTS

Çağla Gizem KARAİBİŞ
Maltepe Üniversitesi, Lisansüstü Eğitim Enstitüsü, Klinik Psikoloji Tezli Yüksek Lisans, İstanbul-Türkiye
ORCID NO: 0009-0009-9280-8341
Barış ÖZDEMİR
Dr. Öğr. Üyesi, Maltepe Üniversitesi, İnsan ve Toplum Bilimleri Fakültesi, Psikoloji Bölümü, İstanbul-Türkiye
ORCID NO: 0000-0002-5955-5030

Abstract

Our perceptions of the past, present, and future shape our approach to life's unknowns. This psychological framework, known as time perspective (TP), organizes personal experiences within different temporal frames, guiding both everyday choices and long-term mental health outcomes. When individuals focus persistently and excessively on particular time frames, they develop biased time perspective profiles that restrict their coping abilities. How individuals view the future may also shape how they respond to situations with uncertain outcomes. Intolerance of uncertainty (IU) refers to the difficulty tolerating the absence of clear and definite information and is associated with psychological strain. Little is known about how the relationship between time perspective and intolerance of uncertainty varies by age. This study examines time perspective and intolerance of uncertainty across young and middle adulthood to shed light on the transition between life stages. Young adulthood is marked by substantial changes in career and identity, while time perspective generally becomes more established in middle adulthood.

This study examined the relationship between time perspective profiles and intolerance of uncertainty in young and middle-aged adults. Using the Zimbardo Time Perspective Inventory (ZTPI) and the short form of the Intolerance of Uncertainty Scale (IUS-12), we assessed participants' scores on the time perspective dimensions and intolerance of uncertainty. Using a comparative cross-sectional design, we examined whether profiles based on these dimensions differed between age groups and how the individual dimensions were associated with the intolerance of uncertainty. The findings are expected to help clarify how time perspective and intolerance of uncertainty are related at different stages of adulthood and inform the development of age-sensitive clinical approaches.

Keywords: time perspective profiles, intolerance of uncertainty, young adulthood, middle adulthood, developmental comparison.

ZAMAN PERSPEKTİFİ PROFİLLERİ VE BELİRSİZLİĞE TAHAMMÜLSÜZLÜK: GENÇ VE ORTA YAŞLI YETİŞKİNLER ARASINDA KARŞILAŞTIRMALI BİR ÇALIŞMA

Özet

Geçmişe, şimdiye ve geleceğe ilişkin algılarımız, yaşamın bilinmezliklerine yaklaşımımızı şekillendirir. Zaman perspektifi (ZP) olarak adlandırılan bu psikolojik çerçeve, kişisel deneyimleri farklı zamansal çerçeveler içinde düzenleyerek hem günlük seçimlere hem de uzun vadeli ruhsal sonuçlara yön verir. Bireylerin belirli zaman dilimlerine sürekli ve aşırı biçimde odaklanması, başa çıkma becerilerini kısıtlayan yanlı profiller geliştirmelerine yol açar. Bireylerin geleceği nasıl değerlendirdikleri, sonucu henüz net olmayan durumlara verdikleri tepkileri de şekillendirebilir. Açık ve kesin bilginin yokluğuna tahammül edememe durumu olarak tanımlanan belirsizliğe tahammülsüzlük (BT), psikolojik zorlanmayla ilişkili olsa da bu iki kavram arasındaki ilişkinin yaşa göre nasıl farklılaştığına ilişkin bilgilerimiz sınırlıdır. Bu çalışma, yoğun

kariyer ve kimlik değişimleriyle karakterize edilen genç yetişkinlikten, zaman perspektifinin genellikle daha yerleşik hale geldiği orta yetişkinliğe geçişi anlamak amacıyla belirsizliğe tahammülsüzlük ve zaman perspektifinin birlikte nasıl değiştiğine ışık tutmaktadır.

Bu araştırmada, genç ve orta yetişkinlerde zaman perspektifi profilleri ve belirsizliğe tahammülsüzlük arasındaki ilişkiler incelenmiştir. Zimbardo Zaman Perspektifi Envanteri (ZZPE) ve Belirsizliğe Tahammülsüzlük Ölçeği Kısa Formu (BTÖ-12) kullanılarak katılımcıların zaman perspektifi boyutlarına ve belirsizliğe tahammülsüzlüğe ilişkin puanları değerlendirilmiştir. Karşılaştırmalı kesitsel desende yürütülen araştırmada, zaman perspektifi boyutlarının oluşturduğu profillerin yaş gruplarına göre farklılaşıp farklılaşmadığının ve bu boyutların belirsizliğe tahammülsüzlükle ilişkilerinin incelenmesi amaçlanmıştır. Bulguların, zaman perspektifi ve belirsizliğe tahammülsüzlük arasındaki ilişkilerin yetişkinliğin farklı dönemlerinde anlaşılmasına ve yaşa duyarlı klinik yaklaşımların geliştirilmesine katkı sağlanması beklenmektedir.

Anahtar Kelimeler: zaman perspektifi profilleri, belirsizliğe tahammülsüzlük, genç yetişkinlik, orta yetişkinlik, gelişimsel karşılaştırma.

Giriş

İçinde bulunduğumuz çağda belirsizlik, toplumsal ve bireysel yaşamın hemen her alanında kaçınılmaz bir olgu olarak karşımıza çıkmaktadır (Yıldız ve Güllü, 2018). İnsanoğlunun kişisel deneyimleri, karar alma ve yaşamın getirdiği belirsizliklerle başa çıkma süreçlerinde, zamanı nasıl algıladığı ve bu zamansal algıları zihninde nasıl yapılandırdığı önemli bir rol oynamaktadır (Holman ve Zimbardo, 2009).

Zaman, nesnel olarak herkes için eşit akan bir süreç olmasına rağmen, zamana dair öznel algılamalar ve değerlendirmeler bireysel farklılıklar göstermektedir (Çivitci ve Baltacı, 2018). Literatürde, zamansal değerlendirmeler Zimbardo ve Boyd (1999) tarafından zaman perspektifi (ZP) kavramı altında kuramsallaştırılmıştır. ZP, bireylerin kişisel ve sosyal deneyimlerini; geçmiş, şimdi ve gelecek gibi zamansal dilimlere ayırarak düzenlemesini ve anlamlandırmasını sağlayan dinamik bir bilişsel süreçtir (Zimbardo ve Boyd, 1999). Kuramsal olarak ZP; bireylerin yaşam olaylarını nasıl algıladığını, karşılaştıkları problemleri nasıl anlamlandırdığını ve eylemlerine nasıl yön verdiğini belirleyen bir bilişsel filtre işlevi görür (Holman ve Zimbardo, 2009). Bireyin hangi zaman dilimine ağırlık verdiği, bir problem karşısında harekete geçme biçimini belirleyebilmektedir: Kimi geçmiş yaşantıların ve başarısızlıkların etkisinde kalarak geri çekilirken, kimi şimdiki anın hazzına veya dürtülerine odaklanmakta, kimi ise gelecekteki hedefleri ve olası sonuçları göz önünde bulundurarak hareket etmektedir (Zimbardo vd., 1997). Zamanla öğrenilerek bilişsel bir alışkanlık ve karakteristik bir kişilik özelliğine dönüşen bu perspektifler, bireyin belirsizliklerle ve günlük problemlerle nasıl başa çıkacağını belirleyen psikolojik bir çerçeve sunmaktadır (Stolarski vd., 2011). ZP, Zimbardo Zaman Perspektifi Envanteri çerçevesinde beş temel alt boyutta değerlendirilmektedir. Geçmiş-Olumlu boyut, geçmişe yönelik nostaljik, olumlu, sıcak duygusal tutumları yansıtmaktadır. Geçmiş-Olumsuz boyut, yaşanan travmatik deneyimler veya geçmiş olayların olumsuz biçimde yeniden yapılandırılması sonucunda ortaya çıkan kaçınmacı tutumu temsil etmektedir. Şimdi-Hazcı boyut, gelecekteki sonuçları göz ardı ederek şimdiki andaki hazza, heyecana, risk almaya odaklanan dürtüsel tutumu göstermektedir. Şimdi-Kaderci boyut, yaşamın ve geleceğin kader tarafından belirlendiğine ve kişinin kontrolünün yetersiz olduğuna dair çaresiz ve pasif bir inancı yansıtmaktadır. Gelecek boyut ise, geleceğe dönük hedefler belirleme ve uzun vadeli planlar yapma, hazzı erteleme ve öz düzenleme davranışları ile karakterizedir (Çivitci ve Baltacı, 2018; Holman ve Zimbardo, 2009).

Açık, kesin ve yeterli bilginin bulunmadığı durumlarla karşı karşıya kalındığında ortaya çıkan olumsuz tepkilere dayanma kapasitesinin yetersizliği ve belirsiz durumların tehdit edici, stres verici ve kabul edilemez olarak değerlendirilmesi belirsizliğe tahammülsüzlük (BT) olarak adlandırılmaktadır (Carleton, 2016). ZP ile BT arasında birbirini besleyen etkileşimler bulunmaktadır. BT'si yüksek olan bireyler, belirsizliğe ilişkin bilgi işleme süreçlerinde yanlılık sergileyerek belirsiz durumları tehdit edici biçimde yorumlamakta ve belirsizlik içeren uyaranları daha kolay hatırlamaktadır (Dugas vd., 2005). Bu durum, belirsizliğin yarattığı olumsuz duygusal gerilimi azaltmak amacıyla bireylerin geleceğe dönük olumsuz senaryolar üreterek endişe

yaşamalarına veya geçmişteki olumsuzluklar üzerinde durmaksızın zihinsel geviş getirmelerine (ruminasyon) yol açmaktadır (Sahib vd.,2024). Ruminasyon ve düşünce baskılama gibi işlevsiz duygu düzenleme stratejileri düşünüldüğünde, bireyin zamansal esnekliğini yitirerek geçmiş-olumsuz veya şimdi-kaderci zamansal odaklara saplanmasına, geleceği ise sürekli bir tehdit kaynağı olarak algılamasına zemin hazırlamaktadır (Celik vd., 2021).

İnsan gelişimi boyunca bireylerin üstlendikleri toplumsal roller, yaşam görevleri ve karşılaştıkları çevresel durumlar zamansal algılarını, bilişsel kontrol kapasitelerini ve belirsizlikle başa çıkma stratejilerini dinamik bir şekilde şekillendirmektedir (Carpenter vd., 2022). Genç yetişkinlik dönemi, halen eğitim görme veya eğitim sonrası iş hayatına atılma, kariyer basamaklarını tırmanma, ekonomik bağımsızlığı sağlamaya çalışma, eş seçimi ve aile kurma gibi uzun vadeli yaşam hedeflerinin ve kararlarının yoğunlaştığı bir evredir (akt; Çok, 2019). İş gücü piyasasındaki rekabet, sosyo-ekonomik dinamikler ve kariyer kararsızlığı gibi etmenler göz önünde bulundurulduğunda, genç yetişkinlerin yoğun şekilde gelecek kaygısı ile yüzleştikleri ve bu durumun da BT düzeylerini ve geleceğe dönük kaygılarını tetikleyebildiği görülmektedir (Bozkur vd., 2020).

Orta yetişkinlik dönemi ise, mesleki, ailevi ve sosyal rollerde görece daha yerleşik, istikrarlı ve dengeli bir yapının sağlandığı bir evredir (Çok, 2019). Bilişsel ve duygusal açıdan, orta yetişkinlikte biriken yaşam deneyimleri ve kazanılan psikososyal olgunluk bireylerin belirsiz durumları yönetme becerilerini geliştirmekte ve daha etkili başa çıkma stratejileri kullanmalarına olanak tanımaktadır (Rucker ve Berry, 2026). ZP açısından yapılan araştırmalar, yaşın ilerlemesi ile geçmişteki olumsuz deneyimlere odaklanma eğiliminin azaldığını, bireylerin geçmiş yaşantıları daha adapte edilebilir biçimde yeniden yapılandıklarını göstermektedir (Carpenter vd., 2022).

Genç ve orta yetişkinler arasındaki bu gelişimsel ve psikososyal farklılıklar, ZP profilleri ve BT düzeyleri etkileşiminin her iki yaş grubunda farklı nitelikler taşıyabileceğine işaret etmektedir. Genç yetişkinler, geleceğe dönük hedeflerin ve yapılandırma süreçlerinin merkezinde yer aldıkları için belirsizliği daha tehdit edici algılamaya ve buna bağlı olarak ileriye yönelik kaygı veya olumsuz düşünce kalıplarına daha kolay saplanmaya yatkınken, orta yetişkinlerde rollerin belirginleşmesi, istikrarın artması ve geçmiş-olumsuz yönelimin azalması sayesinde BT'nin olumsuz etkileri daha sınırlı kalmakta ve zamansal esneklik daha iyi korunabilmektedir (Carpenter vd., 2022; akt; Rucker ve Berry, 2026).

Araştırmanın Önemi ve Amacı

Literatürde zaman perspektifi (ZP) ve belirsizliğe tahammülsüzlük (BT) ayrı ayrı çalışılsa da, ZP profillerinin BT ile olan ilişkisinin genç yetişkin ve orta yetişkin grupları arasında nasıl şekillendiğine dair gelişimsel karşılaştırmalı bilgiler halen sınırlıdır.

Bu araştırmanın temel amacı, genç ve orta yetişkin grubunda Zimbardo Zaman Perspektifi Envanteri ile belirlenen ZP profillerinin dağılımını tespit etmek, bu profillerin yaş gruplarına göre farklılaşıp farklılaşmadığını ortaya koymak ve ZP boyutlarının Belirsizliğe Tahammülsüzlük Ölçeği puanları ile ilişkisini gelişimsel karşılaştırmalı bir tasarımla incelemektir.

Araştırmanın amacı doğrultusunda hipotezler aşağıdaki gibidir:

H1: Genç yetişkinler ile orta yetişkinlerin zaman perspektifi profillerinin dağılımı arasında anlamlı bir farklılık vardır.

H2: Genç yetişkinlerin belirsizliğe tahammülsüzlük düzeyleri orta yetişkinlerden anlamlı derecede daha yüksektir.

H3: Bireylerin belirsizliğe tahammülsüzlük düzeyleri benimsedikleri zaman perspektifine göre anlamlı biçimde farklılaşmaktadır.

H4: Zaman perspektifi alt boyutları ile belirsizliğe tahammülsüzlük arasında yaş gruplarına göre farklılaşan anlamlı ilişkiler vardır.

YÖNTEM

Araştırma Deseni

Bu araştırma, genç ve orta yetişkinlerde zaman perspektifi (ZP) boyutlarının oluşturduğu profiller ile belirsizliğe tahammülsüzlük (BT) arasındaki ilişkileri her yaş grubunda ayrı ayrı incelemek amacıyla karşılaştırmalı kesitsel desende yürütülmüştür. ZP profilleri, beş alt boyut (geçmiş-olumsuz, geçmiş-olumlu, şimdi-hazcı, şimdi-kaderci ve gelecek) olarak ayrı ayrı ele alınmıştır. BT puanları ise toplam puan ve iki alt boyut (ileriye yönelik ve engelleyici kaygı) olarak ayrı ayrı ele alınmıştır.

Katılımcılar

Katılımcılara kolayda örnekleme yöntemiyle ulaşılmıştır. 81 katılımcıdan, 16 kişi kullanılan yaş aralıklarının (25-39 ve 40-65) dışında olduğundan analizlere dahil edilmemiştir. Örneklem, yaşları 25-63 arasında değişen 65 katılımcıdan oluşmaktadır. Genç yetişkin grubunda 41 kişi (%63,1; yaş M=30,24, SD=4,82), orta yetişkin grubunda ise 24 kişi (%36,9; yaş M=49,54, SD=6,62) yer almaktadır. Genç yetişkinlerin 29'u kadın (%70,7), 12'si erkek (%29,3); orta yetişkinlerin 16'sı kadın (%66,7), 8'i erkektir (%33,3). Toplam örneklem 45 kadın (%69,2) ve 20 erkekten (%30,8) oluşmaktadır.

Katılımcıların cinsiyet, yaş, eğitim düzeyi, eğitime devam etme durumu ve çalışma durumuna ilişkin sayı ve yüzdeler Tablo 1'de sunulmuştur.

Tablo 1. *Katılımcıların sosyodemografik özellikleri*

Özellik	Kategori	n	%
Yaş grubu	Genç yetişkin	41	63,1
	Orta yetişkin	24	36,9
Cinsiyet	Kadın	45	69,2
	Erkek	20	30,8
Eğitim düzeyi	İlköğretim	6	9,2
	Lise	8	12,3
	Ön lisans	7	10,8
	Lisans	30	46,2
	Yüksek lisans	11	16,9
	Doktora	3	4,6
Eğitime devam etme durumu	Devam etmiyor	56	86,2
	Lisans öğrencisi	2	3,1
	Yüksek lisans öğrencisi	7	10,8
Çalışma durumu	Çalışıyor	44	67,7
	Çalışmıyor	10	15,4
	Öğrenci	3	4,6
	Emekli	8	12,3

Veri toplama araçları

Belirsizliğe Tahammülsüzlük Ölçeği Kısa Formu (BTÖ-12)

Carleton, Norton ve Asmundson (2007) tarafından 12 maddeye düşürülerek kısa form haline getirilen ölçeğin Türkçe uyarlaması Sarıçam, Erguvan, Akın ve Akça (2014) tarafından yapılmıştır. Beşli Likert tipindeki ölçek, "ileriye yönelik kaygı" ve "engelleyici kaygı" olmak üzere iki alt boyuttan oluşmaktadır. Uyarlama çalışmasında ölçeğin bütünü için Cronbach alfa iç tutarlık sayısı (.88) bulunurken, alt boyutlar için sırasıyla .84 ve.77 olarak tespit edilmiştir. Ölçek puanları 12-60 aralığında değişmekte ve bu ölçekten alınan yüksek toplam puanlar, bireyin genel olarak BT düzeyinin yüksek olduğunu göstermektedir. Bu araştırmada toplam puan ile iki alt boyut puanı analize dahil edilmiştir.

Zimbardo Zaman Perspektifi Envanteri (ZZPE)

Ölçek, Zimbardo ve Boyd (1999) tarafından geliştirilmiştir. Ölçeğin Türkçe geçerlik ve güvenirlik çalışmaları yapılmış olup geçmiş-olumsuz, geçmiş-olumlu, şimdi-hazcı, şimdi-kaderci ve gelecek boyutları değerlendirilmektedir. Akırmak (2019) tarafından yapılan çalışmada alt boyutların Cronbach alfa değerlerinin sırasıyla .84, .74, .68, .78, .75 olarak bulunmuştur. Araştırmada her bir alt boyutun puanları ayrı ayrı analize dahil edilmiştir. Bu ölçekte tek bir toplam puan yerine alt boyutlara ilişkin puanlar ayrı ayrı hesaplanmaktadır. Her bir alt boyuttan alınan yüksek puan, bireyin o zaman yönelimine olan eğiliminin güçlü olduğunu göstermektedir.

İşlem

Veriler Google Forms aracılığıyla çevrim içi olarak toplanmıştır.

Verilerin analizi

Analiz IBM SPSS Statistics 25 programında gerçekleştirilmiştir. Kategorik değişkenler frekans ve yüzde, ölçek puanları ortalama ve standart sapma ile özetlenmiştir. Verilerin normal dağılıma uygunluğu, her iki yaş grubunda ayrı ayrı Shapiro-Wilk testi ile değerlendirilmiştir. Araştırmanın hipotezleri doğrultusunda, zaman perspektifi (ZP) alt boyutları ile belirsizliğe tahammülsüzlük (BT) toplam ve alt boyut puanları arasındaki ilişkiler, genç ve orta yetişkin gruplarında ayrı ayrı Pearson korelasyon analizi ile incelenmiştir. Yaş gruplarının ölçeklerden aldıkları puanların ortalamalarının karşılaştırılmasında bağımsız örneklemler *t* testi kullanılmıştır. Son olarak, BT toplam puanı üzerinde yaş grubu ve baskın ZP'nin etkilerini test etmek amacıyla 2 x 4 faktöriyel varyans analizi (ANOVA) yürütülmüştür. Testler iki yönlü yürütülmüş ve istatistiksel anlamlılık düzeyi .05 olarak alınmıştır.

Bulgular

Genç ve orta yaşlı yetişkinlerin zaman perspektifi (ZP) ve belirsizliğe tahammülsüzlük (BT) puanlarına ilişkin ortalama ve standart sapma değerleri Tablo 2'de sunulmuştur.

Tablo 2. *Yaş gruplarına göre ZP ve BT puanlarının betimsel istatistikleri ve bağımsız örneklemler t testi sonuçları*

Değişken	Genç yetişkinler (n=41) Ort. ± SS	Orta yetişkinler (n=24) Ort. ± SS	***t*(sd[1])**	***p***
BT toplamı	39,10 ± 8,63	36,96 ± 11,05	0,87	,388
İleriye yönelik kaygı	23,51 ± 5,02	21,46 ± 7,20	1,23	,226
Engelleyici kaygı	15,59 ± 4,53	15,50 ± 5,37	0,07	,946
Geçmiş olumsuz	32,54 ± 7,35	31,00 ± 6,52	0,85	,400
Geçmiş olumlu	29,68 ± 5,65	31,92 ± 4,84	−1,62	,110
Şimdi kaderci	26,22 ± 4,44	25,42 ± 4,63	0,69	,491
Şimdi hazcı	48,12 ± 7,30	46,17 ± 7,55	1,03	,307
Gelecek	46,59 ± 5,89	47,29 ± 4,82	−0,50	,621

Not. Ort. = ortalama; SS = standart sapma. [1] sd = serbestlik derecesi. İleriye yönelik kaygı için sd = 36,25, diğer tüm değişkenler için sd = 63'tür.

Tüm BT alt boyutlarında genç yetişkinler yüksek ortalamaya sahip olmasına karşın bu ortalama değer farklılıkları istatistiksel olarak anlamlı seviyeye ulaşmamıştır. Genç ve orta yetişkinlerin ZP alt boyut puanları arasında da istatistiksel olarak anlamlı bir fark saptanmamıştır (Tablo 2).

ZP ile BT arasındaki ilişkiler

ZP alt boyutları ile BT toplam ve alt boyut puanları arasındaki ilişkilere incelemek amacıyla her yaş grubunda ayrı ayrı Pearson korelasyon analizi yapılmıştır. Analiz sonuçları Tablo 3'te gösterilmektedir.

Tablo 3. *Yaş gruplarına göre ZP profilleri ve BT arasındaki Pearson korelasyonları*

BT alt boyutları	ZP profilleri	Genç yetişkinler r	Orta yetişkinler r
BT toplam	Geçmiş olumsuz	,375*	,473*
BT toplam	Geçmiş olumlu	-,079	,264
BT toplam	Şimdi kaderci	,089	,417*
BT toplam	Şimdi hazcı	-,143	,618*
BT toplam	Gelecek	,071	,473*
İleriye yönelik kaygı	Geçmiş olumsuz	,356*	,484*
İleriye yönelik kaygı	Geçmiş olumlu	-,120	,232
İleriye yönelik kaygı	Şimdi kaderci	,045	,462*
İleriye yönelik kaygı	Şimdi hazcı	-,108	,514*
İleriye yönelik kaygı	Gelecek	,061	,421*
Engelleyici kaygı	Geçmiş olumsuz	,320*	,324
Engelleyici kaygı	Geçmiş olumlu	-,018	,232
Engelleyici kaygı	Şimdi kaderci	,119	,239
Engelleyici kaygı	Şimdi hazcı	-,152	,581*
Engelleyici kaygı	Gelecek	,067	,409*

Not. Genç yetişkinler n = 41; orta yetişkinler n = 24. Parantez içindeki değerler iki yönlü p değerleridir. * işareti p<.05 düzeyinde istatistiksel olarak anlamlı korelasyonları gösterir.

Genç yetişkinlerde korelasyon bulguları

Pearson korelasyon analizi sonuçlarına göre, genç yetişkinlerde geçmiş olumsuz ZP'nin BT toplam puanıyla pozitif yönde ve anlamlı bir ilişkide olduğu görülmüştür, r(39) = ,375, p = .016. Geçmiş olumsuz ZP ile ileriye yönelik kaygı arasında, r(39) = ,356, p =,022 ve engelleyici kaygı arasında da r(39) = ,320, p = ,041, pozitif yönde ve anlamlı ilişkiler bulunmuştur. BT toplam puanı ve iki alt boyutunun; geçmiş olumlu, şimdi kaderci, şimdi hazcı ve gelecek ZP alt boyutları ile ilişkileri anlamlı bulunmamıştır.

Orta yetişkinlerde korelasyon bulguları

Orta yetişkin grubunda BT toplam puanının geçmiş olumsuz r(22) = ,473, p = ,020, şimdi kaderci, r(22) = ,417, p = ,043, şimdi hazcı, r(22) = ,618, p = ,001, ve gelecek ZP ile, r(22) = ,473, p = ,019, pozitif yönde ve anlamlı ilişkili olduğu bulunmuştur. Geçmiş olumlu ZP ile toplam puan arasındaki ilişki ise anlamlı bulunmamıştır, r(22) = ,264, p = ,213.

İleriye yönelik kaygı ile geçmiş olumsuz, r(22) = ,484, p =,017, şimdi kaderci, r(22) = ,462, p = ,023, şimdi hazcı, r(22) = ,514, p = ,010 ve gelecek ZP arasında, r(22) = ,421, p = ,040, pozitif yönde ve anlamlı ilişkiler bulunurken, geçmiş olumlu ZP ile ilişki anlamlı bulunmamıştır, r(22) = ,232, p = ,276.

Engelleyici kaygı ile şimdi hazcı, r(22) = ,581, p = ,003 ve gelecek ZP arasında r(22) = ,409, p = ,047, pozitif yönde ve anlamlı ilişkiler bulunurken, engelleyici kaygının geçmiş olumsuz, geçmiş olumlu ve şimdi kaderci zaman perspektifleri ile ilişkileri anlamlı bulunmamıştır.

Yaş grubu ve baskın ZP'ye göre BT

Belirsizliğe tahammülsüzlük toplam puanlarının yaş grubuna ve baskın ZP'ye göre farklılaşıp farklılaşmadığını incelemek için 2 x 4 faktöriyel varyans analizi yapılmıştır. Şimdi-Kaderci grubunda her iki yaş grubunda da yalnızca birer katılımcı bulunduğu için bu grup analize dâhil edilmemiştir. Baskın ZP belirlenemeyen iki katılımcı da analiz dışında bırakılmıştır. Analiz, Geçmiş-Olumsuz, Geçmiş-Olumlu, Şimdi-Hazcı ve Gelecek gruplarında yer alan 61 katılımcıyla yürütülmüştür.

Belirsizliğe tahammülsüzlük toplam puanı üzerinde yaş grubunun ana etkisi ($F(1, 53) = 0,33$, $p = 0,568$, $\eta_p^2 = 0,006$) ve baskın ZP'nin ana etkisi ($F(3, 53) = 2,64$, $p = 0,059$, $\eta_p^2 = 0,130$) istatistiksel olarak anlamlıya yakın bulunmuştur. Yaş grubu ile baskın ZP arasındaki etkileşim ise istatistiksel olarak anlamlı bulunmuştur ($F(3, 53) = 3,42$, $p = 0,024$, $\eta_p^2 = 0,162$). Betimsel olarak, Geçmiş-Olumsuz grubunda genç yetişkinlerin BT puan ortalaması (Ort. = 42,90, SS = 5,36, n = 10) orta yetişkinlerinkinden (Ort. = 35,67, SS = 7,64, n = 3) daha yüksektir. Geçmiş-Olumlu grubunda da genç yetişkinlerin ortalaması (Ort. = 39,00, SS = 8,10, n = 11) orta yetişkinlerinkinden (Ort. = 32,71, SS = 9,98, n = 7) daha yüksektir. Şimdi-Hazcı grubunda farkın yönü tersine dönmüş, orta yetişkinlerin ortalaması (Ort. = 57,50, SS = 3,54, n = 2) genç yetişkinlerinkinden (Ort. = 38,00, SS = 6,40, n = 5) daha yüksek bulunmuştur. Gelecek grubunda ise genç yetişkinlerin (Ort. = 37,33, SS = 12,02, n = 12) ve orta yetişkinlerin (Ort. = 37,73, SS = 9,20, n = 11) ortalamaları birbirine yakındır. Levene testi varyansların homojenliği varsayımının karşılanmadığını gösterdiğinden ($F(7, 53) = 2,22$, $p = 0,047$), etkileşim bulgusu temkinli yorumlanmalıdır.

Tartışma

Bu araştırmada, genç ve orta yetişkinlerin zaman perspektifi (ZP) profilleri ile belirsizliğe tahammülsüzlük (BT) düzeyleri arasındaki ilişkiler gelişimsel bir yaklaşımla karşılaştırılmıştır. Araştırmanın temel bulgularından biri, genç ve orta yetişkinlerin BT toplam ve alt boyut puanları arasında istatistiksel olarak anlamlı bir farklılık bulunmamasıdır. Psikoloji literatüründe, yaşla birlikte artan yaşam deneyiminin ve psikososyal olgunluğun belirsizlikle başa çıkma becerisini artırdığı varsayılsa da (Dugas vd., 2004; Rönnlund vd., 2017; Rucker ve Berry, 2026), bu araştırmanın bulguları içinde bulunduğumuz çağın getirdiği çevresel stresörlerin her iki yaş grubunu da benzer düzeyde etkilediğini gösteren çalışmalarla tutarlıdır (Kothari, 2017). Genç yetişkinler kariyer inşası ve kimlik arayışına bağlı belirsizlikler yaşarken (Arbona vd., 2021); orta yetişkinlerin hızla değişen sosyoekonomik koşullar, ebeveynlik rolleri veya mevcut düzeni koruma çabası nedeniyle benzer seviyede belirsizlik kaygısı yaşadıkları düşünülmektedir (akt; Rucker ve Berry, 2026). Benzer şekilde, yaş gruplarının baskın ZP dağılımı arasında da istatistiksel olarak anlamlı bir fark saptanamamıştır. Bu durum, zaman yönelimlerinin bireysel deneyimler, eğitim ve kültür vasıtasıyla erken yaşlardan itibaren öğrenilerek yerleşik bilişsel bir alışkanlığa ve kararlı bir kişilik yapısına dönüştüğünü gösteren kuramsal yaklaşımları desteklemektedir (Çivitci ve Baltacı, 2018; Holman ve Zimbardo, 2009; Zimbardo ve Boyd, 1999).

ZP alt boyutları ile BT arasındaki ilişkiler incelendiğinde, yaş grupları arasında farklılıklar ortaya çıkmıştır. Genç yetişkinlerde BT yalnızca geçmiş-olumsuz ZP ile anlamlı ve pozitif yönde ilişkiliyken; orta yetişkinlikte BT'nin neredeyse tüm zaman boyutları ile (geçmiş-olumlu hariç) ilişkili olması bu yaş dönemindeki bireylerin belirsizlik kaygılarının zaman algısının genelini yayılmış olduğuna işaret etmektedir. Analiz sonuçlarına göre, genç yetişkinlerde BT yalnızca geçmişteki olumsuzluklara odaklanıldığında tetiklenirken (Dugas vd., 2005; Liao ve Wei, 2011); orta yetişkinlerde anı yaşarken (şimdi-hazcı) (Freeston vd.,1994; Stolarski vd.,2011), geleceği planlarken (gelecek) (Carleton, 2016) veya olan olaylara müdahale edemezken (şimdi-kaderci) (Zimbardo ve Boyd, 1999) BT'nin yüksek olması, kaygının tek bir odakta kalmayıp birden çok zamansal çerçeveye nüfuz ettiğini düşündürmektedir.

Araştırmanın bir başka dikkat çeken bulgusu, bireylerin BT düzeylerinin benimsedikleri/baskın ZP'ye göre farklılaşması ve bu durumun yaş grubuna göre anlamlı bir etkileşim göstermesidir. BT ortalamaları, genç yetişkinlerde "geçmiş-olumsuz" baskın profiline sahip olanlarda en yüksek seviyedeyken; orta yaş yetişkinlerde "şimdi-hazcı" baskın profiline sahip olanlarda en yüksek seviyededir. Genç yetişkinlerin henüz

çözümlenmemiş geçmiş travma veya pişmanlıklarının bilişsel bir yük yaratarak belirsizlik toleransını düşürdüğü anlaşılmaktadır (Dugas vd., 2005; Rönnlund vd., 2017). Buna karşın, orta yetişkinlik döneminde olan bireylerin; anlık hazlara, dürtüselliğe ve risk almaya odaklanmanın (şimdi-hazcı), içinde bulunduğu yaş döneminin gerektirdiği istikrar, sorumluluk ve kabullenme ihtiyaçları ile (akt; Çok, 2019) çeliştiğini; aynı zamanda belirsizliğin yarattığı duygusal sıkıntı ve içsel gerilimden kaçınmak amacıyla anlık hazlara veya dürtüsel/kaçınmacı davranışlara yöneldikleri düşünüldüğünde (Freeston vd., 1994; Stolarski vd., 2011), bu kaçınmacı tutumun geleceğin öngörülmezliğine karşı hissedilen BT'yi daha da arttırdığı söylenebilir.

Bu araştırmanın bazı yöntemsel sınırlılıkları bulunmaktadır. Öncelikle, örneklem büyüklüğünün 65 kişi ile sınırlı olması ve özellikle bazı ZP alt boyutlarındaki katılımcı sayılarının oldukça düşük kalması, istatistiksel analizlerde varsayım ihlallerine yol açmış ve testlerin gücünü sınırlandırmıştır.

Gelecek araştırmalarda, daha geniş ve gruplar arası dağılımı dengeli boylamsal çalışmaların tasarlanması önerilmektedir. Elde edilen bulgular, klinik uygulamalarda belirsizliğe tahammülsüzlük çalışılırken, bireyin içinde bulunduğu gelişimsel dönemin ve zamansal yönelimlerinin dikkate alınmasının önem arz edebileceğini göstermektedir.

Kaynakça

Akirmak, U. (2019). The validity and reliability of the Zimbardo time perspective inventory in a Turkish sample. *Current Psychology*. doi:https://doi.org/10.1007/s12144-019-0153-3

Arbona, C., Fan, W., Phang, A., Olvera, N., & Dios, M. (2021). Intolerance of Uncertainty, Anxiety, and Career Indecision: A Mediation Model. *Journal of Career Assessment*, 1-18. doi:10.1177/10690727211002564

Bozkur, B., Kıran, B., & Cengiz, Ö. (2020). Üniversite Öğrencilerinin Umutsuzluk, Belirsizliğe Tahammülsüzlük, Gelecekte İş Bulmaya Yönelik Algı ve Özyeterliklerinin İncelenmesi. *Kastamonu Education Journal, 28*(6), 2401-2409. doi:10.24106/kefdergi.702233

Carleton, R. N. (2016). Into the unknown: A review and synthesis of contemporary models involving uncertainty. *Journal of Anxiety Disorders, 39*, 30-43. doi:http://dx.doi.org/10.1016/j.janxdis.2016.02.007

Carleton, R. N., Norton, M. A., & Asmundson, G. J. (2007). Fearing the unknown: A short version of the Intolerance of Uncertainty Scale. *Journal of Anxiety Disorders*, 105-117. doi:10.1016/j.janxdis.2006.03.014

Carpenter, R. K., Horton, J. C., & Alloway, T. P. (2022). Time Perspective, Working Memory, and Depression in Non-Clinical Samples: Is There a Link? *The Journal of Psycology*, 414-434. doi:10.1080/00223980.2022.2078948

Celik, D., Alpay, E. H., Celebi, B., & Turkeli, A. (2021). Intolerance of uncertainty, rumination, post-traumatic stress symptoms and aggression during COVID-19: a serial mediation model. *European Journal of Psychotraumatology*. doi:https://doi.org/10.1080/20008198.2021.1953790

Çivitci, N., & Baltacı, H. Ş. (2018). Üniversite Öğrencilerinde Zaman Perspektifi, Yaşam Doyumu ve Sosyal Karşılaştırma. *Pamukkale Eğitim Fakültesi Dergisi*, 107-116. doi:http://dx.doi.org/10.9779/PUJE807

Çok, F. (2019). Gelişim Psikolojisi: Ergenlik ve Yetişkinlik. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi, 27*(2), 905-935.

Dugas, M. J., Hedayati, M., Karavidas, A., Buhr, K., Francis, K., & Phillips, N. A. (2005). Intolerance of Uncertainty and Information Processing: Evidence of Biased Recall and Interpretations. *Cognitive Therapy and Research*(1), 57-70. doi:10.1007/s10608-005-1648-9

Dugas, M. J., Schwartz, A., & Francis, K. (2004). Intolerance of Uncertainty, Worry, and Depression. *Cognitive Therapy and Research, 28*(6), 835-842. doi:10.1007/s10608-004-0669-0

Freeston, M. H., Rhéaume, J., Letarte, H., Dugas, M. J., & Ladouceur, R. (1994). Why do people worry? *17*(6), 791-802. doi:https://doi.org/10.1016/0191-8869(94)90048-5

Holman, E. A., & Zimbardo, P. G. (2009). The Social Language of Time: The Time Perspective-Social Network Connection. *Basic and Applied Social Psychology, 31*(2), 136-147. doi:10.1080/01973530902880415

Kothari, R. (2017). Guided Inernet-based Cognitive Behavioural Therapy for Perfectionism, and its Impact on Self-esteem and Intolerance of Uncertainty: A Randomised Controlled Trial.

Liao, K. Y.-H., & Wei, M. (2011). Intolerance of Uncertainty, Depression, and Anxiety: The Moderating and Mediating Roles of Rumination. *Journal of Clinical Psychology*, 1220-1239. doi:10.1002/jclp.20846

Rönnlund, M., Aström, E., & Carelli, M. G. (2017). Time Perspective in Late Adulthood: Aging Patterns in Past, Present and Future Dimensions, Deviations from Balance, and Associations with Subjective Well-Being. *Timing & Time Perception, 5*(1), 77-98. doi:doi.org/10.1163/22134468-00002081

Rucker, J., & Berry, B. (2026). Psychosocial Differences Between Young and Middle-Adulthood: A Multimethod Assessment of Object Relations. *Journal of Adult Development*, 200-210. doi:https://doi.org/10.1007/s10804-025-09520-2

Sahib, A., Chen, J., Cardenas, D., Calear, A., & Wilson, C. (2024). Emotion regulation mediates the relation between intolerance of uncertainty and emotion difficulties: A longitudinal investigation. *Journal of Affective Disorders*, 194-204. doi:https://doi.org/10.1016/j.jad.2024.08.056

Sarıçam, H., Erguvan, F. M., Akın, A., & Akça, M. Ş. (2014). Belirsizliğe Tahammülsüzlük Ölçeği (BTÖ-12) Türkçe Formu: Geçerlik ve Güvenirlik Çalışması. *Route Educational and Social Science Journal*, 148-157.

Stolarski, M., Bitner, J., & Zimbardo, P. G. (2011). Time perspective, emotional intelligence and discounting of delayed awards. *Time Society, 20*(3), 346-363. doi:10.1177/0961463X11414296

Yıldız, D. Ö., & Güllü, D. Ö. (2018). Belirsizliğe Tahammülsüzlük ile Aleksitimi Arasındaki İlişki ve Bazı Sosyo-Demografik Değişkenlere Göre İncelenmesi. *Eğitim Bilimleri Dergisi, 9*(1), 113-131. http://dergipark.gov.tr/aduefebder adresinden alındı

Zimbardo, P. G., & Boyd, J. N. (1999). Putting Time in Perspective: A Valid, Reliable Individual-Differences Metric. *Jorurnal of Personality and Social Psychology, 77*(6), 1271-1288.

Zimbardo, P. G., Keough, K. A., & Boyd, J. N. (1997). Present Time Perspective as a Predictor of Risky Driving. *Personality and Individual Differences, 23*(6), 1007-1023. doi:10.1016/S0191-8869(97)00113-X

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

EXAMINING THE RELATIONSHIP BETWEEN ADVERSE CHILDHOOD EXPERIENCES AND MENTALIZATION IN ADULTS WITH LOW LEVELS OF ATTENTION DEFICIT/HYPERACTIVITY SYMPTOMS

Zeynep KÜTAY
0009-0008-7988-9776, Maltepe University, Postgraduate Education Institute, Clinical Psychology, İstanbul, Turkey
Barış ÖZDEMİR
Dr., Maltepe University
ORCID NO: 0000-0002-5955-5030

Abstract

Attention deficit hyperactivity disorder (ADHD), characterized by symptoms of inattention, hyperactivity, and impulsivity, is a neurodevelopmental disorder that typically begins in childhood and persists into adulthood. Adult ADHD presents with symptoms of inner restlessness and impulsivity in addition to the hyperactivity seen in childhood, potentially leading to problems in individuals' romantic relationships, social lives, and professional lives. Furthermore, mentalization, defined in the literature as an individual's capacity to understand their own and others' mental states, is known to cause problems in the functional areas of individuals with ADHD. However, mentalization capacity may develop not only from the severity of ADHD symptoms or individual characteristics but also from childhood experiences. In particular, childhood abuse, neglect, violence, and other negative experiences are suggested to be related to an individual's mentalization capacity.

While the relationship between ADHD symptom severity and mentalization capacity has been increasingly studied in the literature, the main aim of this study is to examine the relationship between mentalization capacity and developmental events in cases where ADHD symptoms are mild or absent. In individuals with pronounced ADHD symptoms, the potential influence of neurodevelopmental factors on mentalization levels complicates the investigation of the relationship between early life events and mentalization. Therefore, studying a sample with few or no ADHD symptoms may allow for the investigation of a potential relationship while limiting the impact of ADHD symptoms on the results.

This study analyzed whether negative childhood experiences predicted a decrease in mentalization scores in adults exhibiting few or no ADHD symptoms. The findings of this study are expected to contribute to determining the relationship between childhood experiences and mentalization in a sample of young adults in whom ADHD symptoms have not reached a clinical level. In this context, the study contributes to a better understanding of the role of early life experiences in shaping mentalization capacity.

Keywords: Mentalization, ADHD, Adverse Childhood Experiences.

DÜŞÜK DÜZEYDE DİKKAT EKSİKLİĞİ/HİPERAKTİVİTE BELİRTİLERİ GÖSTEREN YETİŞKİNLERDE OLUMSUZ ÇOCUKLUK DENEYİMLERİ İLE ZİHİNSELLEŞTİRME ARASINDAKİ İLİŞKİNİN İNCELENMESİ

Özet

Dikkat eksikliği ve hiperaktivite bozukluğu (DEHB); dikkatsizlik, hiperaktivite ve dürtüsellik belirtileriyle karakterize, genellikle çocukluk döneminde başlayan ve yetişkinlikte de devam edebilen nörogelişimsel bir bozukluktur. Yetişkinlik dönemindeki DEHB, çocukluktaki hiperaktiviteye ek olarak içsel huzursuzluk ve dürtüsellik belirtileriyle kendini gösterir; bu durum bireylerin romantik ilişkilerinde, sosyal yaşamlarında ve mesleki hayatlarında sorunlara yol açabilir. Ayrıca, literatürde bireyin hem kendi zihinsel durumlarını hem de

başkalarının zihinsel durumlarını anlama kapasitesi olarak tanımlanan "zihinselleştirme" becerisi, DEHB'li bireylerin işlevsel alanlarında sorunlara neden olabilmektedir. Bununla birlikte, zihinselleştirme kapasitesi aynı zamanda çocukluk dönemi deneyimlerinden de etkilenebilir. Özellikle çocukluk döneminde yaşanan istismar ve ihmal gibi olumsuz deneyimlerin, bireyin zihinselleştirme kapasitesiyle ilişkili olduğu öne sürülmektedir. Literatürde DEHB belirti şiddeti ile zihinselleştirme kapasitesi arasındaki ilişki giderek daha fazla inceleniyor olsa da, bu çalışmanın temel amacı, DEHB belirtilerinin düşük olduğu durumlarda zihinselleştirme kapasitesi ile gelişimsel olaylar arasındaki ilişkiyi araştırmaktır. Belirgin DEHB belirtileri olan bireylerde, nörogelişimsel faktörlerin zihinselleştirme düzeyleri üzerindeki olası etkisi, erken dönem yaşam olayları ile zihinselleştirme arasındaki ilişkinin incelenmesini güçleştirmektedir. Dolayısıyla, DEHB belirtilerinin düşük olduğu bir örneklem üzerinde çalışmak, DEHB belirtilerinin sonuçlar üzerindeki etkisini sınırlandırarak, söz konusu olası ilişkinin daha net bir şekilde incelenmesine olanak tanıyabilir. Bu çalışmada, DEHB belirtileri düşük düzeyde olan yetişkinlerde, olumsuz çocukluk deneyimlerinin zihinselleştirme puanlarında bir düşüşe yol açıp açmadığı analiz edilmiştir. Çalışmanın bulgularının, DEHB belirtilerinin klinik düzeye ulaşmadığı yetişkinlerden oluşan bir örneklemde, çocukluk dönemi deneyimleri ile zihinselleştirme arasındaki ilişkinin belirlenmesine katkıda bulunması beklenmektedir. Bu bağlamda çalışma, erken dönem yaşam deneyimlerinin zihinselleştirme kapasitesinin şekillenmesindeki rolünün daha iyi anlaşılmasına katkı sağlamaktadır.

Anahtar Kelimeler: Zihinselleştirme, DEHB, Olumsuz Çocukluk Deneyimleri.

GİRİŞ

1.1 Çocukluk Çağı Olumsuz Deneyimleri

Çocukluk çağı olumsuz deneyimleri, bireyin on sekiz yaşından önce yaşadığı travmatik olarak algılanabilecek ve yoğun stres faktörü içeren deneyimleri tanımlamaktadır (Danielson ve ark., 2025). Bu kapsamda, olumsuz çocukluk deneyimleri iki alt başlıkta değerlendirilmektedir: Çocuk istismarı ve ihmali ve hane içi işlev bozuklukları. Fiziksel, duygusal ve cinsel istismar ile fiziksel ve duygusal ihmal çocuk istismarı ve ihmaline girerken; ebeveyn kaybı, boşanma veya ayrılık, evde madde bağımlılığı, aile bireyinde psikiyatrik bozukluk, aile içinde şiddete tanıklık etme gibi durumlar hane içi işlev bozukluklarına girer (Danielson ve ark., 2025; Spratt ve ark., 2019). Olumsuz çocukluk deneyimlerinin öne çıkan özelliklerinden biri, bir çocuğun bir olumsuz duruma maruz kalması çoğunlukla birden fazla paralel olarak gelişen travmatik deneyime maruz kalmasıdır (Spratt ve ark., 2019). Olumsuz çocukluk deneyimleri ölçeğinden elde edilen toplam puan özellikle 4 ve üzeri olduğunda ise depresif bozukluklar, anksiyete, madde kullanımı ve intihar riski gibi psikiyatrik bozuklukların görülme olasılığının arttığı bilinmektedir (Danielson ve ark., 2025). Ek olarak, bakım verenlerin yokluğunda yaşanan kronik stres nörobiyolojik olarak çocuğu uzun vadede olumsuz yönde etkilemektedir (Spratt ve ark., 2019). Bunun ötesinde, özellikle dikkat eksikliği/hiperaktivite bozukluğunda önemli rol alan prefrontal korteks, hipokampus ve amigdalada olumsuz çocukluk deneyimleriyle beraber oluşan kronik stres sebebiyle anomaliler gelişmektedir (Berens ve ark., 2017).

1.2 Zihinselleştirme Kavramı ve Gelişimi

Zihinselleştirme, bireyin kendisinin ve diğerlerinin davranışlarını, davranışlarının temelinde bulunan niyetini, inançlarını, arzularını, duygularını ve ihtiyaçlarını anlama ve anlamlandırma kapasitesi olarak ifade edilmektedir. Bu kapasite sayesinde bireyler içsel deneyimlerini doğru bir şekilde ifade edebilir ve dürtülerini kontrol edebilirler (Duquette ve Ainley 2019). Fonagy ve arkadaşlarının (2012) çalışmasına göre zihinselleştirmenin bireylerin güvenli bağlanma geliştirmesi ve kişilerarası ilişkilerinin sağlıklı olmasıyla gelişebileceğini öne sürmektedir. Duygu regülasyonu ve dikkat kontrol becerilerinin çocuğa bakım verenler tarafından kazandırılması zihinselleştirme kapasitesinin gelişmesinin en önemli adımlarındandır. Erken yaşam döneminde bakım veren ve çocuk arasında temasın olması ve ihtiyaçların düzgün şekilde karşılanıyor olması, çocuğun sinir sistemini düzenleyerek içsel durumlarını geliştirmesine katkı sağlayabilir. (Duquette ve Ainley 2019).

1.3 Çocukluk Çağı Olumsuz Deneyimleri ve Zihinselleştirme Arasındaki İlişki

Akbari ve arkadaşlarının (2026) çalışmasında belirtildiği üzere çocukluk çağı olumsuz deneyimleri ve zihinselleştirme kavramı beraber değerlendirildiğinde, bakım verenin çocuğu ihmale veya istismara maruz bırakma durumunda zihinselleştirmenin gelişimi sekteye uğrar. Çünkü ihmal veya istismar durumunda çocuğun istekleri, ihtiyaçlar ve niyetleri göz ardı edilebilir (Dollberg ve ark., 2023). Ek olarak Wagner Skacel ve arkadaşlarının (2021) çalışmasında belirtildiği üzere olumsuz çocukluk deneyimine sahip çocuklar dışsal uyaranlarla çok fazla etkileşimde bulundukları için dikkatlerini içsel uyaranlara çevirmekte zorluk yaşayabilirler. Aynı zamanda, olumsuz çocukluk deneyimlerine sahip bireylerde zihinselleştirme kapasitesinin anlamlı düzeyde azaldığı ortaya konmuştur. Zihinselleştirme becerisindeki bu sınırlılık, yetişkinlik döneminde stres deneyimleme ve çatışma durumlarında işlevsizleşmeye yol açabilir (Dollberg ve ark., 2023).

1.4 DEHB, Çocukluk Çağı Olumsuz Deneyimleri ve Zihinselleştirme İlişkisi

Dikkat eksikliği/hiperaktivite bozukluğu (DEHB), dikkat eksikliği, hiperaktivite ve dürtüsellik semptomlarıyla tanımlanan nörogelişimsel bir bozukluktur. DEHB'ye sahip bireylerin semptomları klinik açıdan anlamlı olarak yetişkinlik döneminde de devam ederken semptomlar içsel huzursuzluk, planlama güçlükleri, erteleme, kişilerarası ilişkilerde bozukluk şeklinde gözlemlenebilmektedir (Gabbiadini ve ark., 2026). Son yıllarda yapılan çalışmalar, duygu düzenleme güçlüklerinin DEHB'nin ana semptomlarından biri olduğunu kanıtlamaktadır (Bodalski ve ark., 2023; Salvi ve ark., 2021). DEHB'li birey duygularını anlamlandırma, değerlendirme ve hedefler doğrultusunda düzenleme kapsamında zorluklar yaşayabilir ve bu durumun çıktısı olarak öfke patlamaları, aşırı tepkisellik ve ilişkilerde işlevsizlik olabilmektedir. Bu durumun altında yatan sebepler incelendiğinde çocukluk döneminde maruz kalınan ihmal ve istismar, stres tepkilerinin biyolojik sistemlerini olumsuz yönde etkileyerek duygu düzenlemede zorlanmaya yol açmaktadır (Dollberg ve ark., 2023). Berens ve arkadaşlarının (2017) çalışmasında söz ettiği üzere olumsuz çocukluk deneyimlerinin prefrontal kortekste bozulmaya yol açması sebebiyle bireyin yürütücü işlevleri, dürtü kontrolü ve stres toleransında zayıflama gözlemlenmektedir. Erken dönemde bakım verenle kurulan ilişki ile temeli atılan zihinselleştirme kapasitesinin önemi bu noktada dikkat çekmektedir. Gabbiadini ve arkadaşlarının (2026) çalışmasında belirtilen üzere DEHB'li bireylerin sağlıklı kontrollere kıyasla anlamlı düzeyde daha az zihinselleştirme becerisi sergiledikleri ortaya konmaktadır.

1.5 Araştırmanın Gerekçesi ve Düşük DEHB Belirti Düzeyine Sahip Yetişkinlere Odaklanılması

Shayeghy ve arkadaşlarının (2023) belirttiği üzere zihinselleştirme kapasitesi ve travma geçmişi ilişkisi kapsamında değerlendirilen bireylerin sınır kişilik bozukluğu, depresyon gibi psikiyatrik bozukluklar ve klinik düzeyde DEHB tanısı almış yüksek semptom düzeyi geliştirmiş olmaları yüksektir. Düşük DEHB semptomlarına sahip bireylerde dürtü kontrolü, dikkat sürdürme, çalışma belleği gibi bilişsel süreçler yüksek DEHB semptomlarına sahip bireylere göre gelişmiş durumdadır (Gabbiadini ve ark., 2026). Bu kapsamda, düşük DEHB belirtilerine sahip bireylerde zihinselleştirme kapasitesi ve olumsuz çocukluk deneyimleri arasındaki ilişkinin incelenmesi yürütücü işlevlerdeki eksikliklerin zihinselleştirme kapasitesi üzerindeki etkilerini en aza indirerek doğrudan ilişkiyi inceleme fırsatı sunabilir (Gabbiadini ve ark., 2026). Bu çerçevede, mevcut araştırmanın amacı, yürütücü işlevlerdeki yetersizlikler ve DEHB semptomları kontrol edildiğinde olumsuz çocukluk deneyimleri ve zihinselleştirme becerisi arasındaki ilişkiyi açıklamaktadır.

1.6 Araştırmanın Hipotezleri

H1: Olumsuz çocukluk deneyimleri ile zihinselleştirme kapasitesi arasında negatif yönde anlamlı bir ilişki vardır.

H2: DEHB belirtileri düşük yetişkinlerde olumsuz çocukluk deneyimleri ve zihinselleştirme kapasitesi arasında negatif yönde ve anlamlı bir ilişki vardır.

YÖNTEM

2.1 Katılımcılar

Yaşları 18 ile 66 arasında değişen 46 kadın ve 21 erkekten oluşan 67 yetişkin (Ort=24,94, SS=7,03) , araştırmaya gönüllü olarak katılmıştır. Katılımcılar WhatsApp grupları ve Instagram storyleri üzerinden

paylaşılan form ile ölçekleri doldurmuşlardır. Katılımcılar, Maltepe Üniversitesi tarafından onaylanan bir protokole ilişkin yazılı bilgilendirilmiş onam vermişlerdir.

2.2 Materyaller

Dikkat Eksikliği/Hiperaktivite Bozukluğu Semptom Düzeyi

Erişkin Dikkat Eksikliği ve Hiperaktivite Bozukluğu Kendi Bildirim Ölçeği (ASRS-v1.1), 2005 yılında Kessler ve arkadaşları tarafından geliştirilmiştir. Ölçeğin Türkçe uyarlaması 2009 yılında Doğan ve arkadaşları tarafından gerçekleştirilmiştir. Bu ölçek, 2 alt boyuttan ve 5'li Likert tipi derecelendirme ölçeğiyle (1 = asla, 5 = çok sık) puanlanan toplam 18 maddeden oluşmaktadır. Ölçekteki alt boyutlar dikkat ve hiperaktivitedir. Mevcut çalışma kapsamında, dikkat (1, 2, 3, 4, 5 ve 6. maddeler) ve hiperaktivite (7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 ve 18. maddeler) alt boyutları kullanılmıştır. Ölçeğin alt boyutlarından veya toplamından alınan puanların yüksek olması DEHB belirti şiddetinin yüksek olduğuna; düşük puanlar ise belirti düzeyinin düşük olduğuna işaret etmektedir.

Zihinselleştirme Kapasitesi

Zihinselleştirme Ölçeği, 2018 yılında Dimitrijevic ve arkadaşları tarafından geliştirilmiştir. Ölçeğin Türkçe uyarlaması 2023 yılında Törenli Kaya ve arkadaşları tarafından gerçekleştirilmiştir. Bu ölçek, 3 alt boyuttan ve 5'li Likert tipi derecelendirme ölçeğiyle (1 = Tamamen yanlış, 5 = Tamamen doğru) puanlanan toplam 25 maddeden oluşmaktadır. Ölçekteki alt boyutlar kendilik temelli zihinselleştirmen, ötekiler temelli zihinselleştirme ve zihinselleştirmeye güdülenmedir. Mevcut çalışma kapsamında kendilik temelli zihinselleştirme (1, 4, 7, 9, 13, 15, 22 ve 25. maddeler), ötekiler temelli zihinselleştirme (2, 3, 5, 6, 10, 12, 18, 21 ve 23. maddeler) ve zihinselleştirmeye güdülenme (8, 11, 14, 16, 17, 19, 20 ve 24. maddeler) alt boyutları kullanılmıştır. Ters maddelerin dönüştürülmesinin ardından hesaplanan alt boyut ve toplam puanların yüksek olması bireyin ilgi kapasitesinin yüksek olmasına; düşük puanlar ise bireyin ilgili kapasitesinin düşük olması ile ilişkilidir.

Olumsuz Çocukluk Deneyimleri

Çocukluk Çağı Olumsuz Yaşantılar Ölçeği (ÇÇOYÖ), 1995 yılında Felitti ve arkadaşları tarafından geliştirilmiştir. Ölçeğin Türkçe uyarlaması 2018 yılında Gündüz ve arkadaşları tarafından gerçekleştirilmiştir. Ölçek, 10 maddeden oluşuyor olup ikili (evet/hayır) derecelendirme ile yanıtlanmaktadır. Alınan puanın yüksek olması bireyin çocukluk çağında maruz kaldığı olumsuz yaşantıların ve travmatik durumların sıklığının fazla olduğuna; düşük olması ise olumsuz çocukluk deneyimlerinin azlığına veya yokluğuna işaret etmektedir.

2.3 İşlem

Çalışma, katılımcılara bilgilendirilmiş onam formunun sunulmasıyla başlatılmıştır. Bu form aracılığıyla katılımcılara araştırmanın amacı, yöntemi, olası riskler, gizlilik ilkeleri ve çalışmanın gönüllülük esasına dayandığı hakkında bilgi verilecek ve katılımlarına ilişkin yazılı onamları alınmıştır. Onam formunu onaylayan katılımcılar demografik bilgi formunu, Erişkin Dikkat Eksikliği ve Hiperaktivite Bozukluğu Kendi Bildirim Ölçeğini, Zihinselleştirme Ölçeğini ve Çocukluk Çağı Olumsuz Yaşantılar Ölçeğini doldurmuşlardır.

3. BULGULAR

3.1 Betimsel İstatistikler

Araştırmada katılımcıların dikkat eksikliği ve hiperaktivite belirtileri, zihinselleştirme düzeyleri ve olumsuz çocukluk deneyimlerine ilişkin puanlarını incelemek amacıyla betimsel istatistikler hesaplanmıştır. Bu kapsamda ASRS ölçeğinin dikkat eksikliği alt boyutu (Ort=15,86, SS=7,63), hiperaktivite alt boyutu (Ort=13,23, SS=5,69) ve toplam puanı (Ort=29,10, SS=11,91); Zihinselleştirme ölçeğinin (ZÖ) kendini zihinselleştirme alt boyutu (Ort=31,04, SS=5,26), ötekileri zihinselleştirme alt boyutu (Ort=36,04, SS=5,37), zihinselleşmeye güdüleme alt boyutu (Ort=26,74, SS=6,43) ve toplam puanı (Ort=93,83, SS=12,22); Çocukluk çağı olumsuz yaşantılar ölçeğinin (ÇÇOYÖ) toplam puanı (Ort=2,35, SS=2,64) analiz edilmiştir. ASRS alt boyutları ve toplam puanlarında düşük puan alan katılımcıları belirlemek için çeyreklik bölümlemesi

(percentile split) yöntemi uygulanmıştır. Bu doğrultuda, ASRS puan dağılımının 25 yüzdeliğinin altında kalan katılımcılar 'Düşük DEHB semptom grubu' olarak tanımlanmıştır.

3.2 DEHB, Zihinselleştirme ve Olumsuz Çocukluk Deneyimleri Arası Korelasyonlar

Araştırma değişkenleri arasındaki ilişkileri incelemek amacıyla Pearson korelasyon analizi gerçekleştirilmiştir. Analiz sonuçları Tablo 1'de sunulmuştur. ASRS alt boyutları ve toplam puanı ile ZÖ alt boyutları, ZÖ toplam puanı ve ÇÇOYÖ toplam puanı arasındaki ilişkiler değerlendirilmiştir.

Bulgular incelendiğinde, dikkat eksikliği alt boyutu ile hiperaktivite alt boyutu arasında pozitif yönlü, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r=.59, p<.001). Dikkat eksikliği alt boyutu ile ASRS toplam puan arasında pozitif yönlü, yüksek düzeyde ve anlamlı bir ilişki olduğu görülmüştür (r=.92, p<.001) Dikkat eksikliği alt boyutu ile zihinselleşmeye güdüleme arasında negatif, orta düzeyde ve anlamlı bir ilişki saptanmıştır (r=. -.33, p<.001). Hiperaktivite alt boyutu ile ASRS toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r=.85, p<.001). Hiperaktivite alt boyutu ile zihinselleşmeye güdüleme arasında negatif, düşük düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.25, p<.001). ASRS toplam puanı ile zihinselleştirmeye güdülme arasında negatif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.33, p=<.001). Kendine zihinselleştirme ve ötekilere zihinselleştirme arasında pozitif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r=.64, p<.001). Kendine zihinselleşme ve zihinselleştirme toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r=.77, p<.001). Ötekilere zihinselleştirme ve zihinselleştirme toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r=.75, p<.001). Ötekilere zihinselleştirme ve ÇÇOYÖ toplam puanı arasında negatif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.31, p<.001). Zihinselleştirmeye güdüleme ve zihinselleştirme toplam puanı arasında pozitif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= .62, p<.001).

Diğer değişkenler arasındaki ilişkilerin istatistiksel olarak anlamlı olmadığı görülmüştür (bkz. Tablo 1).

Tablo 1: *Değişkenler Arası Korelasyonlar*

Değişkenler	1	2	3	4	5	6	7	8
1. ASRS_Dikkat	-							
2. ASRS_hpr	.59**	-						
3. ASRS_Toplam	.92**	.85	-					
4. ZÖ_Kendi	.09	.23	.17	-				
5. ZÖ_Öteki	-.05	.12	.02	.64**	-			
6. ZÖ_Güdü	-.33**	-.25*	-.33**	.12	.09	-		
7. ZÖ_Toplam	-.15	.01	-.09	.77**	.76**	.62**	-	
8. ÇÇOYÖ_Toplam	.18	.20	.21	-.06	-.31**	-.01	-.17	-

3.3 Düşük Dikkat Eksikliği Puanına Sahip Katılımcılarda Zihinselleştirme ve Olumsuz Çocukluk Deneyimleri Arası Korelasyonlar

ASRS dikkat eksikliği alt boyutunda düşük puan alan katılımcılar filtrelenerek analizler tekrarlanmıştır. Bu kapsamda kendine zihinselleştirme (Ort=30,47, SS=7,01), ötekilere zihinselleştirme (Ort=36,42, SS=8,49), zihinselleştirmeye güdüleme (Ort=29,15, SS=7,42), zihinselleştirme toplam puanı (Ort=96,05, SS=15,43) ve ÇÇOYÖ toplam puanı (Ort=2, SS=3,12) incelenmiştir.

Bu grupta zihinselleştirme değişkenleri ile ÇÇOYÖ toplam puanı arasındaki ilişkileri incelemek amacıyla Pearson korelasyon analizi yapılmıştır. Analiz sonuçları Tablo 2'de sunulmuştur.

ÇÇOYÖ toplam puanı ve kendine zihinselleştirme arasında negatif, orta düzeyde ve anlamlı bir ilişki bulunmuştur. (r= -.49, p<.001). ÇÇOYÖ toplam puanı ve ötekilere zihinselleştirme arasında negatif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.70, p<.001). ÇÇOYÖ toplam puanı ve zihinselleştirme toplam puanı arasında negatif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.50, p<.001).

Kendine zihinselleştirme ve ötekilere zihinselleştirme arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r= .73, p<.001). Kendine zihinselleştirme ve zihinselleştirme toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r=.83, p<.001).

Ötekilere zihinselleştirme ve zihinselleştirme toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r= .80, p<.001).

Diğer değişkenler arasındaki ilişkilerin istatistiksel olarak anlamlı olmadığı görülmüştür (bkz. Tablo 2).

Tablo 2: *Düşük Dikkat Eksikliği Puanına Sahip Katılımcılar*

Değişkenler	1	2	3	4	5
1. ÇÇOYÖ_Toplam	-				
2. ZÖ_Kendi	-.49*	-			
3. ZÖ_Öteki	-.70**	.73**	-		
4. ZÖ_Güdü	.23	-.05	-.16	-	
5. ZÖ_Toplam	-.50*	.83**	.80**	.36	-

3.4 Düşük Hiperaktivite Puanına Sahip Katılımcılarda Zihinselleştirme ve Olumsuz Çocukluk Deneyimleri Arası Korelasyonlar

ASRS hiperaktivite alt boyutunda düşük puan alan katılımcılar filtrelenerek analizler tekrarlanmıştır. Bu kapsamda kendine zihinselleştirme (Ort=31,05, SS=6,62), ötekilere zihinselleştirme (Ort=36,26, SS=8,37), zihinselleştirmeye güdüleme (Ort=27,84, SS=7,46), zihinselleştirme toplam puanı (Ort=95,15, SS=14,37) ve ÇÇOYÖ toplam puanı (Ort=2,36, SS=3,18) incelenmiştir.

Bu grupta zihinselleştirme değişkenleri ile ÇÇOYÖ toplam puanı arasındaki ilişkileri incelemek amacıyla Pearson korelasyon analizi yapılmıştır. Analiz sonuçları Tablo 3'te sunulmuştur.

ÇÇOYÖ toplam puanı ve kendine zihinselleştirme arasında negatif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.55, p<.001). ÇÇOYÖ toplam puanı ve ötekilere zihinselleştirme arasında negatif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.69, p<.001).

Kendine zihinselleştirme ve ötekilere zihinselleştirme arasında pozitif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= .69, p<.001). Kendine zihinselleştirme ve zihinselleştirme toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r=.78, p<.001).

Ötekilere zihinselleştirme ve zihinselleştirme toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur.

Diğer değişkenler arasındaki ilişkilerin istatistiksel olarak anlamlı olmadığı görülmüştür (bkz. Tablo 3).

Tablo 3: *Düşük Hiperaktivite Puanına Sahip Katılımcılar*

Değişkenler	1	2	3	4	5
1. ÇÇOYÖ_Toplam	-				
2. ZÖ_Kendi	-.55*	-			
3. ZÖ_Öteki	-.69**	.69**	-		
4. ZÖ_Güdü	.40	-.15	-.20	-	
5. ZÖ_Toplam	-.44	.78**	.79**	.33	-

3.5 Düşük ASRS Toplam Puanına Sahip Katılımcılarda Zihinselleştirme ve Olumsuz Çocukluk Deneyimleri Arası Korelasyonlar

ASRS toplam puanında düşük puan alan katılımcılar filtrelenerek analizler tekrarlanmıştır. Bu kapsamda kendine zihinselleştirme (Ort=29,33, SS=7,07), ötekilere zihinselleştirme (Ort=36, SS=8,78), zihinselleştirmeye güdüleme (Ort=29,16, SS=6,65), zihinselleştirme toplam puanı (Ort=94,50, SS=16,02) ve ÇÇOYÖ toplam puanı (Ort=1,77, SS=3,20) incelenmiştir.

Bu grupta zihinselleştirme değişkenleri ile ÇÇOYÖ toplam puanı arasındaki ilişkileri incelemek amacıyla Pearson korelasyon analizi yapılmıştır. Analiz sonuçları Tablo 4'te sunulmuştur.

ÇÇOYÖ toplam puanı ve kendine zihinselleştirme arasında negatif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.52, p<.001). ÇÇOYÖ toplam puanı ve ötekilere zihinselleştirme arasında negatif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.71, p<.001). ÇÇOYÖ toplam puanı ve zihinselleştirme toplam puanı arasında negatif, orta düzeyde ve anlamlı bir ilişki bulunmuştur (r= -.53, p<.001).

Kendine zihinselleştirme ve ötekilere zihinselleştirme arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r= .80, p<.001). Kendine zihinselleştirme ve zihinselleştirme toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur. (r=.90, p<.001)

Ötekilere zihinselleştirme ve zihinselleştirme toplam puanı arasında pozitif, yüksek düzeyde ve anlamlı bir ilişki bulunmuştur (r= .83, p<.001).

Diğer değişkenler arasındaki ilişkilerin istatistiksel olarak anlamlı olmadığı görülmüştür (bkz. Tablo 4).

Tablo 4: *Düşük ASRS Toplam Puanına Sahip Katılımcılar*

Değişkenler	1	2	3	4	5
1. ÇÇOYÖ_Toplam	-				
2. ZÖ_Kendi	-.52*	-			
3. ZÖ_Öteki	-.71**	.80**	-		
4. ZÖ_Güdü	.21	.04	-.16	-	
5. ZÖ_Toplam	-.53*	.90**	.83**	.34	-

Tartışma

Bu çalışma, zihinselleştirme ve olumsuz çocukluk deneyimlerinin arasındaki ilişkiyi düşük düzeyde DEHB belirtilerine sahip olan yetişkinler bağlamında incelemeyi hedeflemiştir. Araştırmanın önemli bulgularından biri, dikkat eksikliği ve hiperaktivite alt gruplarında ve toplam puanlarda düşük puan alan katılımcılarda olumsuz çocukluk deneyimleri ile zihinselleştirme kapasitesi arasında negatif yönlü ve anlamlı ilişkilerin ortaya çıkmasıdır. Bu bulgu, çocukluk döneminde olumsuz yaşantılar deneyimleyen bireylerin kendilerini ve diğerlerinin duygu, düşünce ve eylemlerini anlamlandırmada zorluk yaşayabileceklerini düşündürmektedir. Bu bulgu, çocukluk döneminde ihmal ve istismara maruz kalan çocukların yetişkinlik hayatında diğerlerini ve kendilerini anlamlandırmaya yönelik becerilerinin eksikliği konusunda literatür ile benzerdir (Wagner Skacel ve ark., 2022; Tironi ve ark., 2024.

Araştırmanın dikkat çekici sonuçlarından biri, ana hipotezimiz olan DEHB belirtileri düşük olan katılımcılarda gerçekleştirilen analizlerde ortaya çıkmıştır. Dikkat eksikliği, hiperaktivite ve DEHB toplam puanı düşük olan grupların tamamında olumsuz çocukluk deneyimleri ile kendine zihinselleştirme arasında negatif yönlü ve anlamlı ilişkiler bulunmuştur. ASRS toplam puanı için anlamlı olmayan bu ilişkinin, düşük DEHB belirti düzeyine sahip gruplarda ortaya çıkması dikkat çekicidir. Bu bulgu, olumsuz çocukluk deneyimleri ile kendine zihinselleştirme arasındaki ilişkinin DEHB belirtileri farklı düzeylerde olan gruplarda farklı bir görünüm sergileyebileceğini düşündürmektedir. Bununla birlikte, söz konusu korelasyon katsayılarının gruplar arasında istatistiksel olarak farklılaşıp farklılaşmadığı doğrudan test edilmediğinden, bu farklılığın DEHB belirti düzeyinden kaynaklandığı sonucuna varılamaz.

ASRS toplam puanlar dikkate alındığında, DEHB belirtileri ile zihinselleştirmeye güdülenme arasında negatif yönlü ve anlamlı ilişkiler bulunmuştur. Buna göre dikkat eksikliği, hiperaktivite ve DEHB toplam puanındaki artış, zihinselleştirmeye yönelik motivasyondaki düşüşle ilişkili görünmektedir. Bu bulgu, Bouteloup ve arkadaşlarının (2026) çalışmasında vurgulanan DEHB semptom düzeyi ve zihinselleştirmenin tüm boyutları arasındaki ilişkinin negatif yönlü olması ile benzerdir. Bununla birlikte, DEHB belirtileri ile kendine ve diğerlerine zihinselleştirme arasında anlamlı ilişkiler saptanmamıştır. Bu bulgu, DEHB belirtilerinin zihinselleştirme kapasitesinin bütün boyutlarıyla aynı şekilde ilişkili olmayabileceğini düşündürmektedir. Özellikle zihinselleştirme kapasitesi ile zihinselleştirme sürecine yönelme motivasyonunun birbirinden farklı yapılar olduğu göz önünde bulundurulmalıdır. Bir bireyin kendisinin veya başkalarının zihinsel durumlarını anlama kapasitesi ile bu zihinsel durumları anlamaya yönelik ilgi ve motivasyonu aynı düzeyde olmayabilir. Bu açıdan değerlendirildiğinde, araştırmanın bulguları DEHB belirtilerinin zihinselleştirmenin kapasite boyutlarından ziyade motivasyonel boyutuyla ilişkili olabileceğine işaret etmektedir.

Araştırmada zihinselleştirme alt boyutları arasındaki ilişkiler de incelenmiştir. Toplam ASRS puanları için kendine zihinselleştirme ile diğerlerine zihinselleştirme arasında pozitif yönlü ve anlamlı bir ilişki

bulunmuştur. Bu ilişki düşük DEHB gruplarında da korunmuştur. Özellikle DEHB toplam puanı düşük olan grupta iki alt boyut arasındaki ilişkinin yüksek düzeyde olması, kişinin kendi zihinsel durumlarını anlamlandırması ile başkalarının zihinsel durumlarını anlamlandırmasının birbiriyle bağlantılı süreçler olduğunu düşündürmektedir. Bu bulgu, zihinselleştirmenin kendine ve diğerlerine yönelik boyutlarının birbirinden tamamen bağımsız yapılar olarak ele alınmaması gerektiğine işaret etmektedir.

Genel olarak araştırmanın bulguları, olumsuz çocukluk deneyimleri ile yetişkinlikteki zihinselleştirme süreçleri arasında negatif yönlü ilişkiler bulunduğunu ve bu ilişkilerin DEHB belirtileri düşük olan katılımcılarda da gözlendiğini ortaya koymaktadır. Özellikle diğerlerine zihinselleştirme ile ÇÇOYÖ toplam puanı arasındaki ilişkinin farklı düşük DEHB gruplarında benzer düzeylerde bulunması dikkat çekicidir. Bu sonuçlar, aslında DEHB'ye sahip bireylerde olumsuz çocukluk deneyimlerinin fazlalığı ve zihinselleştirme kapasitesinin eksikliği öne çıkaran literatürde, DEHB belirtileri olmaksızın yetişkinlikteki zihinselleştirme süreçlerinin değerlendirilmesinde erken dönem olumsuz yaşantıların dikkate alınmasının önemini desteklemektedir. Bununla birlikte, araştırmanın kesitsel ve korelasyonel yapısı nedeniyle değişkenler arasında nedensel bir ilişki kurulamayacağı ve gözlenen ilişkilerin farklı bireysel ve çevresel faktörlerle bağlantılı olabileceği göz önünde bulundurulmalıdır.

Referanslar

Akbari, E., Heydarinasab, L., Yaghoubi, H., & Farahani, H. (2026). Childhood abuse and mentalization among students with different levels of suicidal ideation: A comparative study. *Journal of Practice in Clinical Psychology, 14*(2), 175-184. https://doi.org/10.32598/jpcp.14.2.1084.1

Berens, A. E., Jensen, S. K. G., & Nelson, C. A. (2017). Biological embedding of childhood adversity: from physiological mechanisms to clinical implications. *BMC Med, 15,* 135. https://doi.org/10.1186/s12916-017-0895-4

Bouteloup, M., Besch, V., Hasler, R., Nicastro, R., Pham, E., Dieben, K., Blay, M., Rüfenacht, E., Perroud, N., & Debbane, M. (2026). The contributions of mentalizing and impulsivity dimensions to the clinical expressions of attention-deficit hyperactivity disorder during adulthood. *Journal of Affective Disorders Reports, 24.* https://doi.org/10.1016/j.jadr.2026.101060

Danielson, R. A., Schmidt, M., & Griechen, M. (2025). Adverse childhood experiences affect health outcomes for adults in North Dakota: 2019-2022 BRFSS population profile. *Frontiers Public Health, 13.* https://doi.org/10.3389/fpubh.2025.1517431

Dollberg, D. G., & Hanetz Gamliel, K. (2023). Therapeutic work to enhance parental mentalizing for parents with ACEs to support their children's mental health: A theoretical and clinical review. *Front. Child Adolesc. Psychiatry, 2.* https://doi.org/10.3389/frcha.2023.1094206

Duquette, P., & Ainley, V. (2019). Working with the predictable life of patients: The importance of 'mentalizing interoception' to meaningful change in psychotherapy. *Front. Psychol. 10.3389/fpsyg.2019.02173*

Fonagy, P., & Allison, E. (2021). What is mentalization? The concept and its foundations in developmental research. *Semantic Scholar.* 10.4324/9780203123003-8

Gabbiadini, A., Avincola, G., Fichera, C., Maccarone, G., Mineo, L., Rodolico, A., Bondi, E., & Signorelli, M. S. (2026). Emotion dysregulation and mentalization in adult attention-deficit/hyperactivity disorder. *Brain Sciences, 16*(7), 679. https://doi.org/10.3390/brainsci16070679

Hughes, K., Bellis, M. A., Hardcastle, K. A., Sethi, D.Butchart, A., & Milton, C. (2017). The effect of multiple adverse childhood experiences on health: A systematic review and meta-analysis. *The Lancet Public Health, 2*(8). www.thelancet.com/public-health

Long, T., Murphy, A., Elbarazi, I., Ismail Allouche Z., Horen, N., Masuadi, E., Trevithick, C., & Arafat, C. (2024). Prevalence of adverse childhood experiences and their cumulative impact associated lifetime health outcomes in the Emirate of Abu-Dhabi, United Arab Emirates. *Journal of Child*

Abuse and Neglect, 151. 12. 10.1016/j.chiabu.2024.106734

Spratt, T., Devaney, J., & Frederick, J. (2019). Adverse childhood experiences: Beyond signs of safety; reimagining the organisation and practice of social work with children and families. *British Journal of Social Work, 0.* 1-17. https://doi.org/10.1093/bjsw/bcz023

Wagner Skacel, J., Riedl, D., Kapmling, H., & Lampe, A. (2021). Mentalization and dissociation after adverse childhood experiences. *Scientific Reports, 12.* https://doi.org/10.1038/s41598-022-10787-8

Sven, R., & Andreas, S., (2021). Systematic review on mentalization as key factor in psychotherapy. *International Journal of Environmental Research and Public Health, 18*(17). 10.3390/ijerph18179161

Shayegh, E., Ghanbari, S., & Shahidi, S. (2023). The mediating role of mentalization in the relationship between childhood trauma and attachment security and adulthood. *International Journal of Behavioral Sciences, 17*(2), 73-81. 10.30491/ijbs.2023.379916.1893

Zhang, N., Man, G., Yu, J., Qiang, Z., & Wiguang, G. (2022). Understanding the association between adverse childhood experiences and subsequent attention deficit hyperactivity disorder: A systematic review and meta-analysis of observational studies. *Brain and Behavior, 12*(10). 10.1002/brb3.2748

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE MEDIATING ROLE OF PERCEIVED ORGANIZATIONAL SUPPORT IN THE RELATIONSHIP BETWEEN WORK-LIFE BALANCE AND WELL-BEING AT WORK AMONG GEN Z TOURISM EMPLOYEES: THE CASE OF ANTALYA

Mustafa Tuncer OKUMUŞ
Şehriban Buse BAYSAL
0000-0002-6495-3252, Kahramanmaraş Sütçü İmam University, Faculty of Humanities and Social Sciences, Department of Psychology, Kahramanmaraş, Türkiye.
0009-0006-5066-6494, Kahramanmaraş Sütçü İmam University, Faculty of Humanities and Social Sciences, Department of Psychology, Kahramanmaraş, Türkiye.

Abstract

In today's labor-intensive tourism industry, reducing turnover rates among the young workforce (particularly Generation Z) and establishing a sustainable human resource management framework are of critical importance. The aim of this study is to examine the impact of work-life balance on well-being at work among new-generation tourism employees and to determine the mediating role of perceived organizational support in this relationship. The sample of the research consists of 386 new-generation tourism employees working in 4- and 5-star hotel enterprises in Antalya, Türkiye. Data were collected through convenience sampling using face-to-face and online survey techniques. The data were analyzed using the SPSS PROCESS Macro (Model 4) developed by Hayes (2022), alongside a bootstrapping procedure with 5,000 resamples. The findings indicate a statistically significant positive relationship between work-life balance and perceived organizational support ($b = 0.838$, $p < .001$) and well-being at work ($b = 0.799$, $p < .001$). When perceived organizational support was introduced as a mediator into the model, the direct effect of work-life balance on well-being at work decreased but remained statistically significant ($b = 0.420$, $p < .001$). The bootstrapping analyzes indicated that the indirect effect (Effect = 0.378, 95% BootCI [0.283; 0.482]) was statistically significant, supporting the perceived organizational support as a partial mediator in the relationship. The study theoretically and empirically shows that flexible work arrangements improve the well-being of young tourism professionals, but these arrangements are most effective when supported by strong organizational support mechanisms.

Keywords: Work-Life Balance, Perceived Organizational Support, Well-Being at Work, Gen Z Employees, Tourism Industry, Antalya.

Introduction

Tourism is one of the strategic sectors of the Turkish economy and holds a critical position in terms of both foreign-exchange revenue and youth employment. Antalya, which hosts millions of visitors every year, is the country's busiest tourism destination, and this intensity makes the quality and sustainability of the workforce a decisive factor for the region. However, working in the hospitality industry involves long and irregular hours, seasonal work, a concentration of work on weekends and holidays, and high levels of emotional labor. Such features constrain employees' lives outside the work and increase burnout and turnover intentions (Deery & Jago, 2015).

The workforce of the sector has undergone a marked generational shift in recent years. Generation Z, born roughly after 1997, accounts for a growing share of hospitality employees. Compared with previous generations, this cohort is argued to place greater value on leisure, flexibility and life outside work, and to care about meaningful work and supportive supervisors (Twenge, 2010; Goh & Lee, 2018). Identifying the conditions that support the retention and well-being of young tourism employees is therefore important both for organizations and for regional human resource policies.

The positive association between work-life balance and employee well-being has been consistently demonstrated across cultures (Haar et al., 2014; Sirgy & Lee, 2018). However, the organizational processes that generate this relationship are unclear. Organizational support theory suggests that employees' general beliefs about the degree to which their organization values their contributions and cares about their well-being affect their work attitudes and well-being (Eisenberger et al., 1986; Kurtessis et al., 2017). An employee who can reconcile work and private life may interpret this as a sign that the organization cares for them, and this perception may in turn be reflected in well-being. Yet studies examining work-life balance, perceived organizational support and well-being at work together among Generation Z tourism employees are scarce.

The aim of this study is to examine the effect of work-life balance on well-being at work among new-generation tourism employees in Antalya and to test the mediating role of perceived organizational support in this relationship. By linking organizational support theory to the work-life interface literature, the study is expected to contribute both to theory and to human resource practices targeting young employees.

Conceptual Framework and Hypotheses

Work-Life Balance

Work-life balance refers to the reciprocal interaction, in both its negative and positive aspects, between an individual's work role and non-work roles such as family, friends, leisure and personal development. Early research focused mainly on conflict between roles (Greenhaus & Beutell, 1985), whereas later work showed that experiences in one role can improve the quality of life in another, that is, roles can enrich each other (Greenhaus & Powell, 2006). Combining these two perspectives, Fisher, Bulger and Smith (2009) defined work-life balance through four dimensions: work interference with personal life, personal life interference with work, work enhancement of personal life and personal life enhancement of work. Within this framework, high work-life balance denotes low negative spillover and high positive spillover.

Perceived Organizational Support

Perceived organizational support refers to employees' global beliefs about the extent to which their organization values their contributions and cares about their well-being (Eisenberger et al., 1986). According to social exchange theory, employees evaluate favorable treatment by the organization through the norm of reciprocity and respond with positive attitudes and behaviors toward it (Blau, 1964). Meta-analytic evidence shows that perceived organizational support is strongly and positively related to job satisfaction, affective commitment and subjective well-being, and that fair treatment, supervisor support and favorable job conditions are among its main antecedents (Rhoades & Eisenberger, 2002; Kurtessis et al., 2017).

Well-Being at Work

Well-being at work is a multidimensional construct encompassing employees' positive evaluations of their life in general, their job and themselves. Zheng, Zhu, Zhao and Zhang (2015) conceptualized employee well-being in three dimensions: life well-being, workplace well-being and psychological well-being. Because it defines well-being not merely as job-specific satisfaction but as a holistic experience at the intersection of work and life, this approach provides a suitable framework for work-life balance research.

Relationships Among the Variables and Hypotheses

According to conservation of resources theory, individuals are motivated to protect and accumulate the resources they value, such as time, energy and relationships, and the loss or threatened loss of these resources creates stress (Hobfoll, 1989). When work and private life do not deplete but rather nourish each other, the employee's resources are preserved and expanded, which is expected to enhance well-being. Indeed, a study conducted across seven cultures found that work-life balance was positively related to job and life satisfaction and negatively related to anxiety and depression (Haar et al., 2014). Accordingly, the following hypothesis was formulated:

H1: Work-life balance positively affects well-being at work.

Employees largely attribute their ability to balance work and private life to organizational practices such as shift scheduling, leave policies, workload distribution and supervisor understanding. A balanced work-life experience may therefore be read as a signal that the organization cares about the employee's well-being. Kossek, Pichler, Bodner and Hammer (2011) showed meta-analytically that organizational support is strongly and negatively related to work-family conflict, and organizational support theory holds that perceived support enhances well-being by fulfilling employees' socioemotional needs (Kurtessis et al., 2017). In line with this reasoning, the following hypotheses were formulated:

H2: Work-life balance positively affects perceived organizational support.

H3: Perceived organizational support positively affects well-being at work.

H4: Perceived organizational support mediates the relationship between work-life balance and well-being at work.

Materials and Methods

Research Design

The study is a cross-sectional study based on a quantitative, correlational survey design. In the research model, work-life balance is the independent variable, perceived organizational support is the mediator and well-being at work is the dependent variable (Figure 1).

Population and Sample

The population consists of new-generation employees aged 18–44 working in hotels and tourism enterprises in Antalya. The sample was determined through convenience sampling, and data were collected between 15 February and 15 June 2026 through face-to-face and online surveys. A total of 386 employees working in 4- and 5-star hotels in the Manavgat, Serik, Kemer, Kaş, Belek, Alanya, Muratpaşa, Kepez and Konyaaltı districts of Antalya participated in the study.

Of the participants, 38.9% were aged 18–21, 37.3% were aged 22–30 and 23.8% were aged 31–44; in other words, 76.2% of the sample falls within the Generation Z age range (18–30). Most participants were male (54.9%), single (66.1%) and high-school graduates (63.7%). The proportion of those with four years or less of tenure in the sector was 70.2%. Most participants worked in the kitchen (52.6%) and food and beverage (23.3%) departments, followed by the front office (11.1%), housekeeping (5.7%) and other units such as security, human resources and administration (7.3%).

Measures

Demographic Information Form. The form prepared by the researchers asked about participants' age, gender, marital status, education, department, position, tenure in the tourism sector and in the current establishment, and the district in which they work.

Work-Life Balance Scale. The scale developed by Fisher et al. (2009) and adapted into Turkish by Ekinci and Sabancı (2021) consists of 17 items and four subdimensions: work interference with personal life (5 items), personal life interference with work (6 items), work enhancement of personal life (3 items) and personal life enhancement of work (3 items). Items are rated on a five-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). In the adaptation study, the internal consistency coefficients of the subdimensions ranged from .70 to .91. The total work-life balance score was calculated as the mean of the 17 items after reverse-coding the interference items (1–11); higher scores indicate better work-life balance.

Perceived Organizational Support Scale. The nine-item form of the scale developed by Eisenberger et al. (1986) and adapted into Turkish by Yokuş (2006) was used (sample item: "The organization I work for really cares about my well-being and happiness"). Items are rated on a five-point Likert scale. Three negatively worded items (6, 7 and 9) were reverse-coded; higher scores indicate higher perceived organizational support.

Well-Being at Work Scale. The scale developed by Zheng et al. (2015) and adapted into Turkish by Güzel and Mamatoğlu (2024) consists of 18 items and three subdimensions: life well-being, workplace well-being

and psychological well-being. In the adaptation study, the internal consistency coefficients of the subdimensions were .92, .93 and .88, respectively. Items are rated on a five-point Likert scale, and higher total scores indicate higher well-being.

Ethics Approval

Ethics approval for the study was obtained from the Scientific Research and Publication Ethics Committee of Kahramanmaraş İstiklal University (Date: 26.12.2025; Decision No: 2025/15-07). Written permission was obtained from the authors of the scales used. Participants were informed about the purpose of the study, voluntary participation was ensured and informed consent was obtained at the beginning of the survey. No identifying information was collected.

Data Analysis

Data were analyzed using SPSS and Hayes' (2022) PROCESS Macro (version 5.0). Scale scores were calculated as the average of the items answered by each participant, after reverse-coding as described above. Reliability was tested using Cronbach's alpha and bivariate relationships using Pearson correlation coefficients. The normality was checked by the skewness and kurtosis values, with ±2 as the criterion (Kline, 2016). To check the common method variance, Harman's single-factor test was used (Podsakoff et al., 2003). The mediation hypothesis was tested by using the PROCESS MODEL 4. The significance of the indirect effect was assessed with percentile bootstrap confidence intervals based on 5,000 resamples, and a confidence interval excluding zero was taken as evidence of significance (Preacher & Hayes, 2008; Hayes, 2022). The robustness of the findings was examined through three additional analyses: (i) adding age, gender and tenure in the sector as covariates, (ii) repeating the analysis only among participants aged 18–30 (Generation Z), and (iii) recalculating the work-life balance score after removing the first five items, which did not behave in the expected direction.

Findings and Discussion

Preliminary Analyses

Descriptive statistics, reliability coefficients and correlations are presented in Table 1. Skewness and kurtosis values for all variables were within ±2, and the distributions were considered normal. The reliability of the perceived organizational support (α = .75) and well-being at work (α = .85) scales was adequate (Nunnally & Bernstein, 1994), whereas the internal consistency of the total work-life balance score was low (α = .52). At the subdimension level, work interference with personal life (α = .77), personal life interference with work (α = .85) and personal life enhancement of work (α = .85) showed adequate reliability, while work enhancement of personal life showed low reliability (α = .22). Item-level inspection revealed that the first five items measuring work interference with personal life (e.g., "I come home from work too tired to do things I would like to do"), unlike the other interference items, were positively related to organizational support and well-being, which lowers the internal consistency of the total score. Therefore, in addition to the main analysis, a sensitivity analysis was conducted using a 12-item work-life balance score excluding these items (α = .78).

Table 1. Descriptive Statistics, Reliability Coefficients and Correlations (*N* = 386)

Variable	*k*	*M*	*SD*	Skew.	Kurt.	α	1	2	3
1. Work-life balance	17	3.28	0.39	−0.11	−0.44	.52	—		
2. Perceived organizational support	9	3.31	0.64	−0.50	−0.12	.75	.52***	—	
3. Well-being at work	18	3.81	0.55	−0.31	−0.95	.85	.57***	.67***	—

Note. k = number of items; M = mean; SD = standard deviation; Skew. = skewness; Kurt. = kurtosis. Score range is 1–5. ***$p < .001$.

According to the correlation analysis, work-life balance was positively and moderately related to perceived organizational support ($r = .52$, $p < .001$) and well-being at work ($r = .57$, $p < .001$), while perceived organizational support was positively and strongly related to well-being at work ($r = .67$, $p < .001$). In

Harman's single-factor test conducted with all 93 scale items, the unrotated single factor explained 28.2% of the total variance. As this is below the 50% threshold, common method variance was not considered to seriously bias the findings (Podsakoff et al., 2003).

Hypothesis Tests

The regression results for the mediation model are presented in Table 2, and the direct, indirect and total effects in Table 3 and Figure 1.

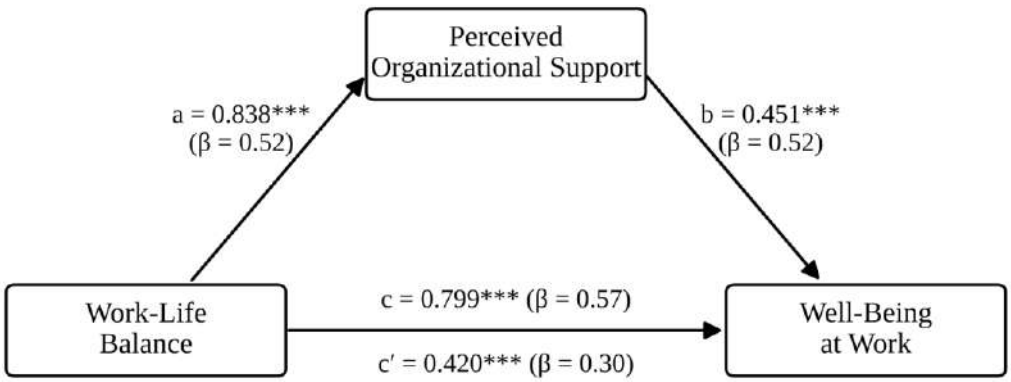
Table 2. Regression Results for the Mediation Model (PROCESS Model 4, *N* = 386)

	Perceived organizational support (M)			Well-being at work (Y)			Well-being at work (total effect)		
Predictor	*b*	*SE*	*t*	*b*	*SE*	*t*	*b*	*SE*	*t*
Constant	0.559	0.233	2.40*	0.939	0.166	5.67***	1.191	0.195	6.11***
Work-life balance	0.838	0.071	11.87***	0.420	0.058	7.23***	0.799	0.059	13.53***
Perceived organizational support				0.451	0.036	12.55***			
R^2		.269			.520			.323	
F		140.93***			207.73***			183.15***	

Note. b = unstandardized regression coefficient; SE = standard error. df = (1, 384) for the M model, (2, 383) for the Y model and (1, 384) for the total effect model. *p < .05; ***p < .001.

Work-life balance positively and significantly predicted well-being at work (b = 0.799, SE = 0.059, t = 13.53, p <.001, 95% CI [0.683, 0.915]) explaining 32.3% of its variance (see Table 2). Thus, H1 was supported. Work-life balance also predicted perceived organizational support significantly (b = 0.838, SE = 0.071, t = 11.87, p <.001, 95% CI [0.699, 0.977], R^2 =.269) supporting H2. Controlling for work-life balance, perceived organizational support positively and significantly predicted well-being at work (b = 0.451, SE = 0.036, t = 12.55, p < .001, 95% CI [0.381, 0.522]), supporting H3. In total, work–life balance and perceived organizational support accounted for 52.0 % of the variance in well-being at work.

Figure 1. Research Model and Results of the Mediation Analysis



Note. Coefficients are unstandardized; standardized coefficients (β) are given in parentheses. c = total effect; c′ = direct effect.

Table 3. Total, Direct and Indirect Effects and Robustness Analyses

Analysis	*n*	Total effect (c)	Direct effect (c′)	Indirect effect [95% BootCI]	Std. indirect effect [95% BootCI]
Main analysis	386	0.799***	0.420***	0.378 [0.283, 0.482]	0.27 [0.20, 0.34]
With covariates[a]	383	0.778***	0.419***	0.358 [0.266, 0.464]	0.26 [0.19, 0.33]
Aged 18–30 only (Gen Z)	294	0.823***	0.465***	0.358 [0.261, 0.467]	0.26 [0.19, 0.34]
WLB without first five items[b]	386	0.671***	0.498***	0.173 [0.104, 0.234]	0.20 [0.12, 0.27]

Note. Indirect effect: Work-life balance → Perceived organizational support → Well-being at work. BootCI = percentile bootstrap confidence interval based on 5,000 resamples. Std. = completely standardized effect. WLB = work-life balance. [a]Controlling for age, gender and tenure in the sector. [b]Work-life balance score based on items 6–17 (α = .78). ***$p < .001$.

The bootstrap results showed that the indirect effect of work-life balance on well-being at work through perceived organizational support was significant (b = 0.378, BootSE = 0.051, 95% BootCI [0.283, 0.482]). The confidence interval did not include zero, and the completely standardized indirect effect was 0.27. When the mediator was added to the model, the effect of work-life balance on well-being at work decreased from 0.799 to 0.420 but remained significant ($p < .001$, 95% CI [0.306, 0.535]); approximately 47% of the total effect was transmitted through perceived organizational support. These findings indicate that perceived organizational support partially mediates the relationship between work-life balance and well-being at work, supporting **H4** (Zhao et al., 2010).

The robustness analyses supported the main finding (Table 3). The indirect effect remained significant when age, gender and tenure were controlled. When the analysis was repeated with the 294 participants within the Generation Z age range, the results were nearly identical to those for the full sample. When the first five items, which did not behave in the expected direction, were removed, the indirect effect became smaller (b = 0.173) but remained significant, and the direct effect also remained significant. Thus, the partial mediation pattern is consistent regardless of which items are used to compute work-life balance.

Discussion

The first finding of the study is that young tourism employees with higher work-life balance also report higher well-being at work. This result is consistent with cross-cultural evidence that work-life balance is positively related to job and life satisfaction (Haar et al., 2014) and with theoretical accounts that treat work-life balance as a key determinant of subjective well-being (Sirgy & Lee, 2018). From the perspective of conservation of resources theory, an arrangement in which work does not deplete private life and private life energizes work preserves the employee's time and energy resources, which is reflected in well-being (Hobfoll, 1989). Preserving these resources is especially important in hotel establishments, where seasonal peaks and shift work are common.

The second finding is that work-life balance is strongly and positively related to perceived organizational support. Employees largely attribute their ability to reconcile work and private life to organizational practices such as shift scheduling, leave arrangements and supervisor understanding, and they therefore interpret a balanced work-life experience as a sign that the organization cares for them. This finding is in line with meta-analytic evidence of a strong relationship between organizational support and work-family conflict (Kossek et al., 2011). The third finding, the strong relationship between perceived organizational support and well-being at work, is consistent with the core proposition of organizational support theory: employees who believe that their organization values them feel that their socioemotional needs are met, and their evaluations of their work and life become more positive (Rhoades & Eisenberger, 2002; Kurtessis et al., 2017).

The study's main finding is that perceived organizational support mediates partially the relationship between work-life balance and well-being at work. About half of the effect of work-life balance on well-being is mediated by employees' perception of work-life balance as a sign of organizational support. The other half is the direct effect. This pattern suggests that work-life balance contributes to well-being both directly, as a

personal resource, and indirectly, through a social exchange process (Blau, 1964; Hobfoll, 1989). For Generation Z employees, who are argued to value flexibility and leisure (Goh & Lee, 2018), the findings suggest that work-life arrangements are valuable, but that their effects become markedly stronger when they are perceived as a concrete expression of organizational support.

Conclusion and Recommendations

This study examined the relationships among work-life balance, perceived organizational support and well-being at work among 386 new-generation tourism employees working in 4- and 5-star hotels in Antalya. The results show that work-life balance enhances well-being at work both directly and indirectly through perceived organizational support. The partial mediating role of perceived organizational support remained consistent when covariates were added, when only the Generation Z age group was examined and when work-life balance was scored differently.

The findings have a number of practical implications for tourism establishments. First, practices that foster work-life balance, such as predictable shift scheduling, equitable distribution of leave, and opportunities for rest during the season, directly contribute to the well-being of young employees. Second, the effect of these practices is strengthened when employees perceive them as a sign that the organization cares about them. It is therefore recommended that flexible arrangements be implemented not in isolation but together with supportive practices such as supervisor support, regular feedback, consideration of employee suggestions and constructive handling of mistakes. Third, since kitchen and food and beverage employees, who make up a large part of the sample, work in the most fast-paced units of the sector, prioritizing these units in work-life balance interventions may be beneficial.

The study has some limitations. First, owing to the cross-sectional design, the relationships among the variables should not be interpreted as causal; testing their direction with longitudinal or experimental designs is recommended. Second, all data were collected from the same source through self-report; although Harman's test indicated that common method variance was not a serious concern, this possibility cannot be ruled out completely. Third, convenience sampling and data collection in a single province limit generalizability. Fourth, the internal consistency of the total work-life balance score was low, and the items measuring work interference with personal life showed an unexpected pattern. Although the sensitivity analysis indicated that the main result did not change, examining the construct validity of the scale among tourism employees with confirmatory factor analysis and conducting subdimension-level analyses are recommended. Finally, the sample also includes participants aged 31–44; although the analysis restricted to Generation Z yielded the same result, future studies comparing generations would contribute to the literature.

Thanks and Information Note

We thank the tourism employees who voluntarily participated in the study. This paper is based on data from the research project entitled "The Effect of Work-Life Balance, Job Satisfaction, Perceived Organizational Support, and Psychological/Well-Being at Work on Work Engagement and Organizational Commitment Among New Generation Tourism Sector Employees: The Case of Antalya", conducted by Şehriban Buse Baysal under the supervision of Assist. Prof. Dr. Mustafa Tuncer Okumuş. Ethics approval was obtained from the Scientific Research and Publication Ethics Committee of Kahramanmaraş İstiklal University (Date: 26.12.2025; Decision No: 2025/15-07). The authors declare no conflict of interest. This work is supported by the **Scientific and Technological Research Council of Turkey (TÜBİTAK)** under the **2209-A** Research Project Support Programme for Undergraduate Students with the project number **[1919B012537203]**.

References

Blau, P. M. (1964). *Exchange and power in social life*. Wiley.

Deery, M., & Jago, L. (2015). Revisiting talent management, work-life balance and retention strategies. *International Journal of Contemporary Hospitality Management, 27*(3), 453–472. https://doi.org/10.1108/IJCHM-12-2013-0538

Eisenberger, R., Huntington, R., Hutchison, S., & Sowa, D. (1986). Perceived organizational support. *Journal of Applied Psychology, 71*(3), 500–507. https://doi.org/10.1037/0021-9010.71.3.500

Ekinci, H., & Sabancı, A. (2021). İş-yaşam dengesi ölçeği'nin Türkçeye uyarlanması: Geçerlik ve güvenirlik çalışması. *Trakya Eğitim Dergisi, 11*(1), 151–163. https://doi.org/10.24315/tred.690816

Fisher, G. G., Bulger, C. A., & Smith, C. S. (2009). Beyond work and family: A measure of work/nonwork interference and enhancement. *Journal of Occupational Health Psychology, 14*(4), 441–456. https://doi.org/10.1037/a0016737

Goh, E., & Lee, C. (2018). A workforce to be reckoned with: The emerging pivotal Generation Z hospitality workforce. *International Journal of Hospitality Management, 73*, 20–28. https://doi.org/10.1016/j.ijhm.2018.01.016

Greenhaus, J. H., & Beutell, N. J. (1985). Sources of conflict between work and family roles. *Academy of Management Review, 10*(1), 76–88. https://doi.org/10.5465/amr.1985.4277352

Greenhaus, J. H., & Powell, G. N. (2006). When work and family are allies: A theory of work-family enrichment. *Academy of Management Review, 31*(1), 72–92. https://doi.org/10.5465/amr.2006.19379625

Güzel, H., & Mamatoğlu, N. (2024). İş yerinde iyi oluş ölçeğinin uyarlama çalışması. *Current Research and Reviews in Psychology and Psychiatry, 4*(1), 1–14.

Haar, J. M., Russo, M., Suñe, A., & Ollier-Malaterre, A. (2014). Outcomes of work-life balance on job satisfaction, life satisfaction and mental health: A study across seven cultures. *Journal of Vocational Behavior, 85*(3), 361–373. https://doi.org/10.1016/j.jvb.2014.08.010

Hayes, A. F. (2022). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (3rd ed.). Guilford Press.

Hobfoll, S. E. (1989). Conservation of resources: A new attempt at conceptualizing stress. *American Psychologist, 44*(3), 513–524. https://doi.org/10.1037/0003-066X.44.3.513

Kline, R. B. (2016). *Principles and practice of structural equation modeling* (4th ed.). Guilford Press.

Kossek, E. E., Pichler, S., Bodner, T., & Hammer, L. B. (2011). Workplace social support and work-family conflict: A meta-analysis clarifying the influence of general and work-family-specific supervisor and organizational support. *Personnel Psychology, 64*(2), 289–313. https://doi.org/10.1111/j.1744-6570.2011.01211.x

Kurtessis, J. N., Eisenberger, R., Ford, M. T., Buffardi, L. C., Stewart, K. A., & Adis, C. S. (2017). Perceived organizational support: A meta-analytic evaluation of organizational support theory. *Journal of Management, 43*(6), 1854–1884. https://doi.org/10.1177/0149206315575554

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology, 88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40*(3), 879–891. https://doi.org/10.3758/BRM.40.3.879

Rhoades, L., & Eisenberger, R. (2002). Perceived organizational support: A review of the literature. *Journal of Applied Psychology, 87*(4), 698–714. https://doi.org/10.1037/0021-9010.87.4.698

Sirgy, M. J., & Lee, D.-J. (2018). Work-life balance: An integrative review. *Applied Research in Quality of Life, 13*(1), 229–254. https://doi.org/10.1007/s11482-017-9509-8

Twenge, J. M. (2010). A review of the empirical evidence on generational differences in work attitudes. *Journal of Business and Psychology, 25*(2), 201–210. https://doi.org/10.1007/s10869-010-9165-6

Yokuş, İ. (2006). *Erkek egemen işlerde çalışanların örgütsel destek algıları ve örgütsel bağlılıkları arasındaki ilişki* [Unpublished master's thesis]. Hacettepe University, Institute of Social Sciences.

Zhao, X., Lynch, J. G., Jr., & Chen, Q. (2010). Reconsidering Baron and Kenny: Myths and truths about mediation analysis. *Journal of Consumer Research, 37*(2), 197–206. https://doi.org/10.1086/651257

Zheng, X., Zhu, W., Zhao, H., & Zhang, C. (2015). Employee well-being in organizations: Theoretical model, scale development, and cross-cultural validation. *Journal of Organizational Behavior, 36*(5), 621–644. https://doi.org/10.1002/job.1990

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

DEEP LEARNING-BASED WEED DETECTION, SEGMENTATION AND SPATIAL MAPPING FOR PRECISION WEED MANAGEMENT

Emine KAYA ALTOP
Prof. Dr., Ondokuz Mayıs University, Faculty of Agriculture, Department of Plant Protection, Samsun, Turkiye
ORCID ID: https://orcid.org/0000-0002-0987-9352
Sine KAYA
Ph.D., Ondokuz Mayıs University, Graduate School of Natural and Applied Sciences, Department of Plant Protection, Samsun, Turkiye
ORCID ID: https://orcid.org/0000-0002-4219-9148

Abstract

Weeds are spatially heterogeneous competitors that, through competition, lower crop productivity and complicate weed control and maintenance of crops. Application of herbicides uniformly can result in the unnecessary use of chemicals when the distribution of weeds is patchy. Computer vision in combination with deep learning is a technique that allows the identification of weeds at the level of crops or individual pixels and produces spatially detailed weed maps for the use in location- specific management of crops. Research has come of age from the use of traditional vegetation indices through CNN-based classification to object detection, semantic segregation, multispectroscopy, drone mapping, and foundation-model techniques.
The weed population varies in space and, therefore, a system of precision management must reflect such spatial heterogeneity to be efficient. Seed-bed disruption, seed-bank distribution, crop population, soil moisture, temperature, and the history of weed elimination are factors that influence seed germination. Thus, it is perfectly legitimate to find two locations within one field having totally different kinds of weeds and the number of weeds respectively. It is helpful to have a field-scale AI tool because, instead of considering the whole field as one homogeneous unit, it can transform such heterogeneity into spatial information. Based on existing literature, this study provides information on deep learning-based weed detection, segmentation, and mapping for precision weed management.

Keywords: weed detection; deep learning; semantic segmentation; precision weed management; UAV; object detection; computer vision.

Introduction

The development phase of computer vision techniques for weed detection has come from color-based color-only rules to highly elaborated learning systems. In the older approaches, vegetation indices or selected features based on the image were used quite frequently. In well-controlled lighting conditions and in relatively simple backgrounds, these approaches can give satisfactory results. However, they can be expected to fail if crop and weed leaves blend together, if soil colors change, or if shadows interfere with the visible spectral reflectances of plants.

Deep learning presents a more adaptable representation since features may be extracted directly from huge image samples (Hasan et al., 2021; Rai & Al., 2023). It is a significant factor to recognize that distinguishing between weed identification and recommending for management is two different things. An image classification model can, for instance, confirm the presence of weed, yet precision agriculture usually demands supplementary details such as localization, abundance, plant species, and spatially continuity. In practice, there is a movement from visual recognition through identification of location, estimation of the number of objects, mapping, and finally decision making. This movement is important for the construction of field-level intelligent weed management systems (Liu & Bruch, 2020; Rai et al., 2023).

A point for a serious thinker is the portability of models across different environments. It is quite possible that a model derived from a regional set of images may come upon quite different weed types, crops, soils, camera setups and growth stages when moved to another region. The generalization issue is thus to consider at the stage of dataset construction and not only when the model is ready.

A model is more likely to serve precision weed control needs in an operational setting if it is trained to handle variation in field conditions, the seasonality of plants, and realistic backgrounds (Hasan et al., 2021; Olsen et al., 2019). Traditional weed control often treats a field as spatially homogeneous. The actual weed distribution may be highly patchy. Precision weed management attempts to identify these patches and apply control selectively (Liu & Bruch, 2020; Rai et al., 2023).

Weed Detection to Site-Specific Control: Field Image→ Deep Learning→ Crop / Weed Separation→ Weed Localization→ Weed Density→ Weed Map→ Prescription Map→ Targeted Herbicide / Mechanical Control

Weed Classificiton

Classification is the first stage of automatic interpretation, where an image/patch or plant is assigned a category. If the purpose is merely weed vs. nonweeds then the categories would just be the weeds. If, however, the goal is to identify different weed species then the plant is classified down to a species level. While species-level classification may be beneficial when different species have different control options, it also adds a layer of complexity because closely related species can have similarly looking leaves and spectral signatures (Hasan et al., 2021; Rai et al., 2023).

The effectiveness of classification relies heavily on the characteristics of the training dataset. Therefore, it is imperative that the selection of images reflect all aspects of the conditions in which the model is to be implemented. These conditions would involve variation in plant size, orientation, visibility of the plant, presence, or absence of the soil background, lighting conditions, crop development stages.

If the pictures used for training predominantly feature lonely weeds on clean background then a machine learning algorithm could pick up such a visual cue and consequently fail at accurately recognizing weeds in realistic cropcanopies (Hasan et al., 2021; Olsen et al., 2019).

Appropriate choice of measures must accompany the performance evaluation. Overall accuracy is not a reliable indicator when different classes are very unbalanced in size. More details on the performance characteristics can be obtained from Precision, Recall, F1-score, class-specific sensitivity, and confusion matrices. With regard to agricultural use, such parameters shall ideally be complemented with measures that refer to a field level and that show whether classification errors significantly affect the resultant management decision (Hasan et al., 2021).

The DeepWeeds dataset is of special significance here because it was created using photos from natural rangeland situations rather than laboratory-controlled scenarios. Such sets give access to the variety of the real-world. Still, no one dataset can encompass all sorts of farming environments; this means that validation of these models outside the dataset must be carried out before commercial deployment (Olsen et al., 2019).

Classification refers to the process of identifying a weed in a image or the species of a weed. One of the main resources in weed identification is the DeepWeeds dataset. Olsen et al. have introduced 17,509 pictures of eight weed species taken in the Australian rangeland settings as a part of their work (2019). The deep network,ResNet-50, delivered an average accuracy of 95.7% in the baseline setup proposed in the paper (ResNet-50, 2012) - see the section on Deep Convolutional Neural Networks here (Table 1).

Table 1. Weed AI Tasks

Task	Output	Management value
Binary classification	Weed/no weed	Basic

Task	Output	Management value
Species classification	Weed species	High
Object detection	Weed bounding boxes	High
Semantic segmentation	Pixel classes	Very high
Instance segmentation	Individual plants	Very high
Density estimation	Weed abundance	Very high
Mapping	Spatial distribution	Very high

Semantic Segmentation

The process of semantic segmentation is considered to be one of the higher levels of interpretation that involves assigning a category to individual pixels. Within a cropped landscape, the computer can differentiate the three main elements: crops, weeds, and the background, and at the same time. This kind of a segmentation image can then be used to measure the weed area in the field by counting the weed-occupied pixels as well as to analyze in detail the shape and position of the weeds (Milioto et al., 2018; Rai et al., 2023).

Weed segmentation is one of the important aspects of robotic weed control because the robot needs to pinpoint the location of the target plant or area for the treatment. The accuracy of the segmented region determines how close the mechanical harvesting devices can get to the ground for digging, harvesting, or spraying etc. Small variations can cause the loss of the whole field but are tolerated for general spraying areas where the plant-specific treatment is not expected (Milioto et al., 2018).

Semantic segmentation is also computationally expensive. In high-resolution imagery, millions of pixels, combined with field-scale processing requirements may demand a very large memory and a long processing time. Efficient network architectures, image tiling, appropriate spatial resolution, and edge-computing strategies may accordingly be required for real-time/NRT (near real-time applications).

Combining the information of Semantic and Instance segmentation has been identified as one of the critical research directions. Through semantic segmentation, one can identify the weed category pixels. Through instance segmentation alone, the weeds of different species would get the right weed identification even after being in the same category.

Which kind of representation suits the situation will depend on the desired outcome in management of the area: a total weed cover estimate might be done based on a semantic segmentation while the use of herbicides or other robotic tools on a plant-by-plant basis will require an instance level detection method. (Rai et al., 2023). Real-time agricultural robotics were a focus area in the study by Milioto et al. (2018) where the authors deployed CNNbased semantic segmentation to classify plant, weed and background of sugar beet using RGB images in real-time.

Multıspectral Weed Detectıon

Multispectral imging is a technique used for extending the RGB image analysis to include information from other spectral bands. The spectral reflectance differences of plant components vary based on the radiation type and wavelength they absorb and reflect which makes spectral data extremely helpful for detecting vegetation types. Incorporating near-infrared or red-edge data will result in an improved discriminatory power when the sole RGB color information is lacking (Sa al. et 2018; Rai et al., 2023).

Vegetation Indices are able to capture vegetation characteristics by summarising the relationship between different parts of the spectrum. Nevertheless, one should not overgeneralize by treating it as a one-size-fits-all solution for weed detection. Both the crop and the weed plants are likely to show similar physiological traits, especially when they are in the same growth phase, or subjected to identical environmental stressors.

Therefore, the use of multispectral imaging should be limited to being one part in a multiple-feature classification framework (Sa et al., 2018; Hasan et al., 2021).

Proper calibration of the sensor and the uniformity of the sensor across different sensors are very important when a training system involves multispectral images as inputs. If a particular sensor or acquisition procedure is strongly represented in the model, a model will erroneously associate these features with the crop versus weed classes. Calibration procedures that comply with industry standards and the use of different data in the training can help in preventing that error (Sa et al., 2018) .

One of the main limitations that multispectral detection introduces is the trade-off between sensor accuracy and cost. Adding a new sensor gives the ability to extract more information and to separate things better but it makes the sensor system more complex, there is a higher data volume and processing requirement. It is therefore quite reasonable that sensor configuration that is finally chosen for a particular situation is the one that is most in accord with one's required accuracy level, field conditions, platform capability, and economic viability. (Hasan et al., 2021; Rai et al., 2023). Vegetation indices serve as an efficient way of distinguishing between crops and weeds. The work done by Sa et al. (2018) made a combination of multispectral images and SegNet with different channel inputs, thereby performing dense semantic weed classification (Figure 2).

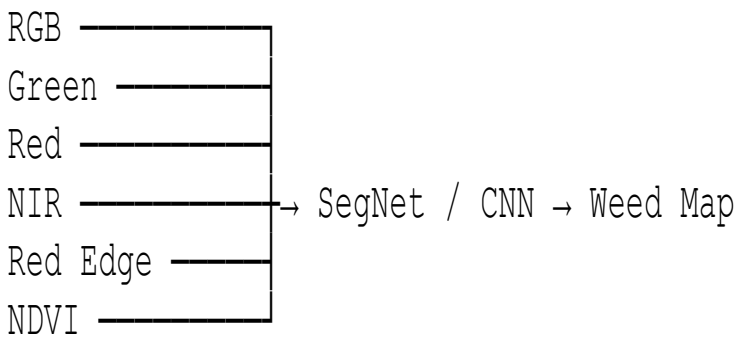


Figure 2 . Multispectral weed detection

UAV-Based Weed Mapping

With U AV -based mapping, a new dimension is introduced to weed detection because it covers the mapping of individual images and field -scale spatial products . As the spatial resolution has to be adequately sufficient to the level of detail which is necessary without being too big that you can't complete the area efficiently is the key issue in such mapping. In order for image tiles from a large area that a single aerial view might include to become weed maps, that is continuous and georeferenced a proper system for storing the dataset should be established (Sa et al., 2018; Rai et al., 2023).

High-resolution map making using large amounts of images is a tricky business involving precise manipulation of the quality of the images, alignment of the sensors, etc. Multispectral data have to be synchronized spatially, the image patches have to retain enough contextual details that the computer vision system can use to tell apart the crop from the weed. If they are not properly aligned, then it's quite likely that your system will start seeing the wrong things like, say, lines from one picture ending up as edges, or spectral changes as plant differences and so on, which are completely different phenomena (Sa et.al., 2018).

Having a weed map alone would be of limited value unless it can also be a comparison against existing agricultural data. One can overlay weed patches with the locations of the crop plants, soil profiles, field outline, or weed infestation map from before. Such overlay of maps could indicate which areas of the field have been more weed-prone and thereby can be more informative for seed-bank management and monitoring (Rai et al., 2023).

Uncertainty is another factor that maps should be able to account for. Certain areas of an image, which have been taken at the ground level, e.g., where crops or weed cover is thick, or have bad camera angles, can provide a very low confidence level of the predictions they make. In order to make a map, which people actually believe in and are willing to act upon, it would be a good idea to incorporate indicators of confidence or quality to it, showing those regions on a field where more careful observation by the growers may be necessary (Rai et al., 2023).

Field-scale maps generated by remotely piloted unmanned vehicles (UAVs) are becoming the norm. The WeedMap project was a successful case of finding the best image resolution and multispectral channel alignment. Additionally, it tackled large orthomosaic processing. By using nine-channel data input, the scientists were significantly enhancing the AUC metric compared to three-channel colour image. This is a clear example of how details such as sensor alignment or spatial resolution are not purely engineering problems but direct factors in the performance of machine learning systems (Sa et al., 2018).

Deep Weeds And Generalization

When agricultural computer vision is used in practice, it's really vital that the model can recognize the same patterns on different occasions. That is, even though the crop is still of the same kind, the weather or the soil can be very different, so the model's performance might drop dramatically when it is used in a different field, despite the fact that it performed really well there before (Hasan et al, 2022; Rai et al., 2023).

On the flip side, a diverse, representative database helps with generalization, but diversity can be interpreted in many different ways. Geographically diverse examples allow the model to encounter a variety of different climates and landscapes, while seasonal diversity will allow it to see plant stages of growth throughout the year, and operational diversity exposes its real-world variability of acquisition such as varying heights, lighting angles, etc.

Finally, when assessing the ability of a model to perform on a new dataset after being trained on a different dataset, one must be careful not to use data belonging to the same field/same location for both the train and evaluation set to the model. For example, if we use the same images from the same field at different times as the train and test set, we might end up overestimating the model's ability to generalize since they are, in the first place, visually very alike (Olsen et al., 2019; Hasan et al., 2021)

It's also worth mentioning that the species distribution follows a long tail phenomenon. Most of the time, a few weed species are the dominant ones that the farmer is familiar with or is interested in monitoring, while some other rare but potentially harmful ones that the farmer might want to watch are represented with just a few images in the datasets. If we're trying to make our ML model recognize these different species, the most frequent ones will get plenty of examples to be learned from, whereas the rare ones will never have enough data.

So, besides regular data balancing by class size, additional sampling strategies that specifically focus on the rarest classes and the use of proper performance metrics can be the solution to such situations (Saleh et al., 2023).

Situational generalization should be assessed only based on the performance of the model using different field-specific independent datasets. In other words, even if a model performs reasonably well on the data it was trained on, it's not a given that the model is ready to be used in field conditions. Testing the model against datasets which have never been seen is the right and most honest way to assess how well the model could perform on other conditions, for example, different soils or weather conditions (Hasan et al., 2021; Olsen et al., 2019).

The DeepWeeds model is trained solely on imagery captured under field conditions. This includes images where the weeds may be partially concealed or the weed may be present together with some background vegetation. This type of dataset is particularly valuable because field generalization remains one of the biggest obstacles to agricultural computer vision (Olsen et al., 2019; Hasan et al., 2021)

Recent Directions

The development of self-supervised and foundation model approaches is a shift in how agricultural image representations can be learned. Rather than depending entirely on huge quantities of manually labeled data, self-supervised methods can acquire general visual representations through unlabeled images and then apply the representations to specific tasks in agriculture (Saleh et al., 2023; Shen et al., 2025).

Contrastive learning is especially suitable for agricultural datasets because one could use visually similar images to train representations that remain effective across varying contexts. These kinds of methods may be of help in the case of restricted availability of labeled data and skewed data distributions although the results will always be affected by the diversity and quality of the underlying imagery. The results will largely depend on the characteristics of the base images.

Weed detection using the general vision model trained to perform weed detection could be another way of doing local adaptation. General model can provide quite broad image information that maybe helpful in understanding what is common in visual patterns of the regions. In this way local weed identification with these models may be carried out. Despite that, very large scale models cannot reduce the necessity for locally conducting checks. In agricultural situations there are still so many factors like crop type, region, sensor characteristics, management practices, and environmental conditions involved.

In addition to the aforementioned approaches it is predicted that research activities are going to focus on developing combined systems with a main model performing general task representation and field-task specific modules like segmentation, detection, and mapping working separately on farm level tasks. Such combined systems allow to have the advantages of wide-spread generalization as well a high level of accuracy that is expected for weed treatment management (Saleh et al., 2023; Shen et al., 2025).

R&D in AI for agriculture has lately centered on self-supervised and foundation-model techniques. One example is WeedCLR, a contrastive representation learning framework that helps with long-tailed dataset issues and achieves better results on popular weed datasets. In this way, this paper also indicated the potential of such models for local adaptation (Shen et al., 2025).

Table 2. Evolution of Weed AI

Generation	Technology	Main limitation
1	Color thresholding	Lighting sensitivity
2	Handcrafted features	Limited representation
3	CNN classification	Limited localization
4	Object detection	Small-object difficulty
5	Segmentation	Computational demand
6	Multispectral DL	Sensor cost
7	Self-supervised learning	Training complexity
8	Foundation models	Generalization and adaptation

Weed Density

Weed density management decisions are frequently based on the total number of weeds that are in a plot besides the variety of those weeds. For instance, one should have different management strategies for a plot where a couple of isolated weed species are present compared to a plot which has high weed density leading to significant crop competition. That being said and understood, density estimation is a very important step towards the linkage between image analysis outcomes and agronomic decision-making (Liu & Bruch, 2020; Rai et al., 2023).

Depending on the situation, density can be defined by several methods like number of detected plants per area unit, proportion of image pixels identified as weeds or percentage of management zones that exceeded a fixed threshold etc .The best measure to be used will be influenced by the imaging method and chosen herbicides etc. The plant count method could well be good if one is dealing with treatments applied only to individual plants; the percentage or cover area of weeds would be more meaningful with regard to spatial management (Rai et al., 2023).
For the purpose of determining whether the intervention to a field will result in a gain that is higher than its cost, a threshold for the density of weeds should be decided based on the factors of weeds and economics. Although a particular model may capture the continuous scale from very low weed numbers to very high weed numbers, management is about making decisions when one is sure that the benefits would exceed the costs of intervention. These types of thresholds vary depending on the crop life cycle stage, target weed, predicted loss in a yield, cost of the control, and the environmental conditions (Liu & Bruch, 2020).

Combination of density mappings with observations carried out throughout earlier years could reveal perpetual weed patches. Occurrences of repeating patterns across space are likely to be areas prone to pressure of seed-bank and to being good places for weeds to come up. Use of such information can lead to more integrated weed management plans with long-term goals rather than being limited to one-season control (Rai et al., 2023).

For management, weed density may be more useful than species classification alone.

A simple density measure is: $WD=ANw$

where Nw is the number of detected weed plants and A is the surveyed area.

For segmentation: $WC=AfAw\times100$

where Aw is weed pixel area and Af is total field-image area.

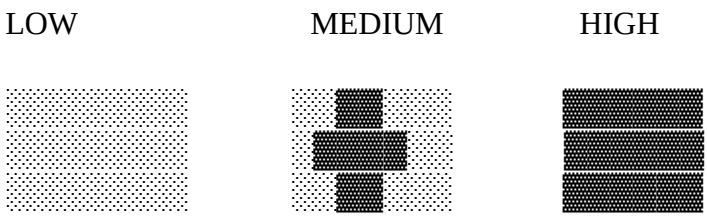


Figure 3. Weed Density Map

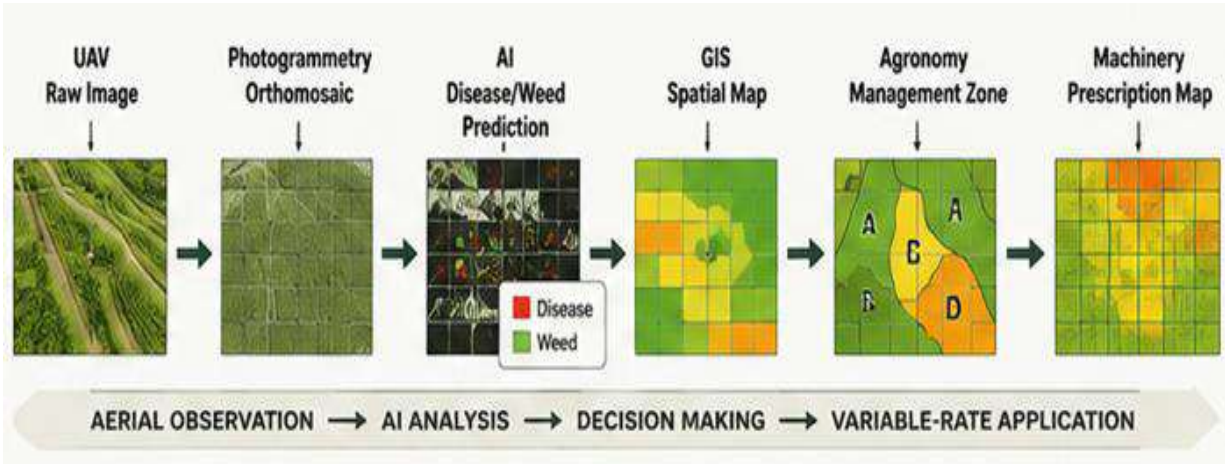


Figure 4. From image to decision

Discussion

Deep learning has allowed researchers to get much more accurate ways of detecting and even mapping various weeds. However, the move from high accuracy in experimental settings to deploying a trustworthy product out in the field is very difficult. Crop-and-weed similarity, leaf overlap, growth stage variability, shadows, changing soil backgrounds, different species of weeds, and fluctuations in surrounding conditions can all result in a reduction of model trustworthiness. These issues prove that agricultural computer vision is not only a question of pattern recognition but also one of environmental generalization (Hasan et al., 2021;Rai et al., 2023).
This means that merging different RGB (Red-Green-Blue) images and multispectral data can help the models get more details. Still, just having more data may not lead to more accurate farming decisions. The choice of sensors is mainly dependent on what is the main feature of interest - the biology - and what limits the operation of farm. Moreover, as the systems get more complicated they are likely to bring along more calibration, maintenance, processing and cost requirements (Sa et al., 2018; Rai et al., 2023).

Future research directions: One important topic for future research is the connection of model outputs and management results. The work in weed detection may focus on assessing whether better weed detection results in lower herbicide application rates, more efficient treatments, less scouting hours, or better crop protection. Thus, an outcome-led type of assessment will allow separating technically interesting models from practically valuable systems ((Liu & Bruch, 2020; Rai et al., 2023).

Lastly, human intelligence cannot be replaced. AI may pick up and classify weeds, and provide an estimation of their spread. But, an agricultural expert must be the one who will have to deal with the cases that are uncertain, take into consideration previous treatment, and come up with intervention decision, if needed. Therefore, working with artificial intelligence seems to be a plausible scenario that can replace full automation of operations (Rai et al., 2023).

Deep learning has made weed detection increasingly practical, but the agricultural environment remains difficult.
Major problems include:

- crop–weed similarity
- overlapping leaves
- different growth stages
- shadows
- soil background
- species diversity
- long-tailed datasets
- changing field conditions.

The future of weed detection will therefore require models capable of learning from diverse environments rather than relying on a single field or season (Hasan et al., 2021; Saleh et al., 2023).

Conclusions and Recommendations

Weed identification utilizing deep learning methods has been developed from the initial stage of simple classification to advanced object detection and further to semantic and instance segmentation, density estimation, and spatial map generating. Crossing these lines gave computer vision a much greater potential for precision weed control at both the level of a plant and of a field. In short, such technologies can now be utilized at a more detailed level and also on a larger scale (Hasan et al., 2021; Rai et al., 2023).

Future weed management systems, apart from other improvements, are likely to have an element of strong generalization, a broad dataset of plants, various sensor inputs, the ability to estimate the levels of uncertainty in their results and a direct relationship of detection outputs with management decisions.The best ones will be probably those transforming complex picture data with great depth into accurate, spatially detailed content that indicates to the user that intervention would be beneficial in those points of the terrain where the weed situation

is the worst, and that only monitoring would be a correct choice for the less problematic sites (Rai et al., 2023; Shen et al., 2025).

The integration of UAV imagery, deep learning, multispectral sensing, and geospatial analysis provides a pathway toward adaptive weed management. Continued progress will depend not only on model architecture but also on field validation, agronomic thresholds, operational feasibility, and economic evaluation (Sa et al., 2018; Rai et al., 2023).

An approach to adaptive weed management combining drone or helicopter images, deep learning (an AI technique), multispectral (sensor images taking several colors) sensors, and geospatial information analysis is presented here. It is clear, however, that only the development of sophisticated models will not be sufficient but rather, field experiments to validate the models as well, understanding of different farming situations through their thresholds for weed management, feasibility of operational procedures at farms and finally costeffectiveness (Milioto et al., 2018; Sa et al., 2018).

An additional factor that must be taken into account is the size of the target weed. Weed individuals can grow from very tiny seedlings to large and fully mature individuals, and besides, they look very different at the different levels of their development, visually a trained model which mostly learns about mature weeds might not work correctly if weeds are still very small. Therefore, the training dataset must include all the necessary developmental stages as well as their evaluation and results should ideally be reported separately for a group of the small targets, the medium-sized ones and the large targets (Hasan et al., 2021).

Patterns of crop rows may be very helpful as supporting evidence in identifying weeds. Typically, most agricultural production systems rely on row planting so that the space of the crop plants is fairly even, in the way of the crops, whereas weeds are likely to grow between rows or form patches. Adding information regarding spatial distribution can help to sort out crop and weeds but it can lead to a major flaw: for example, the model may learn to recognize only those planting rows it trained on and, as a result, not work in case the configuration of planting changes. Hence it is necessary to verify models on different field arrangements (Milioto et al., 2018; Hasan et al., 2021).

An essential step toward building accurate weed detection methods is creating annotated ground truth. Compared with image-level classification, pixel-level segmentation is significantly time-consuming as it requires the drawing of precise and complex boundaries that follow the natural features of objects. On the other hand, the lack of consistency in the annotations may lead to some errors at the labeling stage (i.e., label noise). So the annotation instructions can address these kinds issues, such as, a way to annotate partially exposed objects, leaves which overlay one another, wilted plant tissues, etc. Moreover, uniform annotation of the images has positive effects not only on the training process but also on the understanding of which metrics to focus on for performance assessment (Hasan et al., 2021).

A weed map may have a higher operational relevance if it is linked to management practices or decisions. A treatment planning can be based on weed presence and distribution, so that the weed map can actually be treated as a decision tool. For instance: After a treatment, the difference between weed map produced before treatment and the one produced afterwards will show the degree of treatment effectiveness.

Besides, continuous observations will allow one to detect those areas that are constantly re-infested, which, perhaps, indicate that they are resistant to control measures, or are being reinfected or that they have a particular ecology, which makes a weed favorable condition to its survival In this manner, weed mapping will go beyond the immediate action, and support decision-making for longer time management (Liu & Bruch, 2020; Rai et al., 2023**).**

References

Hasan, A. S. M. M., Sohel, F., Diepeveen, D., Laga, H., & Jones, M. G. K. (2021). A survey of deep learning techniques for weed detection from images. Computers and Electronics in Agriculture, 184, 106067. https://doi.org/10.1016/j.compag.2021.106067

Liu, B., & Bruch, R. (2020). Weed detection for selective spraying: A review. Current Robotics Reports, 1, 19–26. https://doi.org/10.1007/s43154-020-00001-w

Milioto, A., Lottes, P., & Stachniss, C. (2018). Real-time semantic segmentation of crop and weed for precision agriculture robots leveraging background knowledge in CNNs. In 2018 IEEE International Conference on Robotics and Automation (ICRA) (pp. 2229–2235). IEEE. https://doi.org/10.1109/ICRA.2018.8460962

Olsen, A., Konovalov, D. A., Philippa, B., Ridd, P., Wood, J. C., Johns, J., Banks, W., Girgenti, B., Kenny, O., Whinney, J., Calvert, B., Rahimi Azghadi, M., & White, R. D. (2019). DeepWeeds: A multiclass weed species image dataset for deep learning. Scientific Reports, 9, 2058. https://doi.org/10.1038/s41598-018-38343-3

Rai, N., Zhang, Y., Ram, B. G., Schumacher, L. G., Yellavajjala, R. K., Bajwa, S., & Sun, X. (2023). Applications of deep learning in precision weed management: A review. Computers and Electronics in Agriculture, 206, 107698. https://doi.org/10.1016/j.compag.2023.107698

Sa, I., Chen, Z., Popovic, M., Khanna, R., Liebisch, F., Nieto, J., & Siegwart, R. (2018). weedNet: Dense semantic weed classification using multispectral images and MAV for smart farming. IEEE Robotics and Automation Letters, 3(1), 588–595. https://doi.org/10.1109/LRA.2017.2774979.

Sa, I., Popovic, M., Khanna, R., Chen, Z., Lottes, P., Liebisch, F., Nieto, J. I., Stachniss, C., Walter, A., & Siegwart, R. (2018). WeedMap: A large-scale semantic weed mapping framework using aerial multispectral imaging and deep neural network for precision farming. *Remote Sensing*, *10*(9), 1423. https://doi.org/10.3390/rs10091423

Saleh, A., Olsen, A., Wood, J., Philippa, B., & Rahimi Azghadi, M. (2023). WeedCLR: Weed contrastive learning through visual representations with class-optimized loss in long-tailed datasets. arXiv preprint arXiv:2310.12465. https://arxiv.org/abs/2310.12465

Shen, Y., Ayanlade, T. T., Boddepalli, V. N., Saadati, M., Rairdin, A., Deng, Z. K., Arshad, M. A., Balu, A., Mueller, D., Singh, A. K., Everman, W., Merchant, N., Ganapathysubramanian, B., Anderson, M., Sarkar, S., & Singh, A. (2025). WeedNet: A foundation model-based global-to-local AI approach for real-time weed species identification and classification. arXiv preprint arXiv:2505.18930. https://arxiv.org/abs/2505.18930

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

AI-DRIVEN PRECISION CROP PROTECTION: INTEGRATING DISEASE DIAGNOSIS, WEED DETECTION, EARLY WARNING AND DECISION SUPPORT

Emine KAYA ALTOP
Prof. Dr., Ondokuz Mayıs University, Faculty of Agriculture, Department of Plant Protection, Samsun, Turkiye
ORCID ID: https://orcid.org/0000-0002-0987-9352
Sine KAYA
Ph.D., Ondokuz Mayıs University, Graduate School of Natural and Applied Sciences, Department of Plant Protection, Samsun, Turkiye
ORCID ID: https://orcid.org/0000-0002-4219-9148

Abstract

Artificial intelligence (AI) in agriculture is now moving from isolated tools and applications to complete integrated crop protection ecosystems.
Although disease diagnosis, weed detection, early warning, UAV monitoring, computer vision, multimodal imaging, and decision support systems are often built as separate technologies, if they are integrated within a shared information platform, the practical benefits that they offer can greatly increase (Kamilaris & Prenafeta-Boldú, 2018; Tsouros et al., 2019).
With the help of artificial intelligence, recent crop protection developments focus on using machine learning, computer vision, remote sensing, Internet of Things (IoT) technologies, and robotic systems together for monitoring and management of crops' diseases and weeds as well as other health issues related to crops (Javed et al., 2025).
In recent years, researchers have designed an integrated AI crop protection workflow model that combines the sensing techniques for generating field data to a computer vision tool which then detects the presence of diseases weeds and so forth. Besides, multimodal models estimate the overall crop-health status temporal models forecast the occurrence of the disease, whereas, the decision support algorithms are responsible for converting the predictions into management zones and intervention recommendations.
According to their review of current literature, authors point out that for the implementation of AI-based agricultural systems a successful operation of them not only depends on how accurately they classify but also on the other factors such as how field-friendly (i.e., how durable it is in real world environment), the interoperability (how compatible it is with other systems), the external validation (by third parties), how computationally intensive it is, and how seamlessly it is integrated with actual farm practice (Mahlein, 2016; Jensen et al., 2025; 2026).

Keywords: Artificial intelligence; precision agriculture; precision crop protection; disease diagnosis; weed detection; UAV; remote sensing; multimodal data fusion; risk prediction; decision support systems; digital twin; deep learning; smart farming.

Introductıon

Agricultural systems based on AI are designed with the concept that crop protection, besides the fact that there is a need for different tasks, is also dependent on the coordination of these elements. In other words, the combination of outputs from disease diagnosis, weed detection, early warning, crop protection using UAVs, multimodal imaging and decision making will enhance the use and value of these components if the information is passed along a coordinated pathway (Kamilaris & Prenafeta-Boldú, 2018; Javed et al., 2025).
The result of such integrated efforts can be an improved representation of diverse crop health conditions in a single format. Using this, one can better understand how the crop health relates to various crop management practices thereby guiding it better.

The introduction of deep learning in the field of agriculture has greatly improved the capacity of farms to process and understand complex images. A combination of convolutional neural networks as well as other architectures has successfully been applied to image-based plant disease identification and diagnosis (Mohanty et al., 2016; Ferentinos, 2018; Boulent et al., 2019) .

Nonetheless, excellent classification accuracy under carefully controlled conditions does not guarantee that reliable results can be obtained in the real world agricultural conditions. Differences in illumination, crop growth stage, background complexity, sensor characteristics, geography, and the expression of the disease remain a problem for the generalization of models (Mahlein, 2016; Jensen et al. 2025).

Combining such integration with farm decisions is quite necessary because these decisions occur both spatially and temporeally. For example, a disease diagnosis without giving indication about its location has limited real world value while on the other hand, a spatial map showing disease risk without any element of time will also be less useful to farmers. Therefore, one needs to know not only the current status of a disease hotspot but also its future trend i.e., whether it is getting worse, stable or improving. Nowadays, the research in disease forecasting has been mainly centered on environmental, host and pathogen factors and the use of machine learning for processing larger and more complex data than traditional predictive methods (Jensen et al., 2025).

In addition there should be links between different types of information as well as management thresholds within the agricultural systems as a matter of fact, AI can produce such as disease probability of occurrence, weed density or the level of crop-stress but in the final management decisions, agronomic, economic, environmental and regulatory conditions also have to be taken into account.

Interoperability should be treated as a core design principle rather than as a technical detail made at the end of a project. In integrated agricultural systems, there will probably be a need for information exchange between the UAV platform, the farm-management software, the geographic information system, the machinery controller, the weather service, the sensors, and the field-scouting application. The recent research in agricultural digital twins has outlined interoperability, data semantic integration, standardized architectures, and field-level validation as the main requirements and ongoing research problems (Purcell & Neubauer, 2023).

The agricultural AI literature presents many cases of individual technical components that work well by themselves.

Disease classifier ≠ complete crop protection system Weed detector ≠ complete weed management system UAV image ≠ management decision

Integration is therefore the real target.

Disease and Weed as an Integrated Problem

There is a good reason to treat diseases and weeds as one problem in computational terms. Disease as well as weed management, after all, depend on a number of similar features such as image analysis, localization, classification, density or severity estimation, spatial mapping, temporal monitoring, and thresholds of decisions. Recent developments in the field of deep learning have shown that a number of image recognition tasks like object detection, classification, and semantic segmentation can be applied to different agricultural targets including plant diseases and weed infestations (Milioto et al., 2018; Rai et al., 2023; Liu et al., 2025).

Of course, biological aspects have to be specific and varied in each case of crop protection. One disease could be caused largely by host–pathogen interaction and environmental conditions, while weed emergence and development dynamics depend on seed characteristics, disturbance of soil, competition and management history among other factors of species biology. Thus, shared compute facilities should allow for both specialty models and agronomic rules, rather than treating all crop-protection problems as biologically similar.

This holistic view also allows one to make the most efficient use of available field resources at once. A combined scouting/monitoring solution can pinpoint disease hotspots, weed patches, and stressed crops, so that the farm inspectors and agronomists go to places where more observations would generate the highest decision worth.

From the perspective of precision crop management, both disease and weed problems share several computational requirements:

- detection;

- classification;
- localization;
- severity or density estimation;
- spatial mapping;
- temporal monitoring;
- uncertainty estimation;
- decision thresholds.

This makes it possible to build a common AI infrastructure while maintaining biologically specialized analytical models.

Table 1. Common AI Components

Component	Disease	Weed
RGB imaging	✓	✓
Multispectral imaging	✓	✓
Hyperspectral imaging	✓	✓
UAV	✓	✓
Object detection	✓	✓
Segmentation	✓	✓
Time series	✓	✓
Risk prediction	✓	✓
Decision support	✓	✓

Integrated Data Layer

An efficient agricultural intelligence system could integrate various types of images such as RGB, multispectral, thermal, and hyperspectral images with weather data, soil moisture, crop developmental stage, historical sickness outbreaks, and weed maps.

Each of these is an element of field condition that can contribute to better understanding if combined. In particular, the use of multiple sensors together provides a better picture of the situation even when conditions such as weather or light levels are difficult to monitor on the ground. (Mahlein, 2016; Tsouros et al., 2019; Jensen et al., 2026).

According to a study that deals with remote sensing, the combination of various sensors that UAV and proximal sensing systems have, including the camera, multispectral, hyperspectral, and thermal ones, offer additional data for analyzing crop health. Still, the real value of such data is heavily dependent on the data's accuracy, field validation, the calibration of sensors, and the ability of modeling methods to work in various agricultural regions. (Jensen et al., 2026).

A well-known fact is that the combining process should occur when there is a clear understanding of both the spatial and the temporal framework. Images taken by a sensor covering only part of the area may not have the same details level as those from large-area ones, hence, they either need to be interpolated, resampled, and or re-registered so they will be on the same coordinates. Similarly, the comparison of data collected at different times of the day is only possible after the images are time stamped properly and then aligned accordingly. Accuracy in the representation of the plant health depends to a large extent upon the correct handling of such relationships.

The integrated data layer should also maintain provenance information. Users and developers need to know:

- where a prediction originated;
- which sensors contributed to it;
- when observations were collected;
- whether data were missing;
- whether inputs were flagged as low quality.

The aspect of traceability is becoming a crucial factor when agricultural AI systems begin to adopt digital-twin architectures that bring together sensing, modeling, prediction, and decision support. ((Purcell & Neubauer, 2023; Melesse, 2025).
An integrated system may receive:

- RGB images;
- multispectral images;
- thermal images;
- hyperspectral images;
- weather data;
- soil-moisture information;
- crop-stage data;
- historical disease records;
- weed maps.

The system therefore becomes a multimodal agricultural information platform.

Detection Layer

Detection layer is the primary analytical phase of field observation. The disease analysis may include classification (of diseased patches), localization (of diseased regions with respect to healthy regions), and severity estimating, whereas weed analysis will most probably involve classification, object detection, semantic segmentation and density estimation.
Deep learning is proving to be a very successful tool for plant disease detection and classification, and especially through deep convolutional neural networks, and other visionbased architectures like CNN (Mohanty et al., 2016; Ferentinos, 2018; Boulent et al., 2019). Still, the challenge here is deploying this in the field because the agricultural fields have lots of background variations, different lighting conditions, crops being at different growth stages, many overlapped leaved and several different stress factors that may all have different symptoms (Mahlein, 2016; Jensen et al., 2025).
Weed management is another area of research where precision has become a key word. It primarily depends on three types of analytical approaches – image classification, object detection, and image segmentation.
The weeds that get caught by object detection models can be easily determined as being individual weeds, but with semantic segmentation it is possible to clearly map the weed borders and also to know how much total area is going to be covered by these weeds along with the information about their distribution in the spatial direction (Milioto et al., 2018; Rai et al., 2023; Liu et al., 2025).
It is also important to consider the spatial level at which the different analyses are carried out. Object detection for a few plants and semantic segmentation for the entire crop stand may be quite a bit different whereas classification at the field level to determine overall health condition (of crop) may be the biggest difference of all. Hence, an optimal system would match the task-specific algorithm with the target management decision rather than a default use of a machine learning model.
It is very crucial for the information that one gets from the machine to include the confidence level. This is not just about the right or wrong answers but is the machine's opinion that can also help prioritize tasks that are most urgent when one has to process the machine's output for, say, thousands of farms.
Disease: Classification → Localization → Severity Estimation
Weed: Classification → Detection → Segmentation → Density Estimation

Risk Layer

With respect to the risk layer, the present-day data are translated into a measure of risk for the protection of the crop either in the form of threat at the time or forecasted risk. The process involves overlaying the actual status of the field, weather factors, developmental growth stage of the crop, and records from the past to arrive at a prediction.
The disease prediction is becoming an area of research where researchers utilize a wide array of input variables and machine learning methods to develop robust systems (Jensen et al., 2025).

The capability of risk modeling is the foundation of early warning. A region whose risk is going up and whose visible symptoms are still mild suggests that scouting activities and pre-emptive management decisions may be worth the risk before the problem spreads to the entire area. Thus, warning based on early detection can be much more powerful than just a post-diagnosis analysis.

Risk maps have to be considered against the level of reliability with which different sources have contributed to the information. Even predictions from a single source could have low certainty. If one is to act on a high-risk prediction that relies on multiple different and high-quality information sources, the course of action may be different from that triggered by a similar high-risk prediction that arises from a single observation or very uncertain information.

In other words, a risk-based conceptual model could be written as:

$Risk_t = f(Current\ State_t, Weather_t, Crop\ Stage_t, History_t)$

Through this model you get an evolving risk assessment rather than a mere disease identification or a label.

Decision-Support Layer

This part of the process involves taking the information given by an expert system (in agriculture) and developing feasible field management options.

An efficient decision/support system at the farm level not only has to rely on the degree of confidence with which different model predictions come out but also should incorporate factors like biological thresholds, field-level validation, cost factors, physical limitations, etc., in the decision-making process leading to action recommendation.

Rapid development of AI in crop protection suggests that AI applications themselves can be one of the sources of knowledge to support evidence-based agricultural decisions, and not merely provide detection of problems alone.

It is generally agreed that the merging of sensor data collection, predictive modeling, and decision making is fundamental to the success of an industrial scale crop protection activity (Javed et al., 2025). A decision logic can support graduated responses. For instance:

- Low-risk conditions → routinely monitored
- Intermediate-level risk conditions → additional scouting
- High confidence, and high-risk conditions → targeted intervention,
- only when a target situation merits an intervention

Such a design ensures that the AI model remains only as a source of a recommendation and never as a machine automatically giving treatment commands.

A decision logic that is fully transparent is key to gaining the users' trust. Agronomists and farmers must know exactly which data contributed to a particular recommendation and how certain decisions or rules of the model were applied.

Precision Disease Management

Spatial disease risk maps highlight disease hotspots and help decide the areas for targeted monitoring and intervention.

The usefulness of a map in practice mainly depends on how well it matches the reality in terms of a disease's spatial distribution and the risk level of the map that is biologically significant. Whereas even a very small disease infestation can warrant a treatment action, a very big area with high disease risk probably requires a different kind of management.

Disease maps repeated over time can also provide us with information on the trend of disease in the field and treatment outcomes.

For instance, comparing results before and after applying a treatment can help us decide whether the risk of disease in the area: decreased, remained the same (persisted), or in the case of a new problem - expanded into neighboring fields.

If we add more information about weather and conditions we can do a much better job of identifying which spots may harbor disease since development of disease is most often tied to weather and environmental

conditions. (Jensen et al., 2025) Next-generation disease forewarning systems integrate an ever-broadening range of environmental, crop and biology related factors as variables (predictors) to generate the model.
Disease maps can therefore identify:

- high-risk zones;
- emerging hotspots;
- persistent disease areas;
- regions requiring additional field verification.

▓ **= high-risk zone**
▒ **= low-risk zone**
Treatment can then be targeted to high-risk areas when agronomic, economic, and regulatory conditions support intervention.

Precision Weed Management
Precision weed management is an integration system composed detection, species identification, density estimation, spatial distribution, and treatment zoning.
Weed population is known to have great heterogeneity across an agricultural field; therefore, a weed management practice that is highly location-specific has a high potential to significantly reduce the area with little or no weed
If the management strategy varies amongst species, species information plays a key role for accurate management decisions. A density map can still give useful data without being a species classification map, however, a species-level classification that is reliable can improve management decisions where the means of controlling weed and the thresholds of economic profitability are different for different species. Weed population maps that are periodically updated can also assist longer-term weed management. The continued existence of one spot (weeds) may reveal that the physical environment is still favoring the weed, or the same group of weed seeds from the seed bank is repeatedly emerging or the control has been very insufficient. These areas are the best places to monitor and do integrated weed management. Sa et al., 2018, using UAV multispectral images and deep neural network algorithms for weed identification and mapping on a massive level. Rai et al. 2023 summarized the expanding use of deep learning in weed management, yet the latest papers are continuously underscoring the significance of developing, detecting, and segmenting systems that can be deployed easily and reliably on large areas (Liu et al. 2025).
Thus: **Weed Detection→Weed Density→Spatial Distribution→Treatment Zone→Targeted Weed Control**
Edge AI
Agriculture robots like drones, tractors, farm robots, or even cell phones can have AI-powered crop protection that is done instantly without sending information to the cloud first. There are decisions which have to be made while such a machine is working in the field, so local inference can cut down communication time and let the device instantly recognize weeds as well as stressed crop plants and target the treatment areas.
Edge-based implementation needs the factors of computer performance limitations, battery consumption, size of the model, memory utilization, and speed of inference to be taken into account. A well-designed highly accurate AI model that is running on a strong server computer doesn't necessarily qualify automatically as a good system for agricultural mobile platform without some sort of optimization.
Combining edge and centralized devices might be the most practical compromise.
Faster decision-making takes place at the edge (like local machines) while the more complex tasks, such as model refinement and data storage, happen centrally.
In real-time operations, the use of cloud resources is not always a good solution.
Edge hardware can provide answers to queries without having to rely on the external world:
It is a solution to minimize delay as well as internet dependence while it allows a more proactive form of agriculture control.

Feedback Loops

An agricultural AI system works in feedback mode when it keeps on evaluating its predictions against results on the ground. After a change is made on the farm, one can look around for indicators of how things changed and see if it worked as it should have or if it just got worse. Errors in the system, as they reveal themselves in data, give a good point of departure for the identification or correction of problems that have been made in the decision-making process and in the application of the decision as well.

For instance, when an AI system repeatedly overestimates a risk level for a particular disease under certain conditions for the specific crop, a combination of recalibration, more training data, and re-adjusting decision thresholds may be necessary.

Digital twins in agriculture use this idea, whereby sensors in the field continuously feed observations to the digital copy of the agricultural system to make decisions and support monitoring and forecasting (Purcell & Neubauer, 2023; Melesse, 2025).

Hence, it is expected that an agricultural AI system would be able to learn from its latest field data: **Prediction→Management→Field→Observation→Actual→Outcome→Model Update→Improved Prediction.** Ultimately, the whole system leads to a closed-loop agriculture intelligence system

Table 2. Static Versus Integrated AI

Feature	Static AI	Integrated AI
Single image	✓	✓
Temporal data	Limited	✓
Multiple sensors	Limited	✓
Risk prediction	Limited	✓
Decision support	Limited	✓
Feedback learning	Rare	✓
Spatial management	Moderate	High

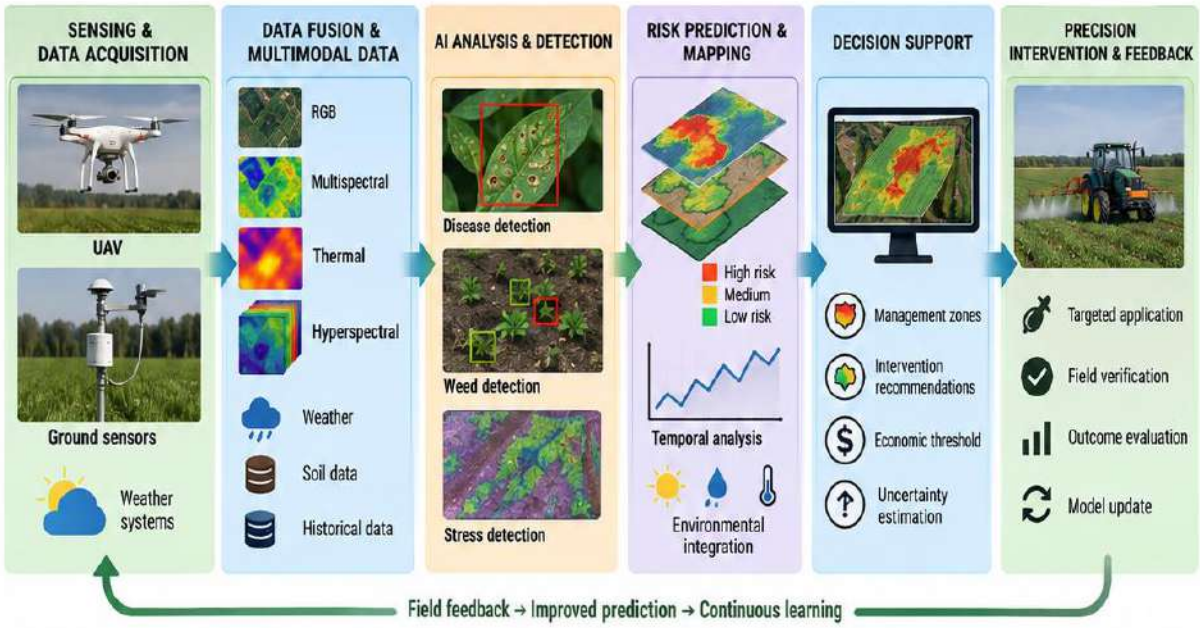


Figure 1. Integrated AI Crop Protection Architecture: From Multimodal Data Acquisition to Precision Intervention and Continuous Learning.

Economic Considerations

Value for money is the fundamental reason crop-protection AI systems should be integrated together with the business aspects. One must ask oneself whether these systems are worth investing more money if one could save that investment by other means.

Recent literature on agricultural AI underscores that merely having a high predictive performance does not automatically result in the product being adopted. The expense of computations, sensing equipment, volume of data, and the complexity of the installation may make access to and usage of AI technologies economically difficult (Jensen et al., 2025; Javed et al., 2025).

Hence, not only by model accuracy but also by the cost-benefit analysis, economic value of AI should be gauged.

Costs may include:

- sensors;
- UAV operation;
- computing infrastructure;
- data storage;
- software;
- maintenance;
- training;
- field verification.

A well-defined economic threshold will also prevent superfluous interventions. When the estimated risk or its uncertainty remains at a minimal level, continued observation could be more profitable than the treatment option.

On the other hand, the risk is high when it is certain that the field requires intervention, which will lead to the highest gain. Targeted application should bring more profit in expectation.

One possible simplified version of this model is:

Net benefit = input saving + yield protection - AI cost - Cost intervention

If accuracy of a system is very close to perfect but it is very expensive to deploy it, it might not be widely adopted.

Therefore, AI evaluation should include:

- input reduction;
- yield protection;
- labor savings;
- scouting time;
- treatment efficiency;
- operational cost.

Environmental Benefits

More targeted treatment has the possibility of helping the environment through the reduction of chemical treatments, but whether the environmental change is going to occur at all is decided by the quality of the whole decision chain.

For example, if the model predictions are correct and then the field application of the control measure also follows them and is efficient, then one can expect environmental gain. On the other hand, if the field application does not match or is not very well executed then no gain is possible.

Most AI crop protection reviews highlight that AI could help in reduction of chemical use as well as better use of the space to apply treatment but in order to derive benefits of AI, you need to have good detection, correct decision thresholds and very efficient implementation, says (Javed et al., 2025).

Environmental evaluation should therefore include measurable indicators such as:

- treated area;
- total input use;
- intervention frequency;
- application efficiency;
- management effectiveness.

Another issue is management to prevent emergence of resistance. If targeted interventions are done too often at the same spots and the farmer is not following the best agronomic and integrated pest management practices at that time of year, then these interventions may create resistance to the control method or lead to other undesirable situations through the selection pressure that poor management strategies could exert.
Environmental benefit depends on:

- model accuracy;
- treatment thresholds;
- application technology;
- farmer decisions;
- resistance management;
- regulatory requirements.

Therefore, AI is an enabling technology rather than an environmental outcome by itself.

Limitations

Combined application of agricultural AI and computer vision techniques is being tested in the field to understand its potential for precision and sustainable agriculture. Several limitations have been identified with relation to data consistency across different systems, accuracy of the model, uncertainty in the input-output relationship in the model, computation load, human willingness to adopt, economic aspects and legal aspects. These aspects are correlated as an initial problem can lead to cascading errors throughout the data handling pipeline.
It is crucial to test models on a wide range of data for Generalization, which is especially relevant for vision transformers, foundation models, and multimodal models. Deep learning architectures tend to grasp general characteristics, but the successful application on a farm still needs proof that these models work well when given the actual crop, geographic, environment, sensor and agronomic data (Jensen et al., 2025; 2026).
A number of recent studies have highlighted the same obstacles to successful implementation at farm level:

Data interoperability

Each sensor and every digital platform creates outputs that differ in formatting, metadata structure, and data types. A consistent exchange of information remains a big issue especially for agtech ecosystems and for developing digital twins.

Data quality

Poor quality of photos, incorrect positioning of locations on the map, not recording environmental data, or the breakdown of sensors that gather data are several factors that could have been considered but ultimately affect the accuracy of predictions made by an AI model.

Generalization

It is possible that models that have been trained on one set of conditions can fail to perform well on the new ones (Mahlein, 2016; Jensen et al., 2026).

Uncertainty

AI predictions are always probabilistic. Hence, a machine or human that uses this information should take into account the levels of confidence and other uncertainty information rather than take it for granted that it is always right.

Societal acceptance

Farmer/agriculturalist needs not just technical aspects, such as accuracy, but also the type of output that allows them to do a field activity, i.e. an output that is both spatial and in the farmer's terms!

Regulation

Drones for spraying herbicides/pesticides can require extra precautions, compliance, monitoring, and possibly, human supervision, etc.

Future Architecture

It is not difficult to imagine that future agri-AI tools may involve the combination of both very powerful pre-trained language models (foundation models) and domain-specific ones such as vision, time series, weather, or geospatial models. An intelligent system of multiple types of inputs could give real-time monitoring and

crop status of the field. In this way, it can capture all data about the crop condition and can even predict any changes or diseases based on the changes in the inputs. Such a system would give farmers timely warnings, so that they could take proper measures at the appropriate time.
The concept of the digitized crop health system is a great way to put together all the information. Such a digital twin could bring together sensing, data processing, analytics, and forecasting to assist farmers in the day-to-day monitoring and strategic decisions (Purcell & Neubauer, 2023; Melesse, 2025). Nevertheless, the current literature is also focusing on the remaining difficulties about data exchange, common structure for different digital platforms to operate and validation on large scale.
In any case, it's one of the main points of the architecture that uncertainty has to be transparent all through the flow. It would be helpful if predictions came with confidence levels or, in the least, with an outline explaining the basis for the findings.
This kind of layout signals a turning point as it is a move from a bunch of AI applications to the integrated agricultural intelligence platform.

Conclusions and Recommendations

Combined application of agri-AI and AI computer vision is, therefore, a major conceptual step forward from one or few detection modules to the complete crop-protection AI system. The successive stages starting with data collection, analysis, prediction, action, and relearning form a closed-loop wherein each phase serves the next.
In the end, for these agri-intelligence systems to succeed at least in the long run, it will be the case that it is not only algorithms, but also several other key factors such as the level of input and output consistency in terms of space and time, validation in fields, handling of uncertainty, data sharing or exchange between different systems, economic value, outcome in terms of environment, acceptance by users, legal standards, etc., that will be the determining factors in deciding if integrated AI becomes routine practice in precision crop protection (Jensen et al., 2025; 2026).
Hence, a more fruitful future direction is not one of full automation purely for that purpose but decision making between humans and machines based on sound scientific evidence wherein AI helps the agronomic professional with increased coverage and faster data processing and the agronomic expert makes interpretation and responsible intervention.

References

Boulent, J., Foucher, S., Théau, J., & St-Charles, P.-L. (2019). Convolutional neural networks for the automatic identification of plant diseases. *Frontiers in Plant Science, 10*, 941. https://doi.org/10.3389/fpls.2019.00941

Ferentinos, K. P. (2018). Deep learning models for plant disease detection and diagnosis. *Computers and Electronics in Agriculture, 145*, 311–318. https://doi.org/10.1016/j.compag.2018.01.009
Javed, K., et al. (2025). Artificial intelligence in crop protection: Revolutionizing agriculture for a sustainable future. *Information Processing in Agriculture*. https://doi.org/10.1016/j.inpa.2025.12.003

Jensen, A., Brown, P., Groves, K., & Morshed, A. (2025). Next generation crop protection: A systematic review of trends in modelling approaches for disease prediction. *Computers and Electronics in Agriculture, 234*, 110245. https://doi.org/10.1016/j.compag.2025.110245

Jensen, A., Brown, P., Groves, K., & Morshed, A. (2025). Next generation crop protection: A systematic review of trends in modelling approaches for disease prediction. *Computers and Electronics in Agriculture, 234*, 110245. https://doi.org/10.1016/j.compag.2025.110245

Kamilaris, A., & Prenafeta-Boldú, F. X. (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture, 147*, 70–90. https://doi.org/10.1016/j.compag.2018.02.016

Majdalawieh, M., Martins, C., Radi, M., Alaraj, M., & Khan, S. (2025). Precision agriculture in the age of AI: A systematic review of machine learning methods for crop disease detection. Smart Agricultural Technology, 12, 101491. https://doi.org/10.1016/j.atech.2025.101491

Mahlein, A.-K. (2016). Plant disease detection by imaging sensors—Parallels and specific demands for precision agriculture and plant phenotyping. *Plant Disease, 100*(2), 241–251. https://doi.org/10.1094/PDIS-03-15-0340-FE

Milioto, A., Lottes, P., & Stachniss, C. (2018). Real-time semantic segmentation of crop and weed for precision agriculture robots leveraging background knowledge in CNNs. In *2018 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 2229–2235). IEEE. https://doi.org/10.1109/ICRA.2018.8460962

Mohanty, S. P., Hughes, D. P., & Salathé, M. (2016). Using deep learning for image-based plant disease detection. *Frontiers in Plant Science, 7*, 1419. https://doi.org/10.3389/fpls.2016.01419

Olsen, A., Konovalov, D. A., Philippa, B., et al. (2019). DeepWeeds: A multiclass weed species image dataset for deep learning. *Scientific Reports, 9*, 2058. https://doi.org/10.1038/s41598-018-38343-3

Purcell, W., & Neubauer, T. (2023). Digital twins in agriculture: A state-of-the-art review. *Smart Agricultural Technology, 3*, 100094. https://doi.org/10.1016/j.atech.2022.100094

Rai, N., Zhang, Y., Ram, B. G., Schumacher, L. G., Yellavajjala, R. K., Bajwa, S., & Sun, X. (2023). Applications of deep learning in precision weed management: A review. *Computers and Electronics in Agriculture, 206*, 107698. https://doi.org/10.1016/j.compag.2023.107698

Sa, I., Popovic, M., Khanna, R., Chen, Z., Lottes, P., Liebisch, F., Nieto, J., Stachniss, C., Walter, A., & Siegwart, R. (2018). WeedMap: A large-scale semantic weed mapping framework using aerial multispectral imaging and deep neural network for precision farming. *arXiv preprint arXiv:1808.00100*.
Melesse, T. Y. (2025). Digital twin-based applications in crop monitoring. *Heliyon, 11*(2), e42137. https://doi.org/10.1016/j.heliyon.2025.e42137

Sankaran, S., Mishra, A., Ehsani, R., & Davis, C. (2010). A review of advanced techniques for detecting plant diseases. *Computers and Electronics in Agriculture, 72*(1), 1–13. https://doi.org/10.1016/j.compag.2010.02.007

Tsouros, D. C., Bibi, S., & Sarigiannidis, P. G. (2019). A review on UAV-based applications for precision agriculture. *Information, 10*(11), 349. https://doi.org/10.3390/info10110349
Zhao, H., & Wang, Y. (2026). Deep learning–based approaches for weed detection in crops. *Frontiers in Plant Science, 16*, 1746406. https://doi.org/10.3389/fpls.2025.1746406

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

BIOLOGICAL CONTROL OF *SCLEROTINIA SCLEROTIORUM* IN LETTUCE: RESEARCH TRENDS, BIOLOGICAL CONTROL AGENTS, AND EFFICACY LEVELS

Ömer Ümit Okçu
Nuray ÖZER
https://orcid.org/0000-0002-4809-4398, Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Plant Protection Tekirdağ, Türkiye.
https://orcid.org/0000-0001-6876-7580, Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Plant Protection Tekirdağ, Türkiye.

Abstract

White mold caused by the soilborne fungal pathogen *Sclerotinia sclerotiorum* can lead to substantial yield losses in lettuce, particularly under cool and humid conditions. In this review, studies on the biological control of *S. sclerotiorum* in lettuce were evaluated with respect to the biological control agents used, experimental conditions, and reported levels of efficacy. The 36 original studies examined included several bacterial and fungal antagonists, along with different microbial preparations and combined treatments. The potential of these biological control agents to suppress mycelial growth of the pathogen, reduce sclerotial formation or viability, and limit disease development was investigated using different experimental systems. A substantial proportion of the studies were based on *in vitro* antagonism assays, while a considerable number of studies were also conducted at the seedling stage and under pot and greenhouse conditions; in contrast, detached-leaf assays and particularly field trials were more limited. These different approaches allow comparison of biological control agents from laboratory to practical application. Although high levels of suppression were frequently reported in *in vitro* studies, this efficacy was not always reflected to the same extent in experiments conducted on plants. Nevertheless, some applications of *Trichoderma* spp. and *C. minitans* were reported to reduce disease development under greenhouse or field conditions and, in some studies, to have positive effects on yield. Differences in efficacy among the experiments appear to be associated with the antagonist isolate, application method and timing, inoculum density, environmental conditions, and pathogen isolate. In addition, findings on the use of biological agents either alone or in combination with other control measures indicate considerable potential for integrated disease management. The available studies show that promising options exist for the biological control of *S. sclerotiorum* in lettuce, although further validation, particularly under field conditions, is needed to translate laboratory findings into practical application.

Keywords: Biological control, lettuce, *Sclerotinia sclerotiorum*, *Trichoderma* spp., antagonistic microorganisms.

MARULDA *SCLEROTINIA SCLEROTIORUM*'UN BİYOLOJİK MÜCADELESİ: ARAŞTIRMA EĞİLİMLERİ, BİYOLOJİK MÜCADELE AJANLARI VE ETKİNLİK DÜZEYLERİ

Özet

Toprak kökenli bir fungal etmen olan *Sclerotinia sclerotiorum*'un neden olduğu beyaz çürüklük, marulda özellikle serin ve nemli koşullarda önemli ürün kayıplarına yol açabilmektedir. Bu derlemede, marulda *S. sclerotiorum*'un biyolojik mücadelesine yönelik çalışmalar; kullanılan biyolojik mücadele ajanları, deneme koşulları ve bildirilen etkinlik düzeyleri açısından değerlendirilmiştir. İncelenen 36 özgün çalışmada çeşitli bakteriyel ve fungal antagonistlerin yanı sıra farklı mikrobiyal preparatlar ve kombine uygulamalar ele alınmıştır. Bu biyolojik mücadele ajanlarının patojenin miselial gelişimini baskılama, skleroti oluşumu veya canlılığını azaltma ve hastalık gelişimini sınırlandırma potansiyelleri çeşitli deneme sistemleri kullanılarak araştırılmıştır. Çalışmaların önemli bir bölümünün *in vitro* antagonizm testlerine dayandığı, fide, saksı ve sera koşullarında yürütülen çalışmaların da dikkate değer sayıda olduğu; buna karşılık koparılmış yaprak ve özellikle tarla koşullarındaki denemelerin daha sınırlı kaldığı görülmüştür. Bu farklı yaklaşımlar, biyolojik

mücadele ajanlarının laboratuvardan uygulamaya geçiş sürecinin karşılaştırılmasına olanak sağlamaktadır. *In vitro* çalışmalarda yüksek baskılama oranları sıklıkla bildirilmesine karşın, bu etkinliğin bitkiler üzerinde yürütülen denemelere her zaman aynı düzeyde yansımadığı görülmüştür. Bununla birlikte, bazı *Trichoderma* spp. ve *C. minitans* uygulamalarının sera veya tarla koşullarında hastalık gelişimini azaltabildiği ve bazı çalışmalarda verim üzerinde olumlu etkiler sağlayabildiği bildirilmiştir. Denemeler arasındaki etkinlik farklılıklarının antagonist izolatı, uygulama şekli ve zamanı, inokulum yoğunluğu, çevre koşulları ve patojen izolatıyla ilişkili olabileceği görülmektedir. Ayrıca, biyolojik ajanların tek başına veya diğer mücadele uygulamalarıyla birlikte kullanımına ilişkin bulgular, entegre hastalık yönetimi açısından da önemli bir potansiyel ortaya koymaktadır. Mevcut çalışmalar, marulda *S. sclerotiorum*'un biyolojik mücadelesinde umut verici seçeneklerin bulunduğunu, ancak laboratuvar sonuçlarının uygulamaya aktarılabilmesi için özellikle tarla koşullarında daha fazla doğrulama çalışmasına gereksinim olduğunu göstermektedir.

Anahtar kelimeler: Biyolojik mücadele, marul, *Sclerotinia sclerotiorum*, *Trichoderma* spp., antagonist mikroorganizmalar

Giriş

Marul (*Lactuca sativa* L.), Asteraceae familyasına ait, yaprakları tüketilen ve açık alan ile örtü altı koşullarında yetiştirilebilen önemli bir sebze türüdür. Kısa yetişme süresi, serin koşullara uyumu ve yılın farklı dönemlerinde üretilebilmesinin yanı sıra vitaminler, mineraller, fenolik bileşikler ve flavonoidler bakımından zengin olması, marulun beslenmedeki önemini artırmaktadır. Bununla birlikte, *Sclerotinia* türlerinin neden olduğu hastalıklar marul üretiminde önemli sorunlardan biri olarak değerlendirilmektedir (Koynov, 2025).

Marulda önemli kayıplara yol açabilen hastalıklardan biri, geniş bir konukçu dizisine sahip nekrotrofik fungus *Sclerotinia sclerotiorum*'un neden olduğu beyaz çürüklüktür (Bolton et al., 2006). Patojenin toprakta uzun süre canlılığını koruyabilen sklerotiler oluşturması, sonraki yetiştirme dönemleri için kalıcı bir inokulum kaynağı yaratmakta ve hastalıkla mücadeleyi güçleştirmektedir. Hastalık genellikle bitkinin toprağa yakın kısımlarında başlayan sulu çürüklüklerle ortaya çıkmakta; ilerleyen dönemde enfekteli dokular beyaz, pamuksu miselle kaplanmakta ve siyah renkli sklerotiler oluşmaktadır (Budge & Whipps, 1991; Smolińska & Kowalska, 2018).

Toprakta bulunan sklerotiler, uygun koşullarda doğrudan misel oluşturarak veya apotesyum geliştirerek çimlenebilmektedir. Apotesyumlarda oluşan askosporlar çevreye yayılarak yeni enfeksiyonlara kaynaklık edebilmektedir. Bu nedenle topraktaki skleroti yoğunluğu ve sklerotilerin çimlenmesini etkileyen çevresel koşullar hastalık gelişiminde önemli rol oynamaktadır. Marulda *S. sclerotiorum* sklerotilerinin apotesyum oluşturması ile hastalık gelişimi arasındaki ilişkiyi inceleyen çalışmalar da sıcaklık ve toprak neminin inokulum oluşumu üzerindeki önemini ortaya koymuştur (Clarkson et al., 2007). Hastalık gelişiminin genel olarak serin ve nemli koşullarda desteklenmesi, özellikle örtü altı veya yoğun yetiştiricilik sistemlerinde çevre koşullarının hastalık yönetimindeki önemini artırmaktadır (Koynov, 2025).

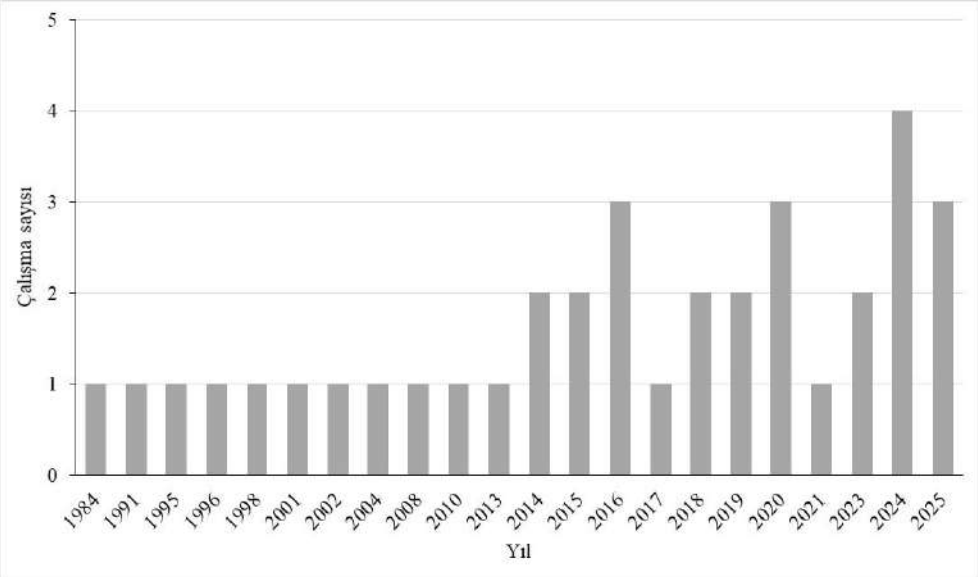
Sklerotilerin toprakta uzun süre canlı kalabilmesi ve patojenin geniş konukçu dizisi, kültürel önlemler ile kimyasal mücadelenin tek başına yeterli ve kalıcı kontrol sağlamasını güçleştirmektedir. Toprakta inokulumun sürekliliği nedeniyle hastalık yönetiminde yalnızca yetiştirme dönemindeki enfeksiyonların azaltılması değil, sonraki dönemlere taşınabilecek skleroti popülasyonunun da baskılanması önem taşımaktadır. Bu özellik, sklerotileri doğrudan hedefleyebilen veya toprakta patojenle etkileşime girebilen antagonist mikroorganizmaların biyolojik mücadelede değerlendirilmesini özellikle önemli hale getirmektedir. Bu nedenle *Coniothyrium minitans*, *Trichoderma* spp., *Bacillus* spp., *Pseudomonas* spp. ve *Streptomyces* spp. gibi farklı biyolojik mücadele ajanlarının kullanımı uzun süredir araştırılmaktadır. Whipps (1992), marulda *S. sclerotiorum*'un biyolojik mücadelesine yönelik önceki sera çalışmalarını değerlendirerek, özellikle *C. minitans*'ın dikim öncesi toprak uygulamalarının hastalık gelişimini ve skleroti popülasyonunu azaltabildiğini bildirmiştir. Derlemede aktarılan çalışmalarda, düzenli *C. minitans* uygulamalarının marulda tekrarlanabilir bir hastalık kontrolü sağladığı ve hasat sonrasında topraktaki skleroti popülasyonunu azaltabildiği; buna

karşılık aynı denemelerde değerlendirilen *Trichoderma* spp. izolatlarının hastalık kontrolü ve skleroti popülasyonu üzerindeki etkilerinin daha sınırlı kaldığı belirtilmiştir.

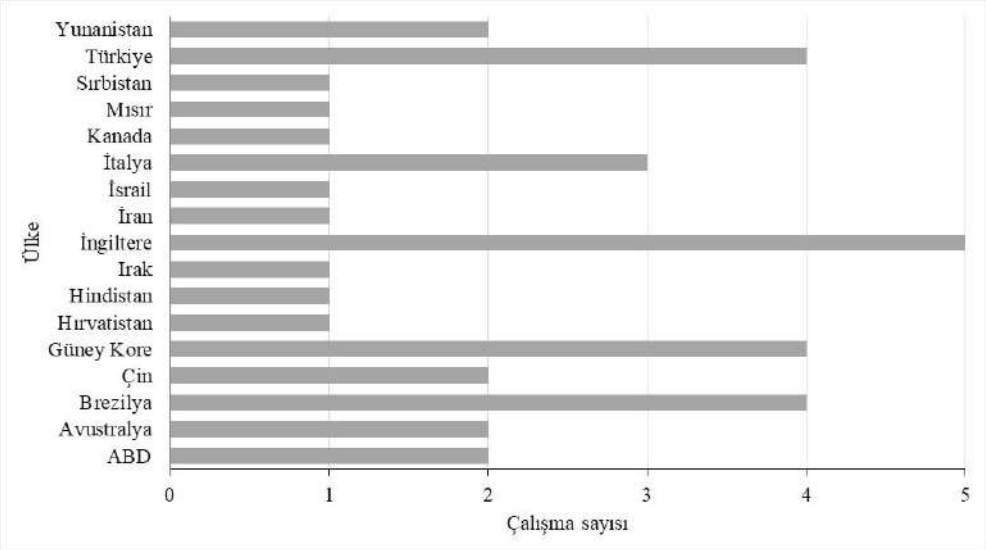
Bu derleme çalışmasında, marulda *S. sclerotiorum*'a karşı biyolojik mücadele konusunda ulaşılabilen yayımlanmış çalışmalar; yıllara ve ülkelere göre dağılım, kullanılan biyolojik mücadele ajanı grupları, deneme koşulları ve bildirilen etkinlik düzeyleri açısından incelenmiş; ayrıca *in vitro* denemelerde, sera ve diğer kontrollü ortamlar ile tarla çalışmalarında kullanılan uygulama yöntemleri karşılaştırmalı olarak değerlendirilmiştir.

Marulda *Sclerotinia sclerotiorum*'un Biyolojik Mücadelesine Yönelik Araştırma Eğilimleri

Marulda *S. sclerotiorum*'un biyolojik mücadelesine yönelik çalışmalar 1984–2025 yılları arasında gerçekleştirilmiş olup, araştırmaların özellikle 2014 sonrasında yoğunlaştığı görülmektedir (Şekil 1). En fazla çalışma 2024 yılında yayımlanmış olup, 2016, 2020 ve 2025 yıllarında da yüksek sayıda yayın bulunmaktadır. Çalışmalar 17 farklı ülkede gerçekleştirilmiş; en fazla araştırma İngiltere'de yapılmış, bunu Türkiye, Brezilya ve Güney Kore izlemiştir (Şekil 2).



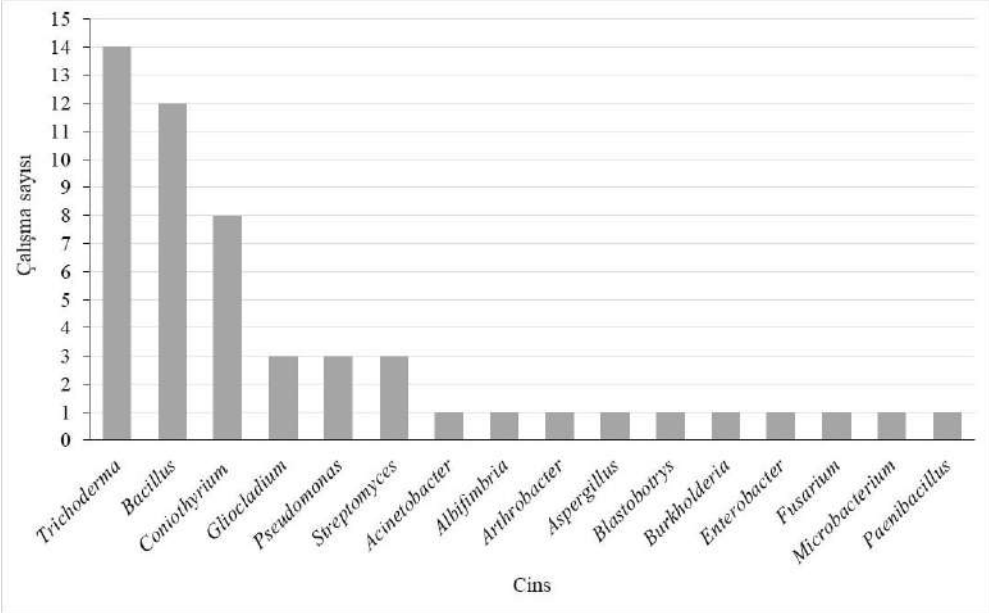
Şekil 1. Marulda *Sclerotinia sclerotiorum*'un biyolojik mücadelesine yönelik çalışmaların yıllara göre dağılımı



Şekil 2. Marulda *Sclerotinia sclerotiorum*'un biyolojik mücadelesine yönelik çalışmaların ülkelere göre dağılımı

Biyolojik Mücadelede Kullanılan Ajanlar

İncelenen çalışmalarda biyolojik mücadele ajanları ağırlıklı olarak fungus ve bakterilerden oluşmuş, aktinomisetler daha sınırlı sayıda çalışmada değerlendirilmiştir. Funguslar 23, bakteriler 14 ve aktinomisetler 3 çalışmada yer almıştır. Tokeshi et al. (1998) ise farklı bir yaklaşım benimseyerek, hastalık baskılayıcı özellik gösteren toprağın *S. sclerotiorum* üzerindeki etkisini incelemiş; skleroti çimlenmesi ve apotesyum oluşumunun yanı sıra ticari marul üretim alanında hastalık bulunma oranını da değerlendirmişlerdir. Cins düzeyinde değerlendirildiğinde, biyolojik mücadele çalışmalarında en sık *Trichoderma* (14 çalışma) ve *Bacillus* (12 çalışma) cinslerinin kullanıldığı, bunları *Coniothyrium*'un (8 çalışma) izlediği görülmüştür. *Gliocladium*, *Pseudomonas* ve *Streptomyces* cinsleri üçer çalışmada yer alırken, diğer cinsler daha sınırlı sayıda çalışmada değerlendirilmiştir (Şekil 3).



Şekil 3. Marulda *Sclerotinia sclerotiorum*'un biyolojik mücadelesinde kullanılan cinslerin dağılımı

Deneme Yaklaşımları ve Uygulama Yöntemleri

Çalışmaların deneme yaklaşımları incelendiğinde, 26 çalışmada *in vitro* testlerin, 30 çalışmada sera veya diğer kontrollü koşullardaki bitki denemelerinin kullanıldığı görülmüştür. Koparılmış yaprak testleri 3, tarla çalışmaları ise 6 araştırmada yer almıştır. Bazı çalışmalarda birden fazla deneme yaklaşımı birlikte kullanılmıştır.

In vitro değerlendirmeler çoğunlukla patojenin miselial gelişiminin engellenmesi, inhibisyon zonu oluşumu ve sklerotilerin oluşumu, canlılığı, çimlenmesi veya parazitlenmesi üzerine yoğunlaşmıştır (Çizelge 1). Daha sınırlı sayıda çalışmada minimum engelleyici konsantrasyon (MEK) ve biyolojik mücadele ajanlarının (BMA) fungisitlerle uyumluluğu da incelenmiştir. Bunların dışında Inbar et al. (1996) Petri kabında tohum çimlenmesi ile çıkış öncesi ve çıkış sonrası hastalık gelişimini, Elias et al. (2016) ise fide canlılığı ve gelişimini değerlendiren farklı sistemleri kullanmışlardır.

Koparılmış yaprak testlerinde biyolojik mücadele ajanları farklı yöntemlerle uygulanmıştır. Albert et al. (2024)'ün çalışmasında marul yaprakları antagonist *Pseudomonas* spp. izolatlarının süspansiyonlarına daldırılmış ve 24 saat sonra patojen inokulumu gerçekleştirilmiştir. Lee et al. (2015)'te bakteriyel antagonist yaprak yüzeyine püskürtülmüş ve bunu takiben *S. sclerotiorum*'un miselial diski yerleştirilmiştir. Li et al. (2025)'te ise yapraklara patojenin miselial diski ile birlikte antagonist fungusların fermantasyon sıvısı uygulanmıştır.

Serada ve diğer kontrollü ortamlarda yürütülen çalışmalarda biyolojik mücadele ajanlarının uygulanma biçimleri önemli farklılıklar göstermiştir. Bazı çalışmalarda BMA fide yetiştirme ortamına veya kök bölgesine önceden uygulanmış ve belirli bir süre sonra fideler *S. sclerotiorum* ile inokule edilmiş toprağa veya substrata aktarılmıştır (Aggeli et al., 2020; Albert et al., 2024; Fatouros et al., 2018). Carlucci et al. (2023) ise marul fidelerini *Streptomyces albidoflavus* CARA17 izolatının propagül süspansiyonu veya kültür filtratı ile muamele ettikten sonra saksılara şaşırtmış ve ardından patojeni fide kök boğazı çevresindeki toprağa uygulamıştır. Diğer bazı çalışmalarda BMA ve patojen doğrudan aynı yetiştirme ortamına uygulanmış ve uygulamalar eş zamanlı veya birbirine yakın zamanlarda gerçekleştirilmiştir (Baniasadipour & Shahidi Bonjar, 2014; Elias et al., 2016; Gupta et al., 2018; Lee et al., 2015; Pinto da Silva et al., 2019; Sitepu & Wallace, 1984; Soylu et al., 2021). Bu denemelerde *S. sclerotiorum* inokulumu kolonize tahıl taneleri, miselial agar diskleri veya sklerotiler gibi farklı biçimlerde toprağa ya da bitki kök bölgesine verilmiştir.

Çizelge 1. Marulda *Sclerotinia sclerotiorum*'a karşı *in vitro* biyolojik mücadele çalışmalarında değerlendirilen özellikler

Yazar	Miselial gelişim	İnhibisyon zonu	Skleroti oluşumu / canlılığı / çimlenmesi / parazitlenmesi	MEK	Fungisit uyumluluğu
Aggeli et al. (2020)	+	+	-	-	-
Akgül & Belgüzar (2024)	+	-	+	-	-
Albert et al. (2024)	-	+	-	-	-
Baniasadipour & Shahidi Bonjar (2014)	+	+	-	+	-
Bonini et al. (2020)	+	-	-	-	-
Budge & Whipps (2001)	-	-	-	-	+
Carlucci et al. (2023)	+	-	-	-	-
Chitrampalam et al. (2008)	-	-	-	-	+
Elias et al. (2016)	-	-	-	-	-
Fatouros et al. (2018)	+	-	-	-	-
Gupta et al. (2018)	+	-	-	-	-
Inbar et al. (1996)	+	-	-	-	-
Jee et al. (2025)	+	+	-	-	-
Kamal et al. (2015)	+	-	+	-	-
Lee et al. (2014)	-	+	-	-	-
Lee et al. (2015)	-	+	-	-	-
Li et al. (2025)	+	+	+	-	-
Monteiro et al. (2013)	+	+	+	-	-
Sitepu & Wallace (1984)	+	+	-	-	-
Son & Kim (2024)	+	-	+	-	-
Soylu et al. (2021)	+	+	+	-	-
Tomah et al. (2024)	+	-	+	-	-
Tomah & Hadi (2025)	+	-	+	-	-
Topolovec-Pintarić et al. (2025)	+	-	+	-	-
Yıldız & Çenberci Çoşkun (2017)	-	+	+	-	-
Živković et al. (2016)	+	-	-	-	-

+ = değerlendirildi, - = değerlendirilmedi

Toprakta önceden mevcut veya suni olarak eklenmiş skleroti popülasyonlarının bulunduğu sistemlerde ise BMA'lar çoğunlukla marulun ekim veya dikiminden önce toprağa uygulanmış ve skleroti canlılığı, inokulum

potansiyeli ya da sonraki ürünlerde hastalık gelişimi değerlendirilmiştir (Budge & Whipps, 1991; Budge et al., 1995; Budge & Whipps, 2001; Jones & Whipps, 2002; Jones et al., 2004; Yıldız & Çenberci Çoşkun, 2017). Başka bir grup çalışmada BMA gelişmekte olan marul bitkisine, kök bölgesine veya kök boğazı çevresindeki toprağa uygulanmış; patojen uygulaması ise eş zamanlı veya ardışık olarak gerçekleştirilmiştir (Akgül & Belgüzar, 2024; Jee et al., 2025; Lee et al., 2014; Monteiro et al., 2013; Son & Kim, 2024). Jee et al. (2025)'in çalışmasında tohumlar saksılara ekilmiş ve uygulamalar altı yapraklı bitkilere yapılmıştır; Monteiro et al. (2013)'te ise uygulama ekimden 60 gün sonra yetişmiş bitkilere yapılmıştır. Bonini et al. (2020) ise doğal olarak *Sclerotinia* ile bulaşık sera toprağında *Trichoderma atroviride* AT10'u yetiştirme dönemi boyunca tekrarlanan uygulamalarla değerlendirmişlerdir. Sklerotilerin saksı/toprak sistemine doğrudan yerleştirildiği çalışmalarda BMA veya BMA kaynaklı preparatlar toprağa karıştırma, kök bölgesine uygulama ya da toprak yüzeyine püskürtme gibi farklı yollarla verilmiştir (Inbar et al., 1996; Kamal et al., 2015; Li et al., 2025; Tomah et al., 2024; Tomah & Hadi, 2025; Topolovec-Pintarić et al., 2025). Patojen inokulumunun biçimi de çalışmalar arasında değişmiştir; örneğin Topolovec-Pintarić et al. (2025)'te marul bitkisinin kök boğazı yakınına bir skleroti ile birlikte miselial disk yerleştirilmiştir. Chen et al. (2016)'da ise BMA ve *S. sclerotiorum* substrata eş zamanlı uygulanmış, marul tohumları aynı gün veya uygulamadan 7 gün sonra ekilerek uygulama zamanının hastalık gelişimine etkisi karşılaştırılmıştır.

Tarla çalışmalarında biyolojik mücadele ajanlarının uygulama zamanı ve patojen inokulasyon düzeni çalışmalar arasında farklılık göstermiştir. Chitrampalam et al. (2008)'de ticari biyolojik mücadele preparatları ekim sırasında tek uygulama veya ekim ve seyreltme sonrasında iki uygulama şeklinde kullanılmış; *S. sclerotiorum* inokulumu laboratuvarda üretilen sklerotilerle Yuma şehrinde seyreltme sonrasında, Holtville şehrinde ise ekimden hemen önce uygulanmıştır. Chitrampalam et al. (2010)'da *C. minitans* farklı dozlarda ekim sırasında uygulanmış, bazı uygulamalarda işlem seyreltme sonrasında tekrarlanmış ve deneme parselleri laboratuvarda üretilen sklerotilerle yapay olarak inokule edilmiştir. Çolak Ateş (2019)'te *C. minitans* ve *T. harzianum* tek başına veya birlikte fidelerin dikiminden hemen sonra toprağa uygulanmış ve uygulamalar daha sonra tekrarlanmış; doğal olarak bulaşık alanlarda inokulumun homojen dağılımını sağlamak amacıyla toprağa ayrıca yapay inokulum verilmiştir. Tewfik et al. (2020)'de doğal olarak bulaşık tarlada *T. asperellum* bitkilere iki kez yapraktan uygulanmıştır. Chen et al. (2016)'da *Streptomyces* spp. izolatlarına ait spor süspansiyonları tohum ekimi sırasında fide yetiştirme ortamına verilmiş, uygulama iki hafta sonra tekrarlanmış; fideler daha sonra *S. sclerotiorum* inokulumu ile yapay olarak inokule edilerek bir gün sonra tarlaya şaşırtılmıştır. Tokeshi et al. (1998)'de hastalık baskılayıcı özellik gösteren toprağın etkisi değerlendirilmiş; sklerotiler deneme toprağına yerleştirilmiş, ticari marul üretim alanındaki hastalık ise doğal bulaşıklık koşullarında izlenmiştir.

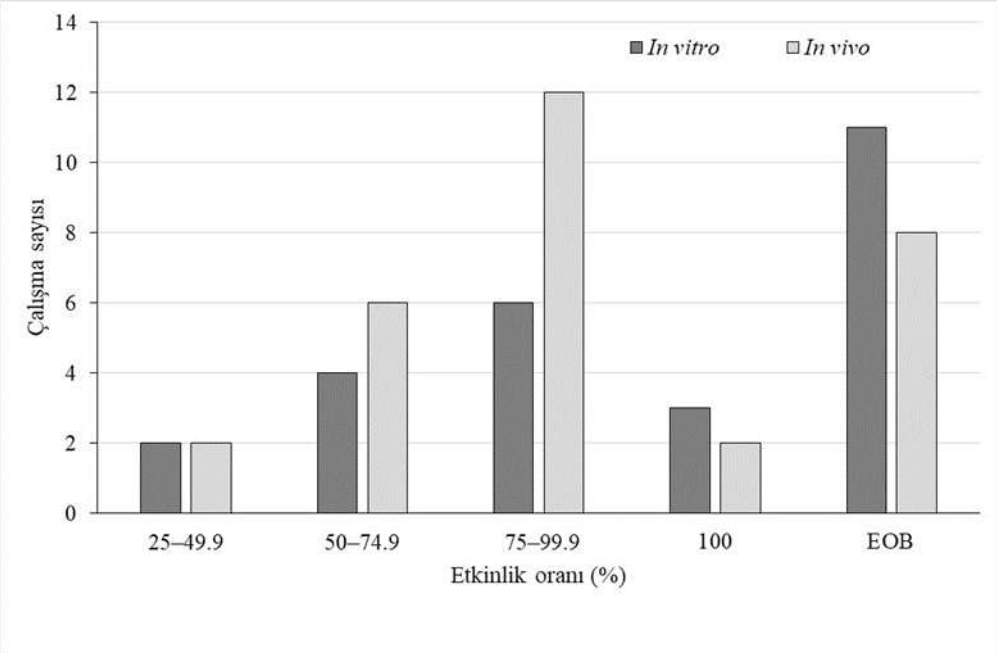
Biyolojik Mücadele Etkinliği

Bildirilen etkinlik oranları incelendiğinde, hem *in vitro* hem de sera ve kontrollü ortamlarda yürütülen *in vivo* çalışmalarda en fazla sonucun %75.0–99.9 aralığında toplandığı görülmüştür. Bu aralıkta 6 *in vitro* ve 12 *in vivo* çalışması yer alırken, %100 etkinlik sırasıyla 3 ve 2 çalışmada bildirilmiştir. Daha düşük etkinlik düzeyleri daha sınırlı sayıda çalışmada görülmüş, ayrıca bazı çalışmalarda etkinlik yüzdesi doğrudan bildirilmediği veya mevcut verilerden hesaplanamadığı için nicel bir oran elde edilememiştir (Şekil 4).

Koparılmış yaprak testlerinde de biyolojik mücadele ajanlarının değişen düzeylerde etkili olduğu bildirilmiştir. Albert et al. (2024)'te *Pseudomonas* cinsine ait B21-058, B21-060 ve B21-062 izolatları lezyon çapını kontrole göre %36–38 azaltmıştır. Lee et al. (2015)'te üçüncü günde *Bacillus amyloliquefaciens* M27 uygulamasında lezyon çapı 39.2 mm, kontrolde ise 108.5 mm olarak belirlenmiştir. Li et al. (2025)'te *Aspergillus terreus* JH92 ve *Albifimbria verrucaria* JH96'nın fermantasyon sıvısı sırasıyla %86.27 ve %86.28 kontrol etkinliği göstermiştir.

Tarla çalışmalarında biyolojik mücadele etkinliği uygulanan ajana ve uygulama düzenine göre değişmiştir. Chitrampalam et al. (2008)'de özellikle iki kez uygulanan *C. minitans* preparatının *S. sclerotiorum* kaynaklı hastalık bulunma oranını anlamlı biçimde azalttığı bildirilmiştir. Chitrampalam et al. (2010)'da tek *C. minitans* uygulamasının dahi hastalık bulunma oranını anlamlı düzeyde azalttığı, ancak farklı dozlar ile tek ve çift uygulamalar arasında belirgin bir fark bulunmadığı belirtilmiştir. Çolak Ateş (2019)'te en yüksek biyolojik mücadele etkinliği *C. minitans* ve *T. harzianum*'un birlikte kullanıldığı uygulamalarda %80.0–86.05, yalnız

T. harzianum uygulamasında ise %54.0–60.47 olarak belirlenmiştir. Tewfik et al. (2020), *T. asperellum* uygulamasında iki yetiştirme sezonunda sırasıyla %77.50 ve %72.57 etkililik bildirmiştir. Chen et al. (2016)'da *Streptomyces exfoliatus* FT05W ve *S. cyaneus* ZEA17I sırasıyla %40 ve %10 koruma sağlarken, *S. lydicus* WYEC108 koruma göstermemiştir. Tokeshi et al. (1998)'de ticari marul üretim alanındaki hastalık bulunma oranı %1.05 olarak belirlenmiş; ancak karşılaştırmaya uygun bir alan bulunmadığından biyolojik mücadele etkinlik oranı hesaplanamamıştır.



Şekil 4. *In vitro* ve *in vivo* çalışmalarda bildirilen biyolojik mücadele etkinlik oranlarının dağılımı. *In vivo*: Sera ve kontrollü ortam/iklim odasında bitkilerle yürütülen denemeleri kapsamaktadır; tarla ve koparılmış yaprak çalışmaları ayrı değerlendirilmiştir. EOB: Etkinlik oranının çalışmada bildirilmediği veya mevcut verilerden hesaplanamadığı çalışmalar.

Sonuç ve Öneriler

İncelenen çalışmalar, marulda *S. sclerotiorum*'a karşı biyolojik mücadele araştırmalarının geniş bir antagonist çeşitliliği ve farklı uygulama sistemleri üzerinden geliştiğini göstermektedir. Bununla birlikte, çalışmalar arasında kullanılan inokulum kaynakları, uygulama zamanları, değerlendirme ölçütleri ve deneme düzenlerinin farklı olması, bildirilen etkinliklerin doğrudan karşılaştırılmasını güçleştirmektedir. Gelecekteki çalışmalarda deneme koşullarının ve etkinlik değerlendirme ölçütlerinin daha açık ve karşılaştırılabilir biçimde sunulması, sonuçların yorumlanmasını kolaylaştıracaktır. Özellikle tarla koşullarında farklı yetiştirme dönemlerini kapsayan çalışmaların artırılması ve başarılı antagonistlerin uygun doz, uygulama zamanı ve uygulama sıklığı bakımından değerlendirilmesi önem taşımaktadır. Ayrıca biyolojik mücadele ajanlarının kültürel ve gerektiğinde azaltılmış kimyasal uygulamalarla birlikte kullanımının araştırılması, marulda beyaz çürüklüğe karşı daha uygulanabilir entegre mücadele programlarının geliştirilmesine katkı sağlayabilir.

Kaynaklar

Aggeli, F., Ziogas, I., Gkizi, D., Fragkogeorgi, G. A., & Tjamos, S. E. (2020). Novel biocontrol agents against *Rhizoctonia solani* and *Sclerotinia sclerotiorum* in lettuce. *BioControl*, *65*(6), 763-773. https://doi.org/10.1007/s10526-020-10043-w

Akgül, A. C., & Belgüzar, S. (2024). The use of rhizobacteria on white rot disease and growth of lettuce. *Black Sea Journal of Agriculture*, *7*(2), 176-183. https://doi.org/10.47115/bsagriculture.1424442

Albert, D., Zboralski, A., Ciotola, M., Cadieux, M., Biessy, A., Blom, J., Beaulieu, C., & Filion, M. (2024). Identification and genomic characterization of *Pseudomonas* spp. displaying biocontrol activity against *Sclerotinia sclerotiorum* in lettuce. *Frontiers in Microbiology*, *15*, 1304682. https://doi.org/10.3389/fmicb.2024.1304682

Baniasadipour, S. H., & Shahidi Bonjar, G. H. (2014). Biological control of *Sclerotinia sclerotiorum* the causal agent of lettuce rot disease by use of soil *Streptomycetes*. *Journal of Biological Control*, *28*(4), 225-233. https://doi.org/10.18311/jbc/2014/14966

Bolton, M. D., Thomma, B. P., & Nelson, B. D. (2006). *Sclerotinia sclerotiorum* (Lib.) de Bary: biology and molecular traits of a cosmopolitan pathogen. *Molecular Plant Pathology*, *7*(1), 1-16. https://doi.org/10.1111/j.1364-3703.2005.00316.x

Bonini, P., Rouphael, Y., Cardarelli, M., Ceccarelli, A. V., & Colla, G. (2020). Effectiveness of Trichoderma application through drip-irrigation to reduce Sclerotinia disease incidence and improve the growth performance of greenhouse lettuce. *Acta Horticulturae*, *1268*, 199-204. https://doi.org/10.17660/ActaHortic.2020.1268.26

Budge, S. P., & Whipps, J. M. (1991). Glasshouse trials of *Coniothyrium minitans* and *Trichoderma* species for the biological control of *Sclerotinia sclerotiorum* in celery and lettuce. *Plant Pathology*, *40*(1), 59-66. https://doi.org/10.1111/j.1365-3059.1991.tb02293.x

Budge, S. P., & Whipps, J. M. (2001). Potential for integrated control of *Sclerotinia sclerotiorum* in glasshouse lettuce using *Coniothyrium minitans* and reduced fungicide application. *Phytopathology*, *91*(2), 221-227. https://doi.org/10.1094/PHYTO.2001.91.2.221

Budge, S. P., McQuilken, M. P., Fenlon, J. S., & Whipps, J. M. (1995). Use of *Coniothyrium minitans* and *Gliocladium virens* for biological control of *Sclerotinia sclerotiorum* in glasshouse lettuce. *Biological Control*, *5*(4), 513-522. https://doi.org/10.1006/bcon.1995.1061

Carlucci, A., Sorbo, A., Colucci, D., & Raimondo, M. L. (2023). Biological control of severe fungal phytopathogens by *Streptomyces albidoflavus* strain CARA17 and its bioactive crude extracts on lettuce plants. *Plants*, *12*(10), 2025. https://doi.org/10.3390/plants12102025

Chen, X., Pizzatti, C., Bonaldi, M., Saracchi, M., Erlacher, A., Kunova, A., Berg, G., & Cortesi, P. (2016). Biological control of lettuce drop and host plant colonization by rhizospheric and endophytic streptomycetes. *Frontiers in Microbiology*, *7*, 714. https://doi.org/10.3389/fmicb.2016.00714

Chitrampalam, P., Figuli, P. J., Matheron, M. E., Subbarao, K. V., & Pryor, B. M. (2008). Biocontrol of lettuce drop caused by *Sclerotinia sclerotiorum* and *S. minor* in desert agroecosystems. *Plant Disease*, *92*(12), 1625-1634. https://doi.org/10.1094/PDIS-92-12-1625

Chitrampalam, P., Turini, T. A., Matheron, M. E., & Pryor, B. M. (2010). Effect of sclerotium density and irrigation on disease incidence and on efficacy of *Coniothyrium minitans* in suppressing lettuce drop caused by *Sclerotinia sclerotiorum*. *Plant Disease*, *94*(9), 1118-1124. https://doi.org/10.1094/PDIS-94-9-1118

Clarkson, J. P., Phelps, K., Whipps, J. M., Young, C. S., Smith, J. A., & Watling, M. (2007). Forecasting Sclerotinia disease on lettuce: a predictive model for carpogenic germination of *Sclerotinia sclerotiorum* sclerotia. *Phytopathology*, *97*(5), 621-631. https://doi.org/10.1094/PHYTO-97-5-0621

Çolak Ateş, A. (2019). Effect of *Coniothyrium minitans* and *Trichoderma harzianum* in the biological control of white mold disease (*Sclerotinia sclerotiorum*) in lettuce (*Lactuca sativa* L.). *Applied Ecology & Environmental Research*, *17*(6), 15687-15701. https://doi.org/10.15666/aeer/1706_1568715701

Elias, L. M., Domingues, M. V. P. F., Moura, K. E. D., Harakava, R., & Patricio, F. R. A. (2016). Selection of *Trichoderma* isolates for biological control of *Sclerotinia minor* and *S. sclerotiorum* in lettuce. *Summa Phytopathologica*, *42*(3), 216-221. https://doi.org/10.1590/0100-5405/2147

Fatouros, G., Gkizi, D., Fragkogeorgi, G. A., Paplomatas, E. J., & Tjamos, S. E. (2018). Biological control of *Pythium*, *Rhizoctonia* and *Sclerotinia* in lettuce: association of the plant protective activity of the bacterium *Paenibacillus alvei* K165 with the induction of systemic resistance. *Plant Pathology*, *67*(2), 418-425. https://doi.org/10.1111/ppa.12747

Gupta, M., Singh, K., & Bhardwaj, R. K. (2018). Biocontrol of lettuce drop caused by *Sclerotinia sclerotiorum* under protected conditions. *The Bioscan*, *13*(Supplement 1), 251-254.

Inbar, J., Menendez, A. N. A., & Chet, I. (1996). Hyphal interaction between *Trichoderma harzianum* and *Sclerotinia sclerotiorum* and its role in biological control. *Soil Biology and Biochemistry*, *28*(6), 757-763. https://doi.org/10.1016/0038-0717(96)00010-7

Jee, J. U., Chang, S. W., Ryu, J., & Chun, S. C. (2025). Isolation and characterization of plant growth-promoting Rhizobacteria from mud flats in South Korea: Potential for lettuce growth promotion and control of Sclerotinia rot. *The Plant Pathology Journal*, *41*(4), 456-471. https://doi.org/10.5423/PPJ.OA.03.2025.0035

Jones, E. E., & Whipps, J. M. (2002). Effect of inoculum rates and sources of *Coniothyrium minitans* on control of *Sclerotinia sclerotiorum* disease in glasshouse lettuce. *European Journal of Plant Pathology*, *108*(6), 527-538. https://doi.org/10.1023/A:1019940820230

Jones, E. E., Mead, A., & Whipps, J. M. (2004). Effect of inoculum type and timing of application of *Coniothyrium minitans* on *Sclerotinia sclerotiorum*: control of sclerotinia disease in glasshouse lettuce. *Plant Pathology*, *53*(5), 611-620. https://doi.org/10.1111/j.1365-3059.2004.01071.x

Kamal, M. M., Lindbeck, K., Savocchia, S., & Ash, G. J. (2015). Bacterial biocontrol of diseases caused by *Sclerotinia* in Australia. *Acta Horticulturae*, *1105*, 123-130. https://doi.org/10.17660/ActaHortic.2015.1105.18

Koynov, M. (2025). Control options and sources of resistance to the pathogens of lettuce drop (*Sclerotinia minor* Jagger and *Sclerotinia sclerotiorum* (Lib.) de Bary: A review. *Agricultural Science and Technology*, *17*(4), 3-17. https://doi.org/10.15547/ast.2025.04.038

Lee, S. Y., Weon, H. Y., Kim, W. G., Kim, J. J., & Han, J. H. (2015). Selection of *Bacillus amyloliquefaciens* M27 for biocontrol on lettuce sclerotinia rot. *The Korean Journal of Mycology*, *43*(3), 180-184. https://doi.org/10.4489/KJM.2015.43.3.180

Lee, H. J., Kim, J. Y., Lee, J. G., & Hong, S. S. (2014). Biological control of lettuce sclerotinia rot by *Bacillus subtilis* GG95. *The Korean Journal of Mycology*, *42*(3), 225-230. https://doi.org/10.4489/KJM.2014.42.3.225

Li, B., Xu, L., Ijaz, M., Hafeez, R., Ayoade, S. O., Shen, Y., Yang, F., Wang, X., Liu, Q., Li, X., Gu, C., Zhang, J., & Li, B. (2025). Effective mitigation of sclerotium rot in lettuce cultivation by two soil fungi *Aspergillus terreus* and *Albifimbria verrucaria*. *Pest Management Science*, *81*(9), 5614-5629. https://doi.org/10.1002/ps.8916

Monteiro, F. P., Ferreira, L. C., Pacheco, L. P., & Souza, P. E. (2013). Antagonism of *Bacillus subtilis* against *Sclerotinia sclerotiorum* on *Lactuca sativa*. *Journal of Agricultural Science*, *5*(4), 214-223. https://doi.org/10.5539/jas.v5n4p214

Pinto da Silva, G. B., Heckler, L. I., Durigon, M., dos Santos, R. F., Lovato, M., Finger, G., & Blume, E. (2019). Biological control of white mold (*Sclerotinia sclerotiorum*) in lettuce using Brazilian *Trichoderma* spp. strains. *Australian Journal of Crop Science*, *13*(6), 803-809. https://doi.org/10.21475/ajcs.19.13.06.p1214

Sitepu, K., & Wallace, H. R. (1984). Biological control of *Sclerotinia sclerotiorum* in lettuce by *Fusarium lateritium*. *Australian Journal of Experimental Agriculture and Animal Husbandry*, *24*(125), 272-276. https://doi.org/10.1071/EA9840272

Smolińska, U., & Kowalska, B. (2018). Biological control of the soil-borne fungal pathogen *Sclerotinia sclerotiorum*—a review. *Journal of Plant Pathology*, *100*(1), 1-12. https://doi.org/10.1007/s42161-018-0023-0

Son, M. R., & Kim, J. W. (2024). Biological control of sclerotinia rot caused by *Sclerotinia sclerotiorum* in lettuce using *Bacillus amyloliquefaciens* HY. *Research in Plant Disease*, *30*(3), 247-255. https://doi.org/10.5423/RPD.2024.30.3.247

Soylu, S., Kara, M., Uysal, A., Kurt, Ş., & Soylu, E. M. (2021). Determination of antagonistic potential of endophytic bacteria isolated from lettuce against lettuce white mould disease caused by *Sclerotinia sclerotiorum*. *Zemdirbyste-Agriculture*, *108*(4), 303-312. https://doi.org/10.13080/z-a.2021.108.039

Tewfik, S., Abou El-Yazied, A., Bondok, A. M., & Abd El-Gawad, H. G. (2020). Potential the biological and chemical control of lettuce white rot and maintain productivity. *Arab Universities Journal of Agricultural Sciences*, *28*(2), 587-599. https://doi.org/10.21608/ajs.2020.23042.1159

Tokeshi, H., Alves, M. C., Sanches, A. B., & Harada, D. Y. (1998). Effective microorganisms for controlling the phytopathogenic fungus *Sclerotinia sclerotiorum* in lettuce. In J. F. Parr & S. B. Hornick (Eds.), Proceedings of the 4th International Conference on Kyusei Nature Farming (pp. 131–139). Paris, France.

Tomah, A. A., Khattak, A. A., Aldarraji, M. H., Al-Maidi, A. A. H., Mohany, M., Al-Rejaie, S. S., & Ogunyemi, S. O. (2024). Sclerotia degradation by Trichoderma-mycoparasitic; an effective and sustainable trend in the drop lettuce disease control caused by *Sclerotinia sclerotiorum*. *Archives of Microbiology*, *206*(7), 286. https://doi.org/10.1007/s00203-024-04014-3

Tomah, A. A., & Hadi, Z. M. (2025). Screening of *Trichoderma* isolate effective in controlling lettuce drop disease caused by *Sclerotinia sclerotiorum*. *Misan Journal of Agricultural and Environmental Sciences*, *1*(1), 1-9. https://doi.org/10.64333/MJAE.25.1.1

Topolovec-Pintarić, S., Kovaček, A. M., Malev, O., Kušan, I., Matočec, N., Pošta, A., Pole, L., & Mešić, A. (2025). Biological control of *Sclerotinia sclerotiorum* on greenhouse lettuce using *Trichoderma koningiopsis* Agg. *Microbiology Research*, *16*(2), 35. https://doi.org/10.3390/microbiolres16020035

Whipps, J. M. (1992). Use of mycoparasites for biological control of *Sclerotinia sclerotiorum* in the glasshouse. In E. C. Tjamos, G. C. Papavizas, & R. J. Cook (Eds.), *Biological control of plant diseases: Progress and challenges for the future* (pp. 437–441). Springer. https://doi.org/10.1007/978-1-4757-9468-7_61

Yıldız, F., & Çenberci Çoşkun, B. (2017). Biological control of white mold disease (*Sclerotinia sclerotiorum*) on lettuce by using fungal antagonists. *Journal of Turkish Phytopathology*, *46*(1), 1-14.

Živković, S., Gavrilović, V., Gašić, K., Ristić, D., Dimkić, I., Stanković, S., & Fira, Đ. (2016). Antagonistic effect of *Trichoderma harzianum* and *Bacillus* sp. against the lettuce pathogen *Sclerotinia sclerotiorum*. VII International Scientific Agriculture Symposium, Agrosym 2016, 6-9 October 2016, Jahorina, Bosnia and Herzegovina. Proceedings, 2016, 1363-1368

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE EFFECT OF CORPORATE SOCIAL RESPONSIBILITY PROJECTS ON STAKEHOLDER PERCEPTIONS IN BUSINESSES

Abdullah ERİŞ
https://orcid.org/0000-0003-1228-5202, Erişler Gıda A.Ş. R&D Center, Istanbul, Türkiye.

Abstract

Corporate social responsibility projects represent an important means through which businesses address their environmental and social responsibilities beyond their economic activities. However, the effects of such projects on stakeholder perceptions depend not only on the scale of the investment but also on perceived sincerity, communication transparency, stakeholder participation, and the consistency between the project and the company's core activities. This study aims to examine the effects of corporate social responsibility projects on stakeholder trust, corporate reputation, and supportive behavioural intentions among employees, consumers, suppliers, and local communities.

An explanatory sequential mixed-methods design will be employed. In the quantitative phase, data will be collected from different stakeholder groups using a structured questionnaire. The relationships among perceived corporate social responsibility, project–company fit, perceived sincerity, communication transparency, corporate trust, corporate reputation, and stakeholder support will be analysed using structural equation modelling. Multigroup analysis will also be conducted to determine whether these relationships differ among employees, consumers, suppliers, and members of local communities.

In the qualitative phase, semi-structured interviews and focus group discussions will be conducted with selected stakeholders. The qualitative component will explore why certain projects are perceived as sincere, credible, or beneficial, whereas others are regarded as symbolic, promotional, or disconnected from stakeholder expectations. The data will be evaluated through thematic analysis and integrated with the quantitative findings.

The study is expected to demonstrate that corporate social responsibility expenditure alone is insufficient to create favourable stakeholder perceptions. Perceived sincerity, transparency, stakeholder involvement, and project–company fit are expected to emerge as key determinants of trust and corporate reputation. The findings may provide practical guidance for businesses seeking to design stakeholder-oriented social responsibility strategies and to strengthen long-term relationships with their internal and external stakeholders.

Keywords: Corporate Reputation; Corporate Social Responsibility; Stakeholder Perception; Transparency; Trust.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

SPEAKING WITHOUT FEAR? EXPLORING THE ROLE OF CHATBOTS IN REDUCING ANXIETY DURING EFL SPEAKING PRACTICE

Stelina Ndreu
10009-0008-6842-5407, University of Tirana, Faculty of Foreign Languages, Department of English Language, Tirana, Albania.

Abstract

Speaking is often one of the most challenging aspects of learning a foreign language, particularly for learners who experience anxiety about making mistakes or being evaluated by others. The growing use of generative artificial intelligence in language education has introduced new opportunities for speaking practice, including interaction with AI-powered conversational tools. This study explores the use of chatbots as conversational partners in EFL speaking practice, with particular attention to learners' self-reported speaking anxiety. A group of 26 EFL learners participated in two comparable speaking activities: one conducted with a peer and another with a chatbot through voice interaction. Following the activities, participants completed a questionnaire examining their anxiety, confidence, willingness to speak, and overall experience under both conditions. The study also included open-ended questions to explore which aspects of AI-supported interaction made speaking easier or more difficult. Quantitative data were analyzed using descriptive statistics and within-participant comparisons, while qualitative responses were examined thematically. The results indicated that participants generally experienced lower levels of anxiety and greater confidence when speaking with chatbots, particularly because they felt less concerned about making mistakes or being negatively evaluated. However, participants also identified limitations related to the naturalness and spontaneity of AI interaction. The findings suggest that conversational AI can serve as a useful supplementary environment for low-pressure speaking practice while complementing rather than replacing peer interaction in the EFL classroom.

Keywords: AI-assisted language learning; conversational AI; EFL speaking; speaking anxiety.

INTRODUCTION

Speaking is a central component of foreign language learning, yet it is also an area where learners may experience considerable anxiety. Unlike receptive language activities, speaking requires learners to produce language in real time while simultaneously managing vocabulary, grammar, pronunciation, and interaction with an interlocutor. The social and evaluative nature of speaking can further increase pressure, particularly when learners are concerned about making mistakes or being judged by others (Özdemir & Seçkin, 2025). Foreign language anxiety has long been recognized as a distinct phenomenon in language learning. Horwitz et al. (1986) conceptualized foreign language classroom anxiety in relation to communication apprehension, test anxiety, and fear of negative evaluation, laying the groundwork for subsequent research into the affective dimensions of language learning. Speaking situations may be particularly sensitive to these factors because learners must make their linguistic ability immediately visible to others.

The increasing availability of artificial intelligence (AI) has introduced new possibilities for creating alternative environments for speaking practice. Conversational AI systems can interact with learners through text and voice, respond immediately, ask follow-up questions, and allow repeated practice without another learner or teacher present (EFL CAFÉ, 2025). Generative AI tools such as ChatGPT therefore have potential not only as sources of language input or feedback but also as conversational partners. From an affective perspective, interaction with an AI system may differ substantially from interaction with another person. Learners may perceive an AI interlocutor as less judgmental and consequently feel more willing to experiment with language, make mistakes, or take additional time to formulate responses. At the same time, technical difficulties, unnatural interaction, speech-recognition problems, or unfamiliarity with AI may create new sources of discomfort (Hornby, 2024).

Recent empirical research has begun to investigate the relationship between AI-supported speaking practice and learners' affective experiences. In a quasi-experimental study involving 131 Chinese EFL university students, an AI speaking assistant was used during a six-week intervention. Learners who used the AI assistant showed increased foreign language enjoyment and willingness to communicate, as well as reduced foreign language anxiety, while the control group showed no comparable changes. These findings suggest that AI-supported speaking environments may influence not only speaking practice itself but also learners' emotional readiness to communicate (Zhang et al., 2024).

Similarly, recent research on conversational generative AI has examined the effects of text- and voice-enabled chatbots on willingness to communicate, foreign language speaking anxiety, perceived communicative competence, and speaking performance. These studies indicate that conversational AI can give learners additional opportunities for interaction beyond conventional teacher- and peer-led speaking activities (Wang et al., 2024). Tai and Chen (2024), for example, found positive effects of generative AI chatbot interaction on EFL speaking development and reported that learners associated chatbot interaction with supportive functions and reduced speaking anxiety. The conversational and human-like characteristics of newer AI systems may therefore make them particularly relevant to speaking practice.

However, the emerging evidence should not be interpreted as demonstrating that AI interaction necessarily produces lower speaking anxiety than human interaction. Ballıdağ and Aydın (2025) directly compared AI-based chatbot speaking activities with traditional peer speaking activities among EFL learners. Their findings showed that chatbot interaction did not produce a statistically significant overall reduction in speaking anxiety, whereas traditional peer-based speaking activities resulted in a significant decrease. Qualitative findings nevertheless suggested that some learners valued the psychological safety of interacting with AI and felt less exposed to judgment. At the same time, technological limitations and difficulties in maintaining natural interaction could themselves contribute to anxiety. These findings demonstrate that the relationship between AI interaction and speaking anxiety is more complex than the assumption that the absence of a human interlocutor automatically makes speaking less stressful.

Differences across previous studies may partly reflect variation in learners, technologies, tasks, duration of exposure, and research designs. Longer interventions can examine changes in general speaking anxiety over time, whereas immediate comparisons can capture how learners experience anxiety during a particular interaction. Furthermore, comparisons between separate experimental and control groups do not necessarily reveal whether the same learner feels differently when speaking with an AI system and with another person.

The present study therefore examines peer-based and AI-supported speaking practice within the same group of learners. Each participant completes comparable speaking activities under both conditions, allowing the learner's experience with a peer to be directly compared with their experience using ChatGPT through voice interaction. Rather than assuming AI interaction is inherently less anxiety-provoking, the study examines whether differences emerge and explores learners' explanations for them. Particular attention is given to speaking anxiety, fear of mistakes and negative evaluation, confidence, and willingness to continue speaking. By combining within-participant comparisons with learners' open-ended reflections, the study aims to provide a more nuanced understanding of the potential affective role of conversational AI in EFL speaking practice.

Accordingly, the study addresses the following research questions:

RQ1. How do EFL learners perceive AI-supported speaking practice compared with peer-based speaking practice?

RQ2. Do EFL learners report different levels of speaking anxiety when interacting with ChatGPT versus a peer?

RQ3. What aspects of AI-supported speaking practice are perceived as reducing or increasing speaking anxiety?

MATERIALS AND METHODS

This study used a within-subject comparative design with 26 Grade 11 EFL learners at approximately B1+ level. Each participant completed two five-minute speaking tasks: one with a peer and one with ChatGPT using voice interaction.

The two tasks were: Planning a Weekend Trip and Planning a Free Day in the City. Both required participants to discuss several options and reach a final agreement.

To reduce order and task effects, the conditions were counterbalanced across four groups:

Table 1. Counterbalancing of Speaking Tasks and Conditions

Group	N	Task 1	Task 2
1	7	Task A – Peer	Task B – ChatGPT
2	6	Task B – Peer	Task A – ChatGPT
3	7	Task A – ChatGPT	Task B – Peer
4	6	Task B – ChatGPT	Task A – Peer

In the AI condition, all participants used the same standardized ChatGPT prompt. ChatGPT acted as a B1+ speaking partner, asked follow-up questions, and maintained the conversation, but did not correct grammar or pronunciation or provide explicit reassurance about mistakes.

Immediately after each task, participants completed a short 10-item questionnaire using a five-point Likert scale. The questionnaire measured speaking anxiety, fear of mistakes and negative evaluation, confidence, and willingness to continue speaking. After completing both conditions, participants also answered comparative and open-ended questions about which interaction felt more comfortable and why.

Quantitative data were analyzed using descriptive statistics and paired within-participant comparisons. As the data were based on Likert-scale responses, the Wilcoxon signed-rank test was used for inferential comparisons. Open-ended responses were analyzed thematically.

RESULTS

Participants reported lower anxiety and greater confidence in the ChatGPT condition.

Table 2. Mean Scores Across Peer and ChatGPT Speaking Conditions

Measure	Peer M	ChatGPT M
Speaking anxiety	3.52	2.58
Fear of mistakes / negative evaluation	3.61	2.44
Confidence	3.10	3.83
Willingness to continue speaking	3.33	4.02

The Wilcoxon signed-rank tests indicated statistically significant differences between the two conditions. Speaking anxiety was significantly lower in the ChatGPT condition, $Z = -3.47$, $p < .001$, $r = .68$. Fear of mistakes and negative evaluation was also significantly lower, $Z = -3.72$, $p < .001$, $r = .73$. In contrast, confidence was significantly higher in the ChatGPT condition, $Z = -3.10$, $p = .002$, $r = .61$, as was willingness to continue speaking, $Z = -2.96$, $p = .003$, $r = .58$. All four comparisons showed large effect sizes.

When asked which condition made them feel more comfortable, 19 of the 26 participants (73.1%) selected ChatGPT, five preferred speaking with a peer, and two reported no clear difference.

The open-ended responses revealed three main themes. First, participants commonly reported less fear of being judged when speaking with AI, particularly when making grammar or pronunciation mistakes. Second, several students felt more comfortable experimenting with English and taking time to formulate their answers. Third, a smaller group preferred peer interaction because it felt more natural, spontaneous, and socially engaging. Some participants also reported occasional difficulties when ChatGPT misunderstood their pronunciation.

AI-supported speaking practice may reduce perceived speaking anxiety, particularly anxiety associated with mistakes and negative evaluation, while increasing confidence and willingness to communicate. However, some learners still preferred peer interaction because of its greater naturalness and interpersonal character.

DISCUSSION

The findings of this study suggest that the nature of the speaking partner can influence learners' affective experience during EFL speaking practice. Participants generally reported lower speaking anxiety and fear of mistakes or negative evaluation when interacting with ChatGPT than when speaking with a peer. At the same time, they reported greater confidence and willingness to continue speaking in the AI-supported condition. These findings suggest that conversational AI may provide a lower-pressure environment in which learners feel more comfortable using spoken English.

One possible explanation concerns the evaluative dimension of speaking anxiety. Fear of negative evaluation has long been considered an important component of foreign language anxiety (Horwitz et al., 1986). The qualitative responses in the present study support this interpretation, as participants frequently associated interaction with ChatGPT with a reduced fear of being judged for grammatical or pronunciation mistakes. Although the AI interaction still required learners to produce language spontaneously, the absence of a human interlocutor may have reduced the social consequences that learners associated with making errors. This may also help explain the higher levels of confidence and willingness to continue speaking reported in the AI condition.

The findings are consistent with recent research suggesting that AI-supported speaking environments can have positive affective effects. Previous studies have reported lower reported anxiety and increases in willingness to communicate following AI-supported speaking practice. Research on conversational generative AI has similarly suggested that learners may value the supportive and relatively low-pressure environment created by chatbot interaction. The present findings extend this perspective by showing differences within the same learners across two comparable speaking conditions. Rather than comparing separate groups of learners, the within-subject design allowed participants to experience both peer and AI interaction, providing a more direct comparison of their immediate affective responses.

However, the findings should not be interpreted as evidence that AI interaction is universally preferable to peer communication. They differ in part from Ballıdağ and Aydın (2025), who found no statistically significant overall reduction in speaking anxiety following AI-chatbot activities and reported a significant reduction following traditional peer-based activities. This contrast reinforces the view that the relationship between AI and speaking anxiety likely depends on the specific learners, tasks, technological conditions, and duration of interaction. In the present study, the focus was on immediate responses to short speaking activities rather than changes in general speaking anxiety over an extended intervention. The results therefore indicate how learners experienced the two interaction conditions at a particular point in time rather than demonstrating a lasting reduction in foreign language anxiety.

The qualitative findings also highlight limitations of AI-supported speaking practice. Although most participants felt more comfortable with ChatGPT, some preferred peer interaction because it felt more natural, spontaneous, and socially engaging. Participants also reported difficulties with speech recognition, suggesting that technological limitations may interrupt communication and potentially create a different form of frustration or anxiety. Human interaction also involves interpersonal and pragmatic features that AI-mediated conversation cannot fully reproduce.

These findings have practical implications for EFL teaching. Conversational AI may be particularly useful as a supplementary speaking environment for learners who hesitate to participate because of fear of mistakes or negative evaluation. Teachers could use AI-supported speaking activities as a preparatory stage before pair work, classroom discussions, or other forms of interpersonal communication. This approach would preserve the communicative and social value of peer interaction while giving learners an additional space to practice speaking with less perceived pressure.

Several limitations should nevertheless be considered. The study involved a relatively small sample of 26 learners and examined only two short speaking tasks, which limits the generalizability of the findings. The measures were based primarily on learners' self-reported experiences and therefore reflect perceived rather than independently observed anxiety. In addition, the study examined immediate responses to ChatGPT interaction rather than the effects of sustained AI-supported practice over time. Future research could involve larger samples, longer interventions, additional speaking tasks, and complementary measures of speaking behavior or performance. It would also be valuable to investigate whether repeated low-anxiety practice with

conversational AI eventually increases learners' confidence when they return to human-to-human communication.

CONCLUSION

This study explored EFL learners' speaking anxiety when completing comparable speaking activities with a peer and with ChatGPT through voice interaction. The findings showed that participants generally experienced lower speaking anxiety and fear of negative evaluation in the AI-supported condition, while reporting greater confidence and willingness to continue speaking. Learners' responses suggested that the reduced social pressure of speaking to AI, particularly feeling less judged for mistakes, contributed to this experience.

At the same time, the findings do not suggest that conversational AI should replace peer interaction. Some learners valued peer communication for its naturalness, spontaneity, and interpersonal character, while technological limitations occasionally affected interaction with ChatGPT. AI-supported speaking practice may therefore be most valuable as a complementary environment in which learners can practice spoken English with relatively low perceived pressure before or alongside human interaction.

Given the small sample and short-term nature of the study, the findings should be interpreted cautiously. Further research involving larger groups and longer periods of AI-supported speaking practice could examine whether reduced anxiety during AI interaction transfers to greater confidence and willingness to communicate with human interlocutors. From a pedagogical perspective, integrating conversational AI alongside peer-based activities may offer EFL teachers an additional way to support learners who experience anxiety during speaking practice.

REFERENCES

Ballıdağ, M., & Aydın, S. (2025). A comparison of the effects of AI-based chatbots and peer interactions on speaking anxiety among EFL learners. *Future in Educational Research, 3*(2), 224–238. https://doi.org/10.1002/fer3.70005

EFL CAFE. (2025, March 28). *Using AI chatbots to improve EFL conversation skills*. https://eflcafe.net/using-ai-chatbots-to-improve-efl-conversation-skills

Hornby, R. (2024). *Is interacting with generative AI like talking with another person?* AlixPartners. https://www.alixpartners.com/insights/102j8p1/is-interacting-with-generative-ai-like-talking-with-another-person/

Horwitz, E. K., Horwitz, M. B., & Cope, J. (1986). Foreign language classroom anxiety. *The Modern Language Journal*, *70*(2), 125–132. https://doi.org/10.1111/j.1540-4781.1986.tb05256.x

Özdemir, O., & Seçkin, H. (2025). Exploring foreign language anxiety in higher education: Multifaceted insights into causes, impacts, and coping strategies. *Social Sciences & Humanities Open, 11*, 101364. https://doi.org/10.1016/j.ssaho.2025.101364

Tai, T. Y., & Chen, H. H. J. (2024). Navigating elementary EFL speaking skills with generative AI chatbots: Exploring individual and paired interactions. *Computers & Education, 220*, 105112. https://doi.org/10.1016/j.compedu.2024.105112

Wang, C., Zou, B., Du, Y., & Wang, Z. (2024). The impact of different conversational generative AI chatbots on EFL learners: An analysis of willingness to communicate, foreign language speaking anxiety, and self-perceived communicative competence. *System, 127*, 103533. https://doi.org/10.1016/j.system.2024.103533

Zhang, C., Meng, Y., & Ma, X. (2024). Artificial intelligence in EFL speaking: Impact on enjoyment, anxiety, and willingness to communicate. *System, 121*, 103259. https://doi.org/10.1016/j.system.2024.103259

HOW ENGLISH SPEAKERS EXPRESS HUMOR IN DAILY LIFE

Nestan Akobia
Doctor in Philology, Associate Professor
DAUG – David Aghmashenebeli University of Georgia

Abstract

Humor is an integral and multifaceted component of everyday human communication, playing a crucial role in strengthening social bonds, relieving tension, and expressing cultural identity. This conference paper explores how humor manifests and is utilized in everyday English-language discourse. The study analyzes key linguistic and socio-cultural mechanisms, such as wordplay (puns), irony, sarcasm, understatement, and self-deprecating commentary. Using pragmatic and sociolinguistic approaches to examine natural conversational contexts, the research demonstrates that everyday English humor is highly context-dependent. It serves not only as a source of entertainment but also functions strategically to reduce social distance, manage interpersonal relationships, and employ "face-saving" tactics in daily interactions.

Keywords: *Humor, Daily Communication, Pragmatics, Irony, Sociolinguistics, English Speakers.*

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

CULTURAL DIFFERENCES AND THE CHALLENGES OF TRANSLATING AZERBAIJANI DOMESTIC AND TRADITIONAL VOCABULARY INTO ENGLISH: A COMPARATIVE STUDY OF AZERBAIJANI LITERATURE

Aysel Ceferova Qezenfer qizi
https://orcid.org/0009-0005-6281-0804
Azerbaijan State Oil and Industry University, Foreign Language Department, Baki, Azerbaijan

Abstract

The translation of culturally specific vocabulary is a significant challenge in literary translation because words associated with domestic life and traditional customs frequently convey meanings that extend beyond their direct lexical equivalents. Azerbaijani contains a rich vocabulary related to hospitality, kinship, household objects, marriage ceremonies, and seasonal celebrations. Many of these expressions reflect historically established social relationships and cultural practices that cannot be fully represented through literal translation. This article investigates the linguistic and cultural difficulties involved in translating Azerbaijani domestic and traditional vocabulary into English, focusing on expressions associated with household life, hospitality, marriage customs, and collective celebrations. The study adopts a qualitative comparative approach informed by Nida's theory of equivalence, Newmark's distinction between semantic and communicative translation, and Venuti's concepts of domestication and foreignization. Selected expressions, including *xonça*, *elçilik*, *cehiz*, *xeyir-dua*, *qonaqpərvərlik*, and *ata ocağı*, are examined in terms of denotative meaning, cultural associations, pragmatic function, and possible English renderings. The discussion draws on research into Azerbaijani cultural realia and considers the relevance of the literary works of Mirza Fatali Akhundzadeh and Jalil Mammadguluzadeh to the representation of domestic life and traditional social relationships. The analysis indicates that direct lexical substitution may obscure significant historical and cultural associations. Transliteration, descriptive translation, contextual explanation, and functional equivalence can offer more appropriate solutions when selected according to context. The article argues that successful Azerbaijani–English literary translation requires an integrated understanding of linguistic meaning, cultural knowledge, and literary function. Preserving cultural specificity while ensuring accessibility is essential for communicating Azerbaijani literary heritage to international readers.

Keywords: Azerbaijani culture; cultural realia; literary translation; domestic vocabulary; translation equivalence; cultural identity.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

IMPROVING ATTENTION FOR BETTER READING OUTCOMES IN PRIMARY SCHOOLS

Irini Arapi (Sylari)
Eftimi Sylari
ORCID ID: 0009-0006-7073-0756 Department of English Language, Faculty of Foreign Languages, University of Tirana
Msc., Department of English Language, Faculty of Foreign Languages, University of Tirana

Abstract

This theoretical review examines how attention can be supported and strengthened during reading activities in primary school education (ages 6–12). It synthesizes perspectives from information processing, cognitive load, metacognition, self-regulated learning, motivation, and embodied cognition to evaluate a range of instructional and classroom-based approaches. The analysis highlights that attention in young learners develops gradually and can be enhanced through structured teaching, supportive environments, and engaging learning experiences. The review suggests that combining active reading practices, explicit strategy instruction, attention-friendly classroom design, motivational supports, and brief mindfulness activities can contribute to improved comprehension and engagement. It also identifies a need for more context-specific research, particularly in underrepresented educational settings such as Albania and similar developing regions. Finally, the article outlines practical implications for teachers, school leaders, and families.

Keywords: attention, reading comprehension, primary education, metacognition, self-regulated learning, cognitive load.

1. Introduction

Reading coordinates working memory, language comprehension, background knowledge, inference, and attention (Kintsch, 1998; RAND Reading Study Group, 2002). Attention enables learners to select relevant information, sustain concentration, and allocate resources; without it, children may recognize words without processing relationships.

These links are particularly important in primary education, where attentional and executive capacities are still developing. Children differ in concentration, reading proficiency, language knowledge, motivation, and behavioural regulation. Inattention should therefore not automatically be read as lack of interest or discipline; it may reflect excessive task demands or unsuitable classroom conditions. Research links attention, working memory, executive functioning, and reading achievement (Savage et al., 2006), but implications for everyday instruction require theoretical synthesis.

This review distinguishes approaches that directly target attention (e.g., mindfulness; Mettler et al., 2023) from those that support it indirectly by reducing cognitive demands or sustaining engagement. *Improving attention* here means *supporting attentional processes during reading*—helping learners select, sustain, and regulate focus—not direct attention training. Improved comprehension is not treated as evidence of improved attention; where evidence concerns comprehension, engagement, or motivation, this is stated.

Previous reviews examine comprehension strategies (National Reading Panel, 2000; Okkinga et al., 2018), motivation (Toste et al., 2020; Van der Sande et al., 2023), and self-regulated learning (Dignath & Büttner, 2008; Xue & Xiao, 2024) separately. This review integrates six perspectives into a single framework (Section 3), links strategies to their functions, distinguishes direct from indirect evidence for attention, and applies the framework to the Albanian context.

The review addresses three questions: (1) Which theoretical perspectives explain attention during primary-school reading? (2) Which instructional and environmental approaches may support it, and how strong is the evidence? (3) How might these approaches be adapted to underrepresented contexts, particularly Albania?

2. Methodology

This article is a narrative theoretical review integrating established theories with selected empirical studies. Literature was purposively selected for its relevance to attention, executive functioning, working memory, cognitive load, metacognition, self-regulated learning, motivation, embodied cognition, classroom environments, and reading comprehension, with particular emphasis on primary-school learners. Priority was given to peer-reviewed theoretical contributions, empirical studies, and meta-analyses examining instructional interventions, cognitive processes, and classroom conditions. Searches targeted ERIC, publisher platforms, and academic resources, while Albanian-language sources and English-language studies relevant to Albanian reading were also considered. The review was limited to English- and Albanian-language sources.

The selected literature was examined through six perspectives—information processing, cognitive load theory, metacognition, self-regulated learning, motivation, and embodied cognition—and synthesised thematically. The review is narrative rather than exhaustive or meta-analytic; no formal quality appraisal was conducted, although meta-analyses were prioritised when discussing intervention effectiveness. The evidence is weighted towards Western contexts (Henrich et al., 2010), and most reported outcomes concern comprehension or engagement rather than direct measures of attention. These limitations delimit the strength of the conclusions and are revisited in Section 9.

3. Theoretical Foundations of Attention in Reading Development

3.1. Attention: Definitions and Components

Attention selects, organizes, and sustains focus while limiting interference (Posner & Petersen, 1990). Its components—selective, sustained, and executive attention—support different aspects of reading. Attention develops at varying rates between ages six and twelve. However, attention is not comprehension, which also depends on decoding, vocabulary, and background knowledge. Improved attention creates favourable learning conditions but cannot replace effective instruction.

3.2. Information Processing Theory

Learning involves selecting, processing, and storing information, with attention prioritising relevant input (Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974). Reading requires coordinated attention and working memory; limited capacity or interruptions reduce processing efficiency (Savage et al., 2006). In the context of reading, this theory explains why a beginning reader, who must consciously decode each word, has fewer attentional resources available for comprehension compared to a fluent reader.

3.3. Cognitive Load Theory

Cognitive Load Theory distinguishes task complexity from unnecessary demands created by presentation (Sweller, 1988; Sweller et al., 2019). Lengthy texts, unfamiliar vocabulary, and multiple instructions can overload pupils, leaving fewer resources for comprehension. Unnecessary load can be reduced without removing meaningful learning challenges.

3.4 Metacognition and Comprehension Monitoring

Metacognition is awareness and regulation of cognitive processes (Flavell, 1979). In reading, it involves recognizing whether a text is understood, identifying difficulties, and selecting strategies. Children who develop metacognitive awareness can recognize when attention has shifted and re-establish concentration—by rereading or asking for clarification. The National Reading Panel (2000) identified effective strategies, including comprehension monitoring, questioning, summarization, and cooperative learning. These practices help direct attention towards meaning and restore focus when comprehension breaks down, making attention regulation a teachable process rather than attention itself.

3.5. Self-Regulated Learning and Reading Development

Self-regulated learning involves planning, monitoring, and evaluating (Zimmerman, 2002). In reading, pupils set goals, maintain attention, monitor comprehension, and reflect on outcomes. These skills develop gradually, requiring teacher guidance for younger learners and greater independence for older students. Dignath and Büttner (2008) reported positive effects, particularly when metacognitive and motivational strategies were combined, while Xue and Xiao (2024) found moderate improvements in reading performance (Hedges' $g = 0.48$), with planning and monitoring emerging as important components. Unlike metacognition, which focuses on awareness and regulation of thinking, self-regulated learning encompasses wider processes through which learners set goals, manage activity, and evaluate outcomes. Together, they help learners direct attention towards meaning and address comprehension difficulties.

3.6. Motivation, Engagement, and Sustained Attention

Motivation influences learners' effort and persistence, while attention allocates cognitive resources. Guthrie (2004) links motivation, cognitive strategies, and social interaction to literacy engagement, while Toste et al. (2020) confirm its relationship with achievement across K–12. A meta-analysis of 39 studies found modest comprehension gains (d = 0.27), particularly from interest-based interventions (Van der Sande et al., 2023). Motivation can support the persistence needed to maintain attention, particularly when reading tasks become challenging

3.7. Embodied Cognition

Embodied cognition highlights how bodily experience, perception, and movement contribute to meaning-making (Barsalou, 2008; Wilson, 2002). Glenberg (2011) explains that reading comprehension involves mentally simulating the actions and situations described in texts. His Moved by Reading approach uses gestures, object manipulation, role-play, and physical representations to support younger learners. For classroom practice, this perspective suggests that incorporating physical movement and sensory experiences into reading activities may help anchor abstract concepts and support comprehension. However, findings remain mixed (Connor et al., 2018; Kaschak et al., 2017), and the role of embodied activities relative to explicit reading instruction remains debated.

4. Factors Influencing Attention During Reading

Attention is shaped by interacting factors: a demanding text raises cognitive load, reducing tolerance for distraction, which may depress motivation.

4.1. Cognitive and Developmental Factors

Children's attention is contingent on working memory, executive functioning, and prior learning. Beginning decoders expend substantial effort on word recognition, whereas fluent readers can direct more attentional resources toward interpretation. Reading tasks should therefore be differentiated by ability, not chronological age alone.

4.2. Linguistic Knowledge

Unfamiliar vocabulary, complex grammar, and limited background knowledge increase effort. In EFL, children process vocabulary, pronunciation, and grammar simultaneously; reduced engagement follows when demands exceed proficiency.

4.3. Motivation and Emotion

Motivation influences how actively children participate in reading and how much effort they invest; anxiety, fear of making mistakes, and negative experiences with reading aloud may reduce participation.

4.4. Classroom Environment

Classroom conditions, including noise, lighting, seating arrangements, and visual organisation, may influence pupils' concentration. Research on classroom acoustics particularly highlights the negative associations between noise, reduced speech clarity, attention, and memory (Mealings, 2022a).

4.5. Individual Differences

Children differ in processing speed, reading proficiency, language background, sensory needs, and behavioural regulation; inclusive reading instruction should provide adjustments—shorter passages, extra processing time, visual prompts, repeated instructions, or opportunities to listen while following written text—to improve access rather than reduce academic expectations. The same adjustment—for example, pre-teaching vocabulary—can simultaneously reduce cognitive load, support linguistic access, and protect perceived competence.

5. Instructional Strategies for Strengthening Attention

This section discusses six instructional strategies—active reading, explicit strategy instruction, self-regulated learning, movement-based activities, motivational supports, and brief mindfulness—with attention-friendly classroom design treated separately in Section 6. For each, it outlines the proposed function, typical actions, and evidence strength. One caveat applies throughout: most evidence concerns comprehension, engagement, or motivation rather than direct measures of attention. Improved comprehension is consistent with, but does not prove, better attentional allocation. Two further assumptions follow from Section 3: the effectiveness of

instructional strategies depends not only on their selection but also on their appropriate implementation, consistency, and alignment with specific reading objectives.

5.1. Active Reading

Active reading engages learners through prediction, questioning, discussion, annotation, and interpretation, so they construct meaning. Teachers structure activities before reading (title, illustrations, vocabulary prediction), during reading (details, questions, unfamiliar expressions), and after reading (summarising, event relationships). Reciprocal teaching (Palincsar & Brown, 1984) uses predicting, questioning, clarifying, and summarising to build monitoring and participation. Sporer et al. (2009) reported stronger comprehension and strategy use than traditional instruction, though this should be read alongside broader meta-analytic evidence. Active reading should remain purposeful, directing attention to meaning without unnecessary interruptions.

5.2. Explicit Strategy Instruction

Explicit strategy instruction teaches systematic reading. Teachers model thinking through explanations and guided practice (e.g., explaining sentence meaning, identifying unfamiliar words, using context clues, inferring, rereading), then transfer responsibility to collaborative and independent use. Meta-analytic evidence supports comprehension gains (National Reading Panel, 2000; Okkinga et al., 2018); as noted, such gains are consistent with improved attentional allocation without directly demonstrating it.

5.3. Self-Regulated Learning Strategies

Self-regulated reading involves goal setting, progress monitoring, and comprehension evaluation. Simple routines can be introduced: before reading, pupils identify what they expect to learn; during reading, they respond to short prompts (Am I concentrating? Do I understand? What is most important? Do I need to reread?); and after reading, they reflect on their comprehension and the strategies they found helpful. These routines build independence and show that reading requires active monitoring, not passive word recognition. Dignath and Büttner (2008) and Xue and Xiao (2024) report positive effects, with monitoring strategies particularly beneficial.

5.4. Movement-Based and Multisensory Activities

Vocabulary gestures, story sequencing with objects, role-play, and word-matching provide opportunities for participation and reinforce language learning. Glenberg (2011) shows that physical and mental simulation connect with meaning. Yet activities must connect to the reading objective; movement alone does not guarantee improvement, and evidence is mixed (Connor et al., 2018; Kaschak et al., 2017). Therefore, movement-based activities should be considered a supplementary tool to reinforce meaning, rather than a primary instructional strategy for reading comprehension.

5.5. Motivational Strategies and Engaging Reading Materials

Reading materials should match children's interests, experiences, and developmental levels. Teachers should offer varied genres—stories, informational texts, biographies, illustrated narratives, and age-appropriate digital materials—and provide choice to strengthen autonomy. Collaborative reading, paired discussions, storytelling, and reading challenges further increase participation. Van der Sande et al. (2023) found that motivation interventions, especially interest-oriented ones, positively affect comprehension. Such activities complement, rather than replace, systematic reading instruction combining vocabulary development, comprehension monitoring, and strategy practice; they support attention indirectly by increasing willingness to engage with text.

5.6. Brief Mindfulness and Attention-Regulation Activities

Mindfulness activities, such as brief breathing exercises before reading, may help pupils practise directing and regulating their attention. Mettler et al. (2023) report potential benefits of mindfulness-based programmes for school adjustment; however, this evidence should not be interpreted as direct proof of improved reading attention or comprehension. It should supplement, not replace, reading instruction.

6. Creating Supportive Reading Environments

Attention-friendly reading environments are defined here as physical and organisational conditions that reduce avoidable distraction and support concentration; the term is used interchangeably with *supportive reading environments*.

6.1. Classroom Organisation and Physical Learning Conditions

Classroom organisation shapes reading conditions. A well-organised environment reduces distractions and improves access to materials. Teachers should consider seating, movement, material location, and group activities. Where possible, a designated reading area can offer a quieter space for independent or paired reading. The aim is not constant silence but appropriate conditions for different reading activities.

6.2. Noise, Reading Media, and Classroom Distractions

Noise interferes with processing and increases concentration effort (Mealings, 2022a). Reduce noise through clear expectations and transitions. The medium of reading (paper vs. screen) may also influence comprehension, though findings are not uniform and may depend on the text's purpose and the reader's familiarity with the medium (Delgado et al., 2018).

6.3. Structured Reading Routines and Clear Instructions

Predictable routines help. A lesson may include introduction, vocabulary preparation, guided reading, independent practice, and reflection. Instructions should be concise with visual reminders for younger learners.

6.4. Teacher Support and Classroom Management

Teachers play a central role in supporting attention, as their instructional decisions shape task complexity, participation, interaction, and feedback. Effective classroom management combines clear expectations, positive reinforcement, and supportive guidance. Rather than responding only to visible distraction, teachers should also consider whether tasks are appropriately challenging, instructions are understood, and sufficient opportunities for participation are provided. Teacher modelling is particularly important, as pupils learn to approach reading through observation, guided practice, and feedback.

6.5. Inclusive and Emotionally Supportive Learning Environments

An inclusive reading environment recognises that students' differing learning needs should inform instructional planning. Teachers can support participation through alternative response modes, additional time, visual supports, and collaborative learning. A positive atmosphere encourages questions, expressed uncertainty, and help-seeking with comprehension difficulties. These conditions build confidence and sustain engagement, especially among learners who have previously struggled with reading.

7. Application to the Albanian Context

The Albanian context raises a relevant question about how first-language literacy may shape the demands of reading in English. Albanian has a relatively transparent orthography, whereas English spelling is less consistent. Hoxhallari et al. (2004) found that Albanian children acquired accurate word reading relatively easily, although reading speed and error patterns also mattered. Cross-linguistic research identifies substantial differences in the pace of early literacy acquisition across European orthographies (Seymour et al., 2003). These studies concern early literacy development; they do not directly establish how Albanian pupils process English texts. Consequently, the implications for instruction are necessarily exploratory.

7.1. Implications for Attention-Supportive Reading Instruction

For Albanian-speaking children learning to read in English, unfamiliar spelling–sound correspondences, vocabulary, and sentence structures may place additional demands on limited attentional resources. However, difficulties vary according to age, prior English exposure, instructional quality, vocabulary, and individual differences. Teachers should therefore identify specific challenges and select texts that balance accessibility with appropriate cognitive demands.

The before-reading phase deserves particular attention: teachers can flag words whose English spelling patterns differ from familiar first-language (L1) correspondences, pre-teach essential vocabulary, and select texts balancing challenge and accessibility—not to lower expectations but to preserve cognitive resources for meaning while developing English spelling and vocabulary. During reading, pupils may need help distinguishing sources of confusion (unfamiliar spelling, unknown word, difficult sentence structure), which require different responses; "sound it out" may be insufficient, so teachers can model questions such as "Do I know this word?" and "Can I use the spelling pattern to work it out?" Gesture, role-play, and dramatisation can

reinforce meaning but should complement explicit language and decoding instruction. Post-reading also matters: children confident in Albanian may find English spelling unexpectedly difficult and, if they interpret this as poor reading, persistence may suffer; teachers can explain that spelling systems differ in regularity, identify progress, and give feedback recognising strategies.

7.2. A Framework-Informed Hypothesis and Relevance Beyond Albania

The proposed application represents a theoretically informed hypothesis rather than an established empirical finding. Albanian primary teachers may need to prioritise vocabulary preparation and support pupils' confidence when decoding becomes difficult, although these needs vary across learners and classrooms. Further research is required to test these assumptions and their effects on reading outcomes. Although the decision principle may apply beyond Albania, its instructional priorities should reflect local conditions, including orthographic differences, age of English introduction, instructional quality, class size, reading resources, teacher preparation, and language exposure. Therefore, attention-supportive instruction requires context-specific evidence rather than the automatic transfer of recommendations across educational settings.

8. Implications for Primary School Education

8.1. Practical Implications for Teachers and Reading Instruction

Attention-supportive reading instruction integrates explicit comprehension teaching, appropriate task design, motivation, and self-regulation, with strategies selected according to pupils' developmental needs, reading objectives, and text complexity. A practical lesson may combine activating prior knowledge, pre-teaching vocabulary, clear objectives, guided reading, comprehension monitoring, discussion or purposeful movement, and concluding reflection. These strategies should extend beyond language lessons to science, mathematics, history, and social studies, where reading comprehension can be reinforced across the curriculum.

8.2. The Role of School Leadership

School leaders should make attention-supportive reading instruction a school-wide priority rather than leaving it to individual teachers. This requires professional development, adequate reading resources, improved classroom conditions, and opportunities to share effective practices. Consistent approaches across grade levels can ensure gradual progression towards more complex texts and independent comprehension strategies.

8.3. Family Involvement and Positive Reading Habits

Families can reinforce reading development by providing regular reading opportunities, discussing stories, encouraging curiosity, and establishing supportive home routines. Shared reading strengthens vocabulary, listening comprehension, and interest in texts, while positive school–family cooperation promotes consistent encouragement and lasting reading habits.

9. Research Gaps and Future Directions

9.1. Limitations of Existing Research

Despite established links between cognition, motivation, and reading achievement, important gaps remain. Attention is assessed inconsistently across studies, using different measures and related indicators, including sustained-attention tasks, working-memory measures, executive-function assessments, and broader task-performance outcomes. Although these constructs are related, they should not be treated as equivalent measures of attention. Moreover, interventions may improve participation without producing measurable comprehension gains, making causal relationships difficult to establish. Research also tends to examine individual strategies rather than their combined effects in everyday classrooms, while much of the evidence comes from WEIRD (Western, Educated, Industrialized, Rich, and Democratic) populations (Henrich et al., 2010).

9.2. The Need for Context-Specific Research

Educational practices depend on linguistic, cultural, socioeconomic, and institutional conditions; therefore, findings cannot be universally generalised. Reading resources, class size, teacher preparation, language backgrounds, and school conditions influence the implementation and effectiveness of attention-supportive strategies, particularly in underrepresented educational contexts.

9.3. Research Priorities in Albania and Comparable Contexts

Albanian primary schools offer valuable opportunities to investigate attention and reading development. Future research should examine: (1) classroom factors associated with reduced attention; (2) the effects of active reading strategies on engagement and comprehension; (3) the relationship between self-regulation and

sustained attention; (4) teachers' perceptions of movement-based and multisensory activities; and (5) the influence of classroom conditions on reading engagement. Such research could inform teacher training and educational policy. Mixed-methods studies combining comprehension tasks, behavioural observations, self-regulation measures, teacher interviews, and student feedback could establish whether improved attention translates into measurable reading gains and identify which strategies work best across age groups and proficiency levels. Such a research agenda would not only advance local knowledge but also contribute valuable data to the global discourse on reading development in diverse linguistic and educational contexts.

10. Conclusion

This review addressed three questions. First, six complementary perspectives explain how attention operates during reading and how instruction can support it. Information processing and cognitive load theory clarify cognitive demands; metacognition and self-regulated learning explain how learners monitor and repair comprehension difficulties; motivation sustains effort; and embodied cognition highlights the contribution of perceptual and motor experiences. Together, these perspectives suggest that attention is not a fixed learner trait but a process shaped by instruction and environment.

Second, the evidence varies across outcomes. Evidence for comprehension is strongest for explicit reading-strategy instruction (National Reading Panel, 2000; Okkinga et al., 2018) and moderate to strong for self-regulated learning interventions (Dignath & Büttner, 2008; Xue & Xiao, 2024, g = 0.48). Motivational interventions show modest positive effects (d = 0.27; Van der Sande et al., 2023), while findings on movement-based approaches remain mixed (Connor et al., 2018; Kaschak et al., 2017). Mindfulness evidence is promising but not reading-specific (Mettler et al., 2023), and evidence for attention-supportive classroom design remains largely indirect (Mealings, 2022a, 2022b). These findings suggest potential benefits for attention but do not directly establish improved attentional allocation.

Third, the Albanian context highlights the importance of linguistic conditions. Differences between Albanian and English orthographic systems may increase word-level processing demands, making vocabulary preparation, explicit spelling instruction, diagnostic questioning, and supportive feedback particularly relevant. However, these proposals remain hypotheses requiring empirical testing. Two conclusions follow: attention should be supported alongside decoding, vocabulary, comprehension instruction, and motivation—not treated as a substitute for them; and effective instruction depends on a small number of complementary, consistently implemented practices rather than numerous isolated activities. Teachers, school leaders, and families all contribute to sustaining these conditions. However, further research—particularly in underrepresented contexts such as Albania—is needed to establish whether these approaches produce measurable improvements in primary pupils' reading outcomes.

References

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 2, pp. 89–195). Academic Press. https://doi.org/10.1016/S0079-7421(08)60422-3

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 8, pp. 47–89). Academic Press.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology, 59*, 617–645. https://doi.org/10.1146/annurev.psych.59.103006.093639

Connor, C. M., Phillips, B. M., Kim, Y.-S. G., Lonigan, C. J., Kaschak, M. P., Crowe, E., Dombek, J., & Al Otaiba, S. (2018). Examining the efficacy of targeted component interventions on language and literacy for third and fourth graders who are at risk of comprehension difficulties. *Scientific Studies of Reading, 22*(6), 462–484. https://doi.org/10.1080/10888438.2018.1481409

Delgado, P., Vargas, C., Ackerman, R., & Salmerón, L. (2018). Don't throw away your printed books: A meta-analysis on the effects of reading media on reading comprehension. *Educational Research Review, 25*, 23–38. https://doi.org/10.1016/j.edurev.2018.09.003

Dignath, C., & Büttner, G. (2008). Components of fostering self-regulated learning among students: A meta-analysis on intervention studies at primary and secondary school level. *Metacognition and Learning, 3*(3), 231–264. https://doi.org/10.1007/s11409-008-9029-x
Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist, 34*(10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906
Glenberg, A. M. (2011). How reading comprehension is embodied and why that matters. *International Electronic Journal of Elementary Education, 4*(1), 5–18. https://www.iejee.com/index.php/IEJEE/article/view/210
Guthrie, J. T. (2004). Teaching for literacy engagement. *Journal of Literacy Research, 36*(1), 1–30. https://doi.org/10.1207/s15548430jlr3601_2
Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences, 33*(2–3), 61–83. https://doi.org/10.1017/S0140525X0999152X
Hoxhallari, L., van Daal, V. H. P., & Ellis, N. C. (2004). Learning to read words in Albanian: A skill easily acquired. *Scientific Studies of Reading, 8*(2), 153–166. https://doi.org/10.1207/s1532799xssr0802_3
Kaschak, M. P., Connor, C. M., & Dombek, J. L. (2017). Enacted reading comprehension: Using bodily movement to aid the comprehension of abstract text content. *PLOS ONE, 12*(1), Article e0169711. https://doi.org/10.1371/journal.pone.0169711
Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge University Press.
Mealings, K. (2022a). Classroom acoustics and cognition: A review of the effects of noise and reverberation on primary school children's attention and memory. *Building Acoustics, 29*(3), 401–431. https://doi.org/10.1177/1351010X221104892
Mealings, K. (2022b). Classroom acoustic conditions and primary school children's behaviour: A scoping review. *Building Acoustics, 29*(4), 543–558. https://doi.org/10.1177/1351010X221126680
Mettler, J., Khoury, B., Zito, S., Sadowski, I., & Heath, N. L. (2023). Mindfulness-based programs and school adjustment: A systematic review and meta-analysis. *Journal of School Psychology, 97*, 43–62. https://doi.org/10.1016/j.jsp.2022.10.007
National Reading Panel. (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction*. National Institute of Child Health and Human Development, National Institutes of Health.
Okkinga, M., van Steensel, R., van Gelderen, A. J. S., & Sleegers, P. J. C. (2018). Effectiveness of reading-strategy interventions in whole classrooms: A meta-analysis. *Educational Psychology Review, 30*(4), 1215–1239. https://doi.org/10.1007/s10648-018-9445-7
Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction, 1*(2), 117–175. https://doi.org/10.1207/s1532690xci0102_1
Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13*, 25–42. https://doi.org/10.1146/annurev.ne.13.030190.000325
RAND Reading Study Group. (2002). *Reading for understanding: Toward an R&D program in reading comprehension*. RAND Corporation.
Savage, R., Cornish, K., Manly, T., & Hollis, C. (2006). Cognitive processes in children's reading and attention: The role of working memory, divided attention, and response inhibition. *British Journal of Psychology, 97*(3), 365–385. https://doi.org/10.1348/000712605X81370
Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94*(2), 143–174. https://doi.org/10.1348/000712603321661859
Sporer, N., Brunstein, J. C., & Kieschke, U. (2009). Improving students' reading comprehension skills: Effects of strategy instruction and reciprocal teaching. *Learning and Instruction, 19*(3), 272–286. https://doi.org/10.1016/j.learninstruc.2008.05.003
Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257–285. https://doi.org/10.1207/s15516709cog1202_4
Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review, 31*, 261–292. https://doi.org/10.1007/s10648-019-09465-5

Toste, J. R., Didion, L., Peng, P., Filderman, M. J., & McClelland, A. M. (2020). A meta-analytic review of the relations between motivation and reading achievement for K–12 students. *Review of Educational Research, 90*(3), 420–456. https://doi.org/10.3102/0034654320919352

Van der Sande, L., van Steensel, R., Fikrat-Wevers, S., & Arends, L. (2023). Effectiveness of interventions that foster reading motivation: A meta-analysis. *Educational Psychology Review, 35*, Article 21. https://doi.org/10.1007/s10648-023-09719-3

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*(4), 625–636. https://doi.org/10.3758/BF03196322

Xue, Y., & Xiao, Y. (2024). The effects of self-regulated learning interventions on primary and secondary students' reading performance: A meta-analysis. *Lecture Notes in Education Psychology and Public Media, 58*, 235–245. https://doi.org/10.54254/2753-7048/58/20241796

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice, 41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE UNIVERSAL ACQUISITION SYSTEM: A COGNITIVE PERSPECTIVE ON ESP LEARNING

Greta Pergjegji
ORCID: 0009-0003-9284-6053, Faculty of Defence and Security Studies, Department of Communication Sciences and Foreign Languages, Tirana Albania

Abstract

Professional language use requires more than grammatical knowledge or general communicative fluency. In military, legal, medical, and aviation settings, learners must interpret relationships accurately, preserve specialised meanings, and communicate within institutional constraints, often under time pressure. This theoretical paper introduces the Universal Acquisition System (UAS), a proposed framework for examining how these demands interact in second language acquisition. Its central construct, the Cognitive Operating System (COS), describes a hypothesised relational architecture through which learners coordinate participant roles, hierarchical relations, temporal sequences, and conditional dependencies. The computational terminology is used as an explanatory analogy, rather than as evidence of an identified neurological system.

The paper develops the framework through a conceptual synthesis of selected work on input processing, skill acquisition, usage based learning, and cognitive load. Illustrative cases involving active and passive constructions, conditional obligations, and specialised vocabulary show how structural alignment might support professional language performance. Three analytical categories are proposed: semantic instability, logical instability, and compliance instability. These categories organise possible performance difficulties without assuming that every professional error has a linguistic or cognitive cause.

The framework generates predictions concerning processing speed, accuracy under additional cognitive load, and transfer to unfamiliar professional tasks. It also outlines comparison conditions and possible findings that would challenge its explanatory value. Claims about processing efficiency and computational scaling remain hypotheses requiring empirical and formal investigation. The contribution is a provisional account linking relational processing to the demands of English for Specific Purposes (ESP), together with a research agenda for testing whether structural alignment explains outcomes beyond established accounts of practice, schemas, and automaticity.

Keywords: second language acquisition; structural alignment; cognitive processing; English for Specific Purposes.

INTRODUCTION

Second language acquisition (SLA) research approaches learning from several directions. Input accounts emphasise exposure and comprehension; interaction research examines the negotiation of meaning; skill acquisition approaches ask how practice changes access to linguistic knowledge (Krashen, 1985; Long, 1983; DeKeyser, 1998). These explanations can complement one another. For professional language learning, a further question concerns the coordination of linguistic relationships when a task demands accuracy under pressure.

I propose the Universal Acquisition System (UAS) as a conceptual framework for investigating these questions. Its central construct, the Cognitive Operating System (COS), names a hypothesised capacity to organise linguistic material through relational representations. Such representations concern who acts, what an action affects, when events occur, and which conditions make an obligation applicable. In this account, acquisition involves structural alignment: linguistic forms become more reliably coordinated with the

relationships they express. The proposal draws on established processing and learning accounts. Its specific architecture, however, has yet to be demonstrated independently.

ESP offers a useful setting for this investigation because successful performance requires professional knowledge as well as language (Hutchinson and Waters, 1987; Basturkmen, 2006). Consider an instruction that is grammatically acceptable but leaves responsibility unclear. A fluent report can likewise misstate a condition, and an otherwise accurate sentence can omit a required procedural detail. I examine these possibilities through the categories of semantic, logical, and compliance instability. Distinguishing them may help explain difficulties that a general proficiency judgement would leave undifferentiated.

The discussion addresses three questions: how structural alignment can be defined; what conceptual distinctions it offers for professional language analysis; and what evidence would distinguish it from existing cognitive explanations. The paper develops an argument from selected literature and constructed examples, without participant data. The word universal indicates the intended scope of the hypothesis, rather than established applicability across languages, learners, or professions.

THEORETICAL BACKGROUND

A learner may be able to explain a grammatical rule and still struggle to use it under pressure. Skill acquisition research accounts for this gap by showing how practice can make performance faster and less dependent on conscious rule retrieval (DeKeyser, 1998). In professional settings, however, efficient use of a form is only one part of successful performance. Canale and Swain (1980) situate grammatical accuracy within the broader concept of communicative competence, while Willis and Willis (2007) show how learners can attend to form while carrying out meaningful tasks. Skehan's (1998) account of attention during task performance helps explain why these demands can compete for limited cognitive resources. For UAS, the question is whether directing learners' attention to participant roles, relationships between conditions and outcomes, and institutional constraints improves performance beyond the gains associated with equally meaningful task practice.

Research on input and cognitive resources provides a basis for testing this question. Krashen (1985) emphasises the importance of comprehensible input, while VanPatten (2004) examines how learners connect linguistic forms with meaning. Bybee (2010) considers how repeated encounters with language support categorisation and the development of representations, and Sweller et al. (2011) explain how prior knowledge and instructional design shape the demands placed on working memory. Together, these accounts provide a basis for examining how learners coordinate linguistic relationships and professional requirements in English for Specific Purposes (ESP). The contribution of UAS depends on whether relational alignment yields testable predictions that can be distinguished from those of existing accounts of proceduralisation, automaticity, and task performance.

MATERIALS AND METHODS

This paper adopts a qualitative conceptual approach. Its materials are the theoretical works discussed in the background and the constructed language examples examined below. The purpose is to specify a framework, examine the consistency of its distinctions, and derive propositions that could be tested. The unit of analysis is a proposed relationship between linguistic form, relational meaning, and task constraints. There are no participants, recorded performances, interviews, classroom intervention data, or statistical comparisons in the present analysis.

The literature is organised by its relevance to the explanatory problem rather than by a claim to comprehensive coverage. Input and interaction accounts provide a background for access to language and meaning (Krashen, 1985; Long, 1983). Communicative competence and task based work situate performance within purposeful activity (Canale and Swain, 1980; Willis and Willis, 2007). Skill acquisition, input processing, and usage based accounts provide comparisons for learning through practice and the development of representations

(DeKeyser, 1998; VanPatten, 2004; Bybee, 2010). Cognitive load and fluency research inform the discussion of processing demands (Sweller et al., 2011; Segalowitz, 2010). ESP and professional discourse scholarship establish the importance of domain knowledge and communicative purpose (Hutchinson and Waters, 1987; Basturkmen, 2006; Hyland, 2006).

The analytical procedure has three connected steps. First, the argument separates established explanations of practice, form and meaning, and processing demands from the additional claims proposed under UAS. Second, it defines structural alignment and the semantic, logical, and compliance domains, examining where they overlap and where nonlinguistic explanations are possible. Third, it applies these distinctions to constructed examples and specifies what evidence would be needed to move from an illustration to an explanatory claim. The comparison is qualitative; it does not assign scores to theories or estimate their relative effects.

The examples are chosen to make different relationships inspectable. Voice alternation illustrates the distinction between participant roles and grammatical functions; a conditional instruction illustrates the scope of an obligation and its exception; specialised terms illustrate the limits of fixed meaning in professional contexts. Each case is examined in terms of the relationship to be preserved, the change in its linguistic expression or task context, the possible interpretation difficulty, and an alternative explanation. A reader can follow the analysis using the stated sentences, conditions, and definitions. The cases are illustrative constructions, not authentic professional records, representative samples, or observations of learner behaviour.

The analysis is assessed through explicit definitions, consistency between each example and the proposed distinction, acknowledgement of competing explanations, and separation of conceptual outputs from empirical predictions. These safeguards make the reasoning open to scrutiny; they do not establish measurement reliability or construct validity. No independent coding or interrater reliability estimate is reported. The results below refer to the framework and distinctions developed through this reasoning. Any claim about learning gains, cognitive architecture, or transfer requires separate empirical investigation.

RESULTS

UAS distinguishes the capacity to represent relationships from the language specific and professional knowledge brought to a task. The COS refers to the proposed coordination of these resources. Grammar, vocabulary, and discourse conventions provide ways of expressing the relationships. Describing these resources as applications can help explain the distinction, although the software analogy has limits: linguistic knowledge and processing probably interact more closely than separate software layers would suggest.

Functional architecture

The proposed architecture has four functional dimensions. Here, a slot means a representational position within a relationship, rather than a literal memory location or a fixed place in a sentence. Learners may draw on relational capacities they already possess. That possibility does not imply that second language structures are innate, fully specified, or unaffected by experience.

Role assignment involves identifying participants and separating their semantic roles from their grammatical functions. Passive constructions make the distinction clear: the agent is not necessarily the subject.

Hierarchical organisation allows a learner to distinguish a main proposition from a subordinate condition, qualification, or piece of background information. Interpretation depends on preserving the scope of each.

Temporal and conditional representation concerns the order of events and the dependencies, exceptions, and consequences that connect them. An event's place in time must be distinguished from its logical relationship to another event.

Stabilisation describes the proposed process through which mappings between form and meaning become more consistent across encounters and task conditions. It does not imply that processing is immediately reliable or free of error.

More accessible relationships may require less reconstruction during familiar tasks, leaving attention available for other demands. This expectation fits accounts of schema development and automaticity (Sweller et al., 2011; Segalowitz, 2010). Compatibility alone, though, does not establish a separate UAS mechanism. Evidence would have to distinguish relational knowledge from vocabulary knowledge, familiarity with a task, and general proficiency.

The kernel and application analogy

The kernel and application analogy separates coordination from the knowledge being coordinated. It helps express a practical possibility: teaching additional terminology may leave a learner's difficulty with responsibility or conditions unresolved. The analogy should not be taken literally. No brain structure has been identified as the COS, and the present paper supplies neither a computational implementation nor evidence that the COS manages memory as a software kernel does. Representations, attention, and task knowledge may change reciprocally during learning. The proposed architecture is therefore a functional description whose value depends on what it can explain and predict.

Structural alignment and instability domains

Structural alignment means reliably mapping linguistic expressions onto participant roles, dependencies, and relevant task constraints. One way to assess it would be to vary the wording of interpretation and production tasks while keeping the underlying relationships constant. Success with a rehearsed sentence would not suffice. The following categories identify possible difficulties within this account; they may overlap, and the same difficulty may have more than one cause.

Semantic instability occurs when a task relevant meaning is interpreted or expressed inconsistently, as in confusion between specialised terms. Unfamiliar vocabulary and legitimate differences in professional interpretation must be considered separately.

Logical instability concerns distorted causal, conditional, temporal, or scope relationships. An assessment must establish whether the learner misunderstood the language or the situation it described.

Compliance instability concerns failure to express or follow a specified institutional requirement. Language processing is one possible source, alongside missing professional knowledge, unclear instructions, and organisational conditions. Such failures cannot simply be assigned to the COS.

These distinctions connect UAS with ESP needs analysis and professional discourse (Hutchinson and Waters, 1987; Hyland, 2006). They make possible sources of difficulty more explicit. Before they become assessment dimensions, however, their practical usefulness and the reliability with which they can be coded need to be tested.

Participant roles in active and passive constructions

An active–passive pair makes the difference between semantic roles and grammatical positions visible. Instruction may initially lead learners through several transformation steps. Practice can make those operations less conscious and less sequential (DeKeyser, 1998). UAS describes the relationship as a remapping of grammatical functions that preserves the event and its participants. The example illustrates that description; it does not show that producing a passive sentence requires just one mental operation. Figures 1 and 2 make this distinction explicit by presenting the same event with different grammatical subjects.

Active construction: The boy eats the apple. Agent: the boy; action: eating; patient: the apple. The agent is expressed as the grammatical subject.

SLOT 1		SLOT 2		SLOT 3
The boy	→	eats	→	the apple
Agent and subject		Action		Patient and object

Figura 1. ***Active construction. The agent is the grammatical subject; the patient is the grammatical object. Slot numbers identify positions in the diagram.***

Passive construction:The apple is eaten by the boy. Patient: the apple; action: eating; agent: the boy. The patient is expressed as the grammatical subject, while the agent appears in a by phrase.

SLOT 1		SLOT 2		SLOT 3
The apple	→	is eaten	→	by the boy
Patient and subject		Action and morphology		Agent in a by phrase

Figura 2. ***Passive construction. The patient becomes the grammatical subject; the agent is expressed in a by phrase. Semantic roles are preserved.***

The participants retain comparable semantic roles across the two sentences, although their grammatical expression changes. Structural alignment would involve preserving those roles even when time is limited. This still leaves morphology, auxiliary selection, agreement, and discourse appropriateness to be explained. A test could use unfamiliar verbs and reversible events, recording interpretation accuracy alongside response time. Input processing research is an essential comparison here because it already examines connections between form and meaning (VanPatten, 2004).

Conditional dependence and the scope of obligations

Conditional language makes a different demand. Consider the following constructed instruction: if it rains tomorrow, construction is suspended and the 5 PM deadline does not apply. If it does not rain, the wall must be completed by 5 PM, and missing that applicable deadline constitutes a contractual breach. The scope matters. Failure to complete the wall cannot be treated as a breach irrespective of the weather condition.

The weather determines whether the obligation applies; a breach depends on failure to meet that applicable obligation. These are branching dependencies, rather than a simple sequence of events. Knowing the sentences individually does not ensure that a learner preserves the connection between condition and consequence. UAS predicts that instruction which makes this connection explicit may help learners interpret unfamiliar instructions with comparable structures. Figure 3 represents these dependencies within the constructed instruction; it does not depict measured learner processing.

Assessment should distinguish relational understanding from recall of a familiar wording. Learners might judge whether a breach occurs when rain suspends construction and then explain the exception. An active comparison group receiving equivalent vocabulary instruction and task practice would help establish whether an advantage came from relational training. Professional knowledge and general reasoning ability would also need to be considered.

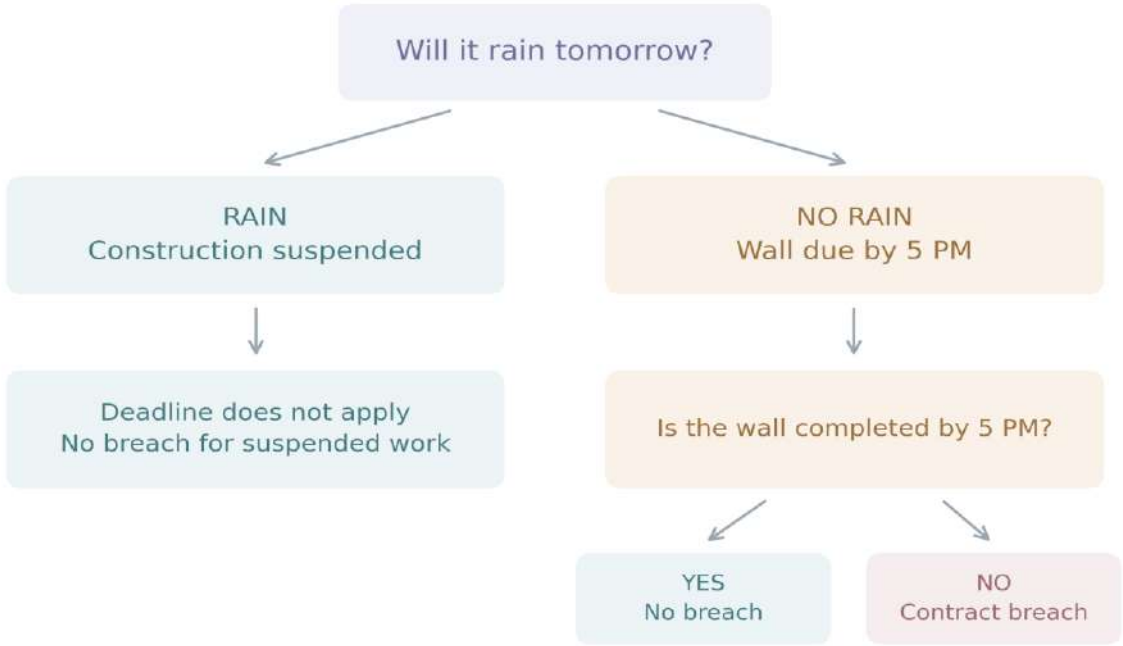


Figura 3.*Conditional dependencies in the constructed instruction. The deadline and its consequence apply only on the no rain branch.*

Semantic precision and professional judgement

Professional context shapes specialised meanings, which cannot always be expressed through fixed numerical thresholds (Basturkmen, 2006). Reasonable and negligent, for example, may require contextual judgement. Alignment in UAS should therefore refer to a relevant definition, decision criterion, or institutional interpretation. It cannot promise absolute semantic precision. Where a military task permits, an imprecise deadline such as soon could be replaced by a stated time. A legal standard may remain context sensitive. Recognising uncertainty and seeking clarification when a term is insufficiently specified are themselves part of successful alignment.

Across the cases, alignment concerns the preservation of a task relevant relationship rather than the retention of a particular sentence pattern. The voice example separates grammatical position from participant role. The conditional example separates the applicability of an obligation from whether an action was completed. The vocabulary example shows why professional interpretation may require contextual judgement rather than a fixed verbal substitute. Together, these distinctions provide an analytical vocabulary for specifying difficulties that would otherwise be grouped under general inaccuracy.

The three instability domains therefore function as provisional questions for analysis: which meaning is uncertain, which relationship is misrepresented, and which requirement is not expressed or understood? Their usefulness depends on keeping language knowledge, professional knowledge, and task conditions analytically distinct. This conceptual organisation supports the formulation of testable propositions, but does not show that the domains are independent psychological mechanisms or that instruction based on them is more effective.

DISCUSSION

Processing demands and scaling claims

Processing demands can rise as learners coordinate more relationships or retrieve less familiar language. Yet the number of rules in an instructor's explanation does not determine the computational complexity of the

learner's performance. Practice can make rule based performance rapid, and relational representations may themselves demand complex coordination (DeKeyser, 1998; Skehan, 1998). Multiple grammatical rules therefore provide no basis, on their own, for inferring exponential growth in cognitive demand.

The UAS hypothesis is narrower: a stable representation may reduce the need to reconstruct relationships in tasks that share an underlying structure. Under restricted conditions, processing time might grow in a near linear fashion. Neither that pattern nor an advantage over other architectures has been demonstrated. A formal account must first define input size, representations, permitted operations, and the relevant measure of cost. Equating human response time with algorithmic complexity would require further assumptions. Whether growth is linear or combinatorial remains a question for research.

Cognitive efficiency and alternative explanations

Cognitive load theory provides grounds for investigating how prior knowledge and instructional support affect processing demands (Sweller et al., 2011). Relational training might reduce unnecessary search or help learners process familiar elements as a unit. An unfamiliar task can still make substantial demands, however well its elements are organised. Response speed, hesitation, perceived effort, and accuracy need separate measures, since a faster answer may be a less accurate one. Segalowitz (2010) offers a further basis for distinguishing cognitive processing from the fluency observed in performance.

Development and structural flexibility

A possible developmental sequence helps clarify the proposal. It is a heuristic, not a universal set of stages: the same learner may develop differently across structures, genres, and professional settings.Early encounters may involve a small set of relationships and considerable support. Repeated experience could make familiar patterns easier to recognise, without producing a linear rate of improvement.

As demands increase, learners may have to coordinate interacting conditions with unfamiliar vocabulary and competing interpretations. Temporary inconsistency could accompany reorganisation, although it would not constitute evidence unique to UAS.

More advanced performance may allow efficient access to familiar relationships alongside flexible interpretation of exceptions and new situations. Fluency with practised material is not enough to establish this flexibility. Transfer needs its own assessment.

This sequence is broadly consistent with usage based learning and skill acquisition (Bybee, 2010; DeKeyser, 1998). UAS may contribute by specifying which relationships remain stable as professional demands change. If those specifications neither explain additional variance nor generate different outcomes, the framework would remain a descriptive synthesis rather than a distinct explanatory theory.

Relationship to existing accounts

UAS centres the discussion on professional language use by examining relational mapping together with task constraints. Semantic, logical, and compliance instability supply connected categories for that analysis. Much of the underlying territory is already covered: schemas concern organised knowledge, skill acquisition explains changes through practice, and input processing addresses connections between form and meaning. The proposed relational measures must consequently predict professional performance beyond these established constructs. Explicit instruction, meaningful input, and communicative practice retain their place in the account.

Propositions for empirical investigation

The processing efficiency prediction concerns accuracy under pressure. With instructional time and exposure held equivalent, learners receiving relational mapping support should retain higher interpretation accuracy under time pressure or an additional task than an active comparison group. Proficiency and professional knowledge should be matched. If an advantage consistently fails to appear after controlling for practice and familiarity, the prediction would be weakened. Faster responding would not rescue it if accuracy fell.

The error distribution prediction connects independent measures of role and dependency interpretation to corresponding errors in professional tasks, after accounting for vocabulary and general proficiency. Testing it requires explicit criteria for semantic, logical, and compliance errors, together with independent raters. Unreliable coding would limit the categories' usefulness. So would a failure to predict anything beyond established measures.

The structural flexibility prediction concerns transfer. Benefits should appear on unfamiliar tasks that retain relevant relationships while changing their wording and context. Delayed assessment would help separate durable learning from immediate rehearsal effects. Gains confined to trained items would more readily support task specific learning than a broadly transferable architecture. Transfer between professional domains would require additional evidence.

Requirements for future validation

A first study could compare relational mapping instruction with an active condition matched for materials, feedback, practice time, and instructor attention. Both practised and unfamiliar professional tasks could be included at pretest, immediate posttest, and delayed posttest. Measures might cover role interpretation, judgements about conditions and exceptions, written task accuracy, response time, and performance under a carefully designed additional load. Alignment should be assessed independently of the outcome task. Otherwise, explaining successful performance through alignment risks defining the explanation by the result.

Computational testing requires an explicit implementation and comparison with alternative learning models. A simulation would need to explain how representations are acquired, how ambiguity is resolved, and how errors occur. Placing correct answers in fixed slots would not explain acquisition. Further research must separate general reasoning capacity from language specific learning and professional knowledge. If the COS cannot be independently measured, or if simpler accounts explain the same outcomes as well, it should be revised or abandoned as an explanatory construct. Such findings would still help establish which parts of the framework merit further development.

Limitations of the theoretical analysis

The selective literature base cannot establish how the proposal relates to every relevant account of language learning. Constructed cases make relationships easier to inspect but do not demonstrate their frequency, difficulty, or importance in authentic professional performance. The analysis is interpretive and does not provide independently replicated coding. The COS remains a functional hypothesis without an independent operational measure, and the instability domains may overlap with established constructs or with nonlinguistic difficulties. Neither crosslinguistic universality nor transfer across professions follows from the examples. These limitations restrict the present contribution to conceptual clarification and the design of subsequent tests.

CONCLUSION

The conceptual analysis develops UAS as a framework for examining how linguistic relationships and professional constraints are coordinated. Its principal outputs are an explicit account of structural alignment, a provisional distinction among semantic, logical, and compliance instability, and illustrative analyses of participant roles, conditional obligations, and specialised meanings. The COS names the hypothesised coordination of these resources; it is not an established neurological or computational mechanism.

For ESP, the contribution is a more explicit set of questions about what learners must preserve when wording or task conditions change. The examples indicate how those questions can be formulated, while the comparison with existing accounts identifies practice, input processing, schemas, and automaticity as explanations that future studies must address. The paper does not demonstrate that relational instruction improves learning or that processing follows a particular scaling pattern.

Further evaluation requires independent measures of alignment, transparent criteria for the proposed error domains, active comparison conditions, and tasks that distinguish rehearsal from transfer. Computational

claims additionally require a specified implementation and cost measure. UAS should be retained, revised, or rejected according to whether these tests establish explanatory value beyond existing accounts. Its present status is a theoretically articulated proposal rather than an empirically validated system.

REFERENCES

Basturkmen, H. (2006). *Ideas and options in English for specific purposes*. Lawrence Erlbaum Associates. Pg 63-66 and 134-137

Bybee, J. (2010). *Language, usage and cognition*. Cambridge University Press. Pg 1-13

Canale, M., & Swain, M. (1980). Theoretical bases of communicative approaches to second language teaching and testing. *Applied Linguistics, 1*(1), pg.1–47.

DeKeyser, R. M. (1998). Beyond focus on form: Cognitive perspectives on learning and practicing second language grammar. In C. Doughty & J. Williams (Eds.), *Focus on form in classroom second language acquisition* Cambridge University Press. (pg. 42–63).

Hutchinson, T., & Waters, A. (1987). *English for specific purposes: A learning-centred approach*. Cambridge University Press. Pg 53-64

Hyland, K. (2006). *English for academic purposes: An advanced resource book*. Routledge. Pp 340

Krashen, S. D. (1985). *The input hypothesis: Issues and implications*. Longman. pg 2

Long, M. H. (1983). Native speaker/non-native speaker conversation and the negotiation of comprehensible input. *Applied Linguistics, 4*(2), pg 126–141.

Segalowitz, N. (2010). *Cognitive bases of second language fluency*. Routledge. Pp 222

Skehan, P. (1998). *A cognitive approach to language learning*. Oxford University Press. Pg (97-112)

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. Springer. pg.203

VanPatten, B. (Ed.). *(2004). Processing instruction: Theory, research, and commentary*. Lawrence Erlbaum Associates. pg.5

Willis, D., & Willis, J. (2007). *Doing task-based teaching*. Oxford University Press. Pg 113-117

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ASSESSING THE DIVERGENCE BETWEEN CLASSROOM INSTRUCTION AND STANAG 6001 HIGH-LEVEL PROFICIENCY TESTING

Monika Myrto
ORCID: 0009-0003-6710-6889, Defence and Security College, Department of Foreign Languages, Tirana, Albania

Abstract

In military language education, STANAG 6001 serves as the institutional standard for measuring professional language competence. However, language instructors and testing boards frequently encounter a persistent gap between candidate performance in routine classroom settings and their final outcomes on standardized examinations. This paper explores the roots of this disconnect by focusing on two structural factors: the functional distinction between the classroom instructor and the certified tester, and the growing divergence between instructional practice and test demands at higher proficiency levels. While classroom teachers naturally prioritize student progress, syllabus coverage, and supportive feedback, STANAG testers must maintain a strict, criterion-referenced evaluation of unassisted language performance. Experience shows that this division of roles operates smoothly at elementary and functional thresholds (SLP 1111 and 2222), where classroom tasks and test prompts share a focus on routine vocabulary, basic grammar, and transactional communication. However, the gap becomes far more pronounced at advanced target levels (SLP 3232 and 3333). At Level 3, the test requires spontaneous abstract reasoning, hypothesis formulation, structural cohesion, and stylistic nuance. In contrast, classroom assessments often continue to emphasize content mastery, familiar topics, or explicit grammar accuracy, leading instructors to overestimate candidate readiness for the cognitive and communicative demands of higher-level testing. By examining specific evaluation challenges in writing and speaking, this paper outlines practical steps to harmonize classroom practices with high-level STANAG criteria. Recommendations emphasize targeted professional development for instructors, the integration of spontaneous, higher-order tasks into regular coursework, and closer communication between teaching departments and testing authorities.

Keywords: divergence; candidate performance; classroom instructor; certified tester; evaluation; integration.

INTRODUCTION

Military language courses serve several purposes at once. Learners need English for study, professional communication, and participation in multinational settings. Institutions also need dependable evidence that personnel can meet the language requirements attached to particular assignments. These purposes overlap, yet they do not generate identical assessment questions. A course may document substantial learning without establishing that a candidate can sustain the required proficiency outside the conditions in which that learning occurred. This distinction corresponds to the difference between achievement tests, which relate to course objectives, and proficiency tests, which assess specified abilities beyond a particular syllabus (Hughes, 2003).

In the institutional setting described in this paper, the STANAG examination follows a language course of 13 weeks. A separate professional testing team trained by BILC administers the examination; classroom instructors do not test their own students. Teachers have not attended BILC testing seminars. Uncertainty is reported about the distinctions between levels among recently recruited staff, but also occasional misinterpretations among experienced personnel. Such difficulties may affect both judgments of student performance and the selection of classroom materials and tasks. These observations provide the context for this paper rather than measured findings about staff competence.

BILC identifies STANAG 6001 Edition 5 as the agreed standard informing language curricula, test development, and the reporting of Standardized Language Profiles (Bureau for International Language

Coordination [BILC], n.d.-a). A published standard does not ensure that everyone interprets its levels in the same way, particularly when new staff have not received a structured introduction to them. Nor does it make a course grade a proficiency rating. The issue addressed here is the movement from evidence collected for learning to a claim about readiness for independent performance.

This paper asks three questions. What can the distinction between instructional assessment and proficiency testing explain about apparently conflicting judgments? Why might that distinction become particularly consequential when developing Level 3 speaking and writing? What institutional practices could improve readiness judgments without reducing language education to examination rehearsal? The central proposal is that institutions should make the relationship between task demands, available support, and assessment purpose visible throughout a course.

MATERIALS AND METHODS

Design and analytical materials

This paper uses a qualitative conceptual analysis to examine how classroom achievement and independent proficiency judgments can differ. The analytical materials comprise the NATO proficiency descriptors cited here, public BILC assessment criteria and testing guidance, and selected literature on achievement and proficiency, validity, formative assessment, feedback, assessment literacy, and washback. These sources provide complementary perspectives on what a performance sample can justify. The synthesis is focused and selective, not a systematic review; it makes no claim to exhaustive searching or formal screening of the literature.

Context and status of the evidence

The programme arrangements described in this paper provide the institutional context: a 13-week course followed by examination by a separate BILC-trained professional testing team. Observations about staff familiarity with descriptors identify a problem for discussion. No student scripts, examination scores, staff interviews, or classroom materials were systematically analysed. These observations cannot establish the frequency, size, or causes of a classroom–examination gap. The writing and speaking scenarios are constructed illustrations rather than participant data.

Analytical procedure

The analysis proceeds in four steps. First, it distinguishes achievement judgments from proficiency claims by their purpose, the support available during performance, and the range of tasks sampled. Second, it examines the cited speaking and writing descriptors alongside the assessment literature to identify what kinds of evidence are relevant to independent performance. Third, it applies those distinctions to paired classroom scenarios, comparing supported or prepared work with performance under changed conditions. Each comparison considers the target skill, communicative function, discourse demand, assistance provided, and interpretation warranted by the sample. Fourth, it derives a proposed instructional cycle and identifies what evidence would be required to evaluate its usefulness. Table 1 records the central analytical distinctions, while Figure 1 translates them into a proposed cycle.

Interpretive safeguards and limitations

Descriptor requirements, contextual observations, analytical inferences, and proposed practices are kept distinct. The analysis considers alternative explanations, including task familiarity, entry proficiency, sampling, and examination quality, rather than attributing disagreement to instructors alone. Its credibility rests on explicit reasoning and consistency with the cited constructs, not on measured reliability or demonstrated effectiveness. No independent coding, inter-rater analysis, or empirical validation of the framework was conducted. The resulting propositions remain open to testing with classroom and examination evidence.

Skill profiles and assessment conditions

The analysis follows the four SLP positions in their established order: listening, speaking, reading, and writing. SLP 3232 specifies Level 3 in the receptive skills and Level 2 in the productive skills, whereas 3333 specifies

Level 3 in all four (NATO Standardization Office [NSO], 2016). Accordingly, the discussion of Level 3 speaking and writing applies to profiles that require those levels. Institutions need to make this distinction explicit when selecting materials, setting course outcomes, and interpreting readiness.

STANAG 6001 provides the proficiency descriptors; testing programmes specify how evidence is elicited and evaluated. Examination durations, word counts, permitted aids, and interview procedures should therefore be checked against the relevant local specifications. In the setting discussed here, BILC has trained the professional testing team, which administers the examination independently of classroom instructors.

RESULTS OF THE CONCEPTUAL ANALYSIS

Assessment purpose and the interpretation of evidence

The conceptual analysis yields three linked propositions. Assessment purpose limits what a successful performance can demonstrate; support and task familiarity affect the interpretation of that performance; and readiness claims require evidence appropriate to the specified skill and level. These are analytical conclusions drawn from the comparison, not measured findings about learners or instructors. The following sections develop their reasoning and illustrative applications.

In this programme, instructors and the professional testing team have separate operational responsibilities. The distinction should not be framed as a conflict between professional identities: both groups contribute to the quality of language education, but they make judgments for different purposes. Classroom assessments can apply explicit criteria, while external testing can generate useful information for teaching. What matters is the purpose of a particular judgment and the evidence supporting it. Table 1 summarises the distinction proposed here without suggesting that every course or testing programme follows an identical model. The meaning of a result depends on the purpose of the assessment and the evidence collected, as the distinction between achievement and proficiency makes clear (Hughes, 2003).

Table 3. Assessment Purposes and the Interpretation of Evidence

Dimension	Instructional assessment	Proficiency assessment
Primary question	What has the learner achieved and what needs development?	What ability can the candidate sustain independently?
Evidence	Work across lessons, including supported and revised tasks	Performance elicited through specified assessment procedures
Use of feedback	Guides revision and subsequent learning	Does not supply the language being assessed
Interpretive limit	Achievement alone does not establish a proficiency level	A result does not describe the entire learning process

Note. Analytical comparison developed for this paper; institutional arrangements may differ.

Formative assessment is valuable because information about performance can guide subsequent learning. Black and Wiliam (1998) connect effective classroom assessment with feedback and changes in learning activity. From this perspective, a learner's response to assistance is educationally meaningful. An instructor who comments on an argument, models a clearer transition, and then evaluates the revision is examining a legitimate learning process. The difficulty begins only if the final product is taken to show what the learner could already produce independently.

The testing perspective carries its own responsibilities. A defensible result requires sufficient opportunity to demonstrate ability, appropriate tasks, and consistent interpretation. BILC's best practice guidance emphasises sustained performance, representative sampling, and ratings that do not allow one strength to compensate for

failure to meet another essential requirement (BILC, 2025). A fluent but narrow response may therefore be insufficient, yet a single unsuccessful answer should not become the whole basis of a judgment. Differences between classroom and examination results warrant scrutiny of both evidence sets.

The distinction also concerns what a result allows us to conclude. Kane (2013) argues that validation concerns the interpretations and uses of scores. A course grade may show what a learner has achieved with the support available during instruction. Predicting independent performance across other tasks asks more of that evidence. Recording the support provided and examining several independent samples would help instructors explain their readiness judgments, while recognising that these remain judgments rather than guarantees of examination success.

Within a fixed course of 13 weeks, completing planned content may be easier to document than establishing readiness for a new proficiency level. Course duration alone cannot show whether that level is attainable for every learner; entry proficiency, instructional hours, and opportunities for practice also matter. Institutional friction becomes more likely when the meaning of a grade is left implicit. If attendance, effort, content knowledge, language quality, and revision all contribute to one total, that total may be entirely appropriate for course completion. It is nevertheless difficult to interpret as a prediction of independent proficiency. The practical response is to state what the grade includes and to report readiness separately. This protects the value of classroom achievement while making its limits transparent to learners and administrators. Using the same total to predict readiness would require further evidence (Kane, 2013).

The transition towards Level 3

Differences between supported classroom performance and independent proficiency can occur at any level. At Levels 1 and 2, repeated exposure to familiar situations may make classroom work appear closely aligned with assessment demands, but rehearsal can still conceal limitations. Level 2 also extends beyond isolated grammar and vocabulary exercises. The particular concern at Level 3 is whether instruction develops the broader communicative functions required, rather than merely increasing the difficulty of texts and terminology.

BILC's speaking criteria distinguish Level 2 factual narration and description in paragraphs from Level 3 extended discourse involving supported opinions, hypotheses, clarification, and less familiar situations (BILC, n.d.-b). The teaching implication proposed here is that increasing lexical difficulty alone cannot demonstrate progress across that boundary. A longer account of a routine procedure may remain an account of a routine procedure. To investigate broader ability, the instructor must vary what the learner is asked to accomplish with the language.

For example, a class may study the organisation of a multinational exercise. Describing the exercise sequence gives learners a clear purpose and relevant vocabulary. A different task might ask them to explain why a proposed training arrangement could produce unequal benefits, compare alternatives, and respond to an objection. The topic remains accessible, but the communicative work changes. This contrast is an instructional illustration, not a claim that one prompt by itself establishes a proficiency level.

An uncertain interpretation of the descriptors can affect instruction before assessment begins. A text containing specialised vocabulary may appear advanced, although the activity requires only factual recall. An accessible text, by contrast, can support demanding speaking or writing if learners examine assumptions, justify alternatives, or respond to objections. Suitability therefore depends on the relationship between the source, the task, the support provided, and the expected performance. The reading demand of a text and the productive demand of the activity need separate consideration. Weigle (2002) similarly shows why writing tasks need to reflect the purpose of the assessment and the kind of performance it seeks to elicit.

Familiar topics, model texts, and repeated practice can help learners develop language, but they may also conceal dependence on support. Readiness requires evidence from changed conditions. At the same time, abstract communication should not become a test of intelligence or specialist knowledge. A simple position expressed clearly can offer better evidence of language ability than sophisticated ideas whose relationships remain unclear. Materials should give learners a reasonable basis for responding, while evaluation should concern how they communicate rather than whether the instructor agrees with their position. Speaking

judgments also depend on the opportunities and conditions through which a performance sample is elicited (Luoma, 2004).

The same caution applies to stylistic expectations. NSO (2016) permits limitations and occasional errors at Level 3; highly refined control of nuance is more prominent at Level 4. Instructors should therefore avoid replacing an overly generous readiness judgment with an unrealistic demand for flawless language. The proposed target is dependable communication across appropriate tasks, not native pronunciation, literary elegance, or uninterrupted speech. A developmental judgment needs to recognise both the learner's demonstrated strengths and the limits of the available sample.

Writing and speaking as sites of divergence

Writing

Writing makes the conditions of production especially important. A portfolio may contain thoughtful work developed through reading, planning, consultation, and revision. Such practices belong in a serious writing course. Independent writing under examination conditions asks a different question about what the candidate can organise and express within the opportunities allowed. The two forms of evidence should be connected through instruction, but one should not silently stand in for the other. Weigle (2002) treats timed writing, classroom assessment, and portfolios as distinct approaches whose designs influence the evidence available about writing ability.

The BILC writing criteria describe Level 3 through extended argumentation, analysis, hypothesis, and the communication of abstract concepts, with errors that do not obstruct comprehension (BILC, n.d.-c). For classroom purposes, this directs attention beyond the presence of specialised terms or linking expressions. A recommendation needs reasons that support it; a proposed consequence needs a clear relationship to its stated condition. These are relationships that the teacher can discuss explicitly with the writer.

An illustrative task could ask whether an academy should replace some residential training with distance learning. A first response might list advantages and disadvantages accurately but leave the recommendation unexplained. During instruction, the teacher could ask which consideration matters most, why it should outweigh another, and when the recommendation would cease to apply. A later independent task could address a different institutional choice. Comparing the two performances would help distinguish improvement in the original text from the ability to organise a fresh argument.

Feedback should make this distinction visible. "Good vocabulary" offers little guidance when the main weakness is an unsupported inference. A more useful comment would identify where the reader loses the reasoning and ask the learner to make that connection explicit. Grammar feedback remains necessary where wording obscures relationships or weakens precision. The point is to interpret language choices in relation to the message, rather than rewarding complexity regardless of its contribution. This emphasis accords with feedback directed towards the task and the processes needed for improvement, rather than general praise alone (Hattie & Timperley, 2007).

Independent writing can include planning and revision within the allotted period. For examination familiarization, conditions should follow local specifications. Short classroom exercises remain useful diagnostically but cannot substitute for a complete assessment.

Speaking

A prepared presentation can demonstrate organisation, pronunciation, and effective delivery. It does not necessarily reveal how the speaker responds when another person challenges a claim or changes the direction of discussion. This is not a reason to abandon presentations. It is a reason to include interaction after them and to distinguish prepared delivery from the language generated during that interaction. Luoma (2004) highlights the importance of task design and the conditions under which speaking ability is assessed, supporting the use of more than one kind of speaking evidence.

Suppose a learner presents a proposal to improve cooperation between units. The instructor might first invite clarification of a key point, then introduce a plausible constraint, such as reduced staffing. The learner would need to explain whether the recommendation still holds and why. In a supported lesson, the teacher could help the learner notice an unclear relationship or reformulate an answer. In an independent observation, the teacher would withhold that instructional assistance and record how the learner manages the exchange.

The quality of the interaction matters. A neutral request for clarification gives a candidate room to make meaning clearer. Supplying the missing argument or completing the answer changes the evidence. At the same time, independence should not be confused with an unresponsive or adversarial examiner. The purpose of questioning is to elicit a fair sample of language, not to reward speed, confidence, or agreement. Pauses should be interpreted in the context of the overall performance rather than counted mechanically. Luoma (2004) likewise draws attention to how speaking tasks and assessment procedures shape the performance available for judgment.

DISCUSSION: A PROPOSED APPROACH TO INSTITUTIONAL ALIGNMENT

Alignment should begin with the required skill profile and the purpose of each assessment. Figure 1 presents an instructional cycle proposed for local adaptation. Its stages are not an official NATO testing procedure. They show how supported learning and independent evidence can inform each other without collapsing into a single grade.

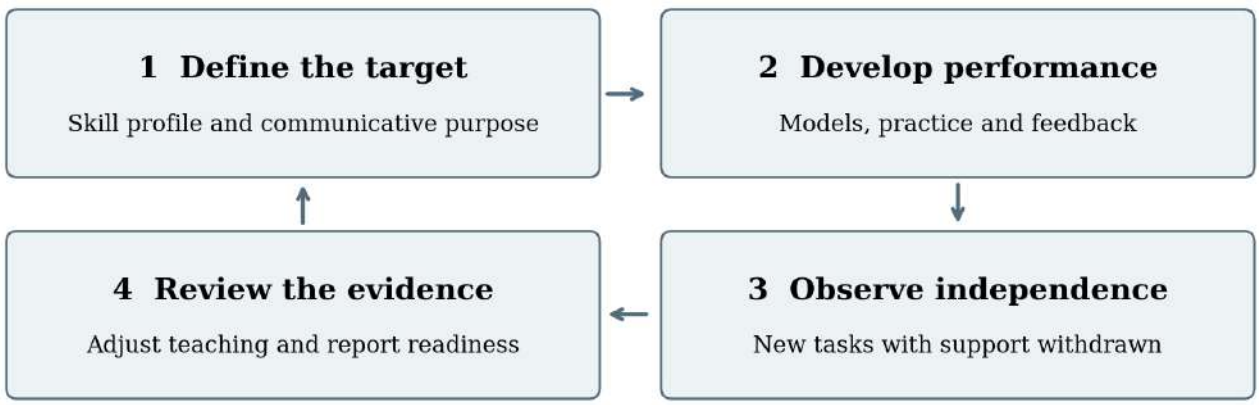


Figure 1.Proposed cycle connecting instruction and readiness judgments

Note. This is a proposed instructional framework, not an official STANAG assessment model.

Clarify outcomes and preserve support

At the beginning of a course, instructors should explain the difference between completing the syllabus, improving from an entry point, and demonstrating readiness for the target assessment. Course documentation can state which activities are supported, which produce independent evidence, and how each contributes to reporting. This need not create a complicated administrative system. A brief annotation beside an assignment can identify whether models, collaboration, feedback, or reference materials were available. Explaining these conditions helps define the scope of the resulting claim about ability (Kane, 2013).

A possible schedule within the existing course would begin with diagnostic tasks in week 1, combine instruction and supported practice during weeks 2 to 5, and review independent samples around weeks 6 or 7. Weeks 8 to 11 could address the difficulties identified, with further independent observations in weeks 12 and 13 before the final examination. This is a proposed arrangement, not a description of current practice. Its timing should be adapted to contact hours and learner needs, and classroom observations should remain separate from official testing.

Design informative classroom judgments

A classroom rubric could address communicative purpose, development of ideas, organisation, language control, and suitability for the audience. These are proposed teaching categories, not universal STANAG scoring headings. Instructors should connect them to the descriptors for the intended skill and level. Feedback should explain whether language choices help the learner accomplish the task: specialised vocabulary cannot replace a missing explanation, while occasional errors need to be judged by their effect on communication. As Weigle (2002) explains, scoring procedures need to fit the purpose and design of the writing assessment. A classroom rubric should therefore make its intended use clear.

Readiness reporting could use brief descriptive judgments accompanied by evidence. A report might state that the learner independently explains and supports positions across several tasks but still needs assistance when responding to objections. This is more informative than an unsupported prediction that the learner will pass. Where evidence is limited, the report should say so. Such statements would help learners understand what to practise and help administrators distinguish a learning recommendation from a certification decision. Such reporting follows Kane's (2013) principle that the evidence must support the interpretation made from it.

Develop shared professional understanding

The reported difficulties call for continuing professional development across the teaching team. New instructors need induction, while experienced colleagues also need opportunities to revisit distinctions between levels. Experience does not eliminate interpretive errors, and testing seminar attendance alone would not establish consistent understanding. Workshops should address both the assessment of performance and the choice of instructional materials. The professional testing team could contribute its expertise while retaining responsibility for the separate final examination. Fulcher's (2012) study of teachers' assessment training needs supports giving this work a regular place in professional development.

Joint workshops could begin with anonymised performance samples, followed by review of the materials and tasks intended to develop comparable abilities. Participants would explain their judgments by reference to the descriptors. For each proposed lesson, they could identify the target skill, communicative function, expected discourse, available support, and evidence the task is likely to elicit. A difficult article followed only by factual questions should not automatically be treated as preparation for Level 3 argumentation. Nor should one successful activity establish readiness. Reviewing both samples and lesson choices would connect interpretation with instructional decisions. Discussing why a particular judgment is justified would give assessment literacy a practical role in everyday teaching (Fulcher, 2012).

Public BILC materials can support these discussions. Departments could also review a small selection of existing lessons and record why each material and task is suitable for its purpose. This would encourage reasoned selection without requiring every lesson to reproduce examination conditions. Secure examination prompts are unnecessary. Subsequent review could consider whether revised activities give learners the intended opportunities to practise and demonstrate language, with uncertainty recorded rather than resolved through seniority alone.

Monitor educational consequences

Closer alignment does not automatically improve teaching. Alderson and Wall (1993) caution against treating the influence of tests on classrooms as simple or uniform. Their discussion supports examining what actually changes in practice. In the present proposal, the relevant question is whether learners gain broader opportunities to communicate independently or merely practise a narrower set of expected responses. Alignment should be evaluated through the work learners produce, not through the resemblance of lessons to an examination timetable. Monitoring educational consequences also belongs to the justification of assessment uses, particularly where results influence consequential decisions about learners (Kane, 2013).

Limitations and directions for investigation

The observations made suggest a possible connection between descriptor interpretation and instructional choices, including among experienced staff. Establishing that connection would require analysis of actual

materials, tasks, and teaching practices. Entry proficiency, contact hours, opportunities to use English, assessment conditions, and test quality may also influence results. The paper consequently proposes an explanation to investigate rather than attributing examination outcomes to teachers or materials alone.

Further investigation could compare course grades, independent performance samples, instructor readiness judgments, and official results from the same consenting learners. Reviewing classroom materials and associated tasks would help identify whether descriptor interpretations influence instruction. Speaking and writing should be analysed separately, with comparisons respecting the target profile. Such evidence could test the proposed explanation without assuming that staff seniority predicts accuracy or that improved pass rates alone demonstrate better instructional alignment.

CONCLUSION

Classroom achievement and STANAG 6001 readiness can diverge because the judgments draw on different purposes, conditions, and samples of performance. The separation of teaching and testing makes communication between the two teams particularly important. At Level 3, instructional choices need to provide opportunities for extended explanation, argumentation, and response to unfamiliar demands. Neither a demanding syllabus nor successful work on familiar topics is sufficient by itself to establish readiness.

For a programme followed by independent testing after 13 weeks, coordination should begin with a shared interpretation of the descriptors. This includes examining how those interpretations inform material selection, task design, and readiness judgments. Both new and experienced instructors should participate. Reviewing lesson choices alongside independent performance samples can make expectations clearer while preserving supportive teaching and separate examination responsibilities. The proposed framework offers a basis for such work; its effectiveness requires evidence from actual instruction and subsequent performance.

REFERENCES

Alderson JC, Wall D 1993. Does washback exist? *Applied Linguistics*, *14*(2), 115–129. Available at: https://doi.org/10.1093/applin/14.2.115

Black P, Wiliam D 1998. Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, *5*(1), 7–74. Available at: https://doi.org/10.1080/0969595980050102

Bureau for International Language Coordination. (n.d.-a). *STANAG 6001*. Available at: https://nato-bilc.org/stanag-6001/

Bureau for International Language Coordination. (n.d.-b). *STANAG 6001 speaking proficiency assessment criteria*. Available at: https://nato-bilc.org/wp-content/uploads/2024/11/STANAG-6001-Speaking-Assessment-Criteria.pdf

Bureau for International Language Coordination. (n.d.-c). *STANAG 6001 writing proficiency assessment criteria*. Available at: https://nato-bilc.org/wp-content/uploads/2024/11/STANAG-6001-Writing-Assessment-Criteria.pdf

Bureau for International Language Coordination. (2025, August). *Best practices in STANAG 6001 testing*. Available at: https://nato-bilc.org/wp-content/uploads/2025/08/Best_practices_in_stanag_6001_testing_august_2025-upd.pdf.pdf

Fulcher G 2012. Assessment literacy for the language classroom. *Language Assessment Quarterly, 9*(2), 113–132. Available at: https://doi.org/10.1080/15434303.2011.642041

Hattie J, Timperley H 2007. The power of feedback. *Review of Educational Research, 77*(1), 81–112. Available at: https://doi.org/10.3102/003465430298487

Hughes A 2003. *Testing for language teachers* (2nd ed.). Cambridge University Press, pp. 11-23.

Kane MT 2013. Validating the interpretations and uses of test scores. *Journal of Educational Measurement, 50*(1), 1–73. Available at: https://doi.org/10.1111/jedm.12000

Luoma, S 2004. *Assessing speaking*. Cambridge University Press, pp. 50 -100.

NATO Standardization Office 2016. *Language proficiency levels* (ATrainP-5, Edition A, Version 2). North Atlantic Treaty Organization. Available at: https://nato-bilc.org/wp-content/uploads/2024/11/ATrainP-5-EDA-V2-E.pdf

Weigle SC 2002. *Assessing writing*. Cambridge University Press, pp.75-95.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

DEVELOPING A DIGITAL COMPETENCE ASSESSMENT TOOLKIT FOR GRADE 11 STUDENTS IN LITERATURE SUBJECT BASED ON THE DIGCOMP COMPETENCE FRAMEWORK

Nguyen Chi NGUYEN
Nguyen Thi Hong NHO
Luong Duy DAL
Quach Tuyet Minh
Dong Thap University, Dong Thap Province, Vietnam
ORCID ID: 0009-0009-6583-5096
Dong Thap University, Dong Thap Province, Vietnam
Dong Thap University, Dong Thap Province, Vietnam
Can Tho University, Can Tho City, Vietnam
ORCID ID: 0009-0003-0650-5456

Abstract

In the context of strong digital transformation in Vietnam, the education sector is facing high expectations, with the goal of keeping pace with developed education systems around the world. Therefore, organizing teaching and learning activities to develop students' digital competence is an important step to meet the requirements of the digital age. To make this process effective, it is necessary to develop a toolkit that can measure and provide guidance. In this paper, with the aim of bringing literature closer to students' lives and helping students change their learning methods through technology, we develop a digital competence assessment toolkit for Grade 11 Literature based on the DigComp competence framework.

Keywords: assessment toolkit; digital competence; Literature; Grade 11; DigComp.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

BEYOND THE TEXTBOOK: THE USE OF AUTHENTIC MATERIALS IN TEACHING ENGLISH IDIOMS TO ALBANIAN EFL LEARNERS

Elsuida Hani
ORCID ID 000900088809617
PhD Candidate**,** University of Tirana, Faculty of Foreign Languages, Department of English Language, Tirane, Albania

Abstract

Authentic materials such as: movies, Tv shows and series, songs, online videos and social media content in general, provide valuable opportunities for language learners to encounter expressions in different communicative and cultural contexts. These resources may be particularly relevant to teaching English idioms considering that their meaning is often very figurative and closely connected to the cultural contexts from which they derive. However, despite their potential pedagogical value, the integration of authentic materials into English language teaching presents both opportunities and challenges as well for English teachers. This research paper aims to explore how Albanian EFL teachers use authentic materials to teach English idioms. It will investigate which types of materials teachers use, how they select materials that are appropriate for their students' age and English proficiency and what challenges or difficulties they experience when using these resources in the classroom. The study will also explore teachers' views on the extent to which authentic materials help students understand the meanings of idioms and the cultural references behind them. By examining the experiences of the teachers, this study aims to identify practical ways of using authentic materials in idiom instruction as well as the challenges that teachers may face when incorporating these resources into their lessons. The findings are expected to provide insights into how authentic materials can support the teaching of English idioms and help teachers make informed decisions about their use in the Albanian EFL context.

Keywords: authentic materials, English idioms, Albanian EFL teachers, cultural context, language teaching, challenges.

1. INTRODUCTION

Idiomatic expressions are an important part of everyday communication. They allow speakers to express meanings in concise, vivid and often culturally familiar ways. However, the meaning of an idiom cannot always be understood by interpreting its individual words literally. For learners of English as a foreign language, expressions such as "break the ice" or "it's raining cats and dogs" may therefore present difficulties, particularly when learners have limited experience with the situations and cultural references in which these expressions are used.

In many language classrooms, idioms may be introduced through textbook definitions, lists or isolated example sentences. These approaches can familiarize learners with an expression's form and basic meaning but they may provide limited exposure to how idioms function in communication. Films, television programs, songs, online videos, articles and social media posts can offer examples of language produced for real communicative purposes. When selected carefully, such resources can place idioms within situations that help learners interpret meaning, tone and use.

Authentic materials do not automatically make learning easier. They may contain unfamiliar vocabulary, cultural references, rapid speech or language unsuitable for a particular age or proficiency level. Teachers must decide which materials are appropriate, whether adaptation is necessary and how classroom activities can guide learners towards figurative meaning. This study investigates Albanian EFL teachers' reported use of authentic

materials in teaching English idioms, focusing on resources, selection criteria, perceived effectiveness and implementation challenges.

Research questions

1. Which types of authentic materials do Albanian EFL teachers report using when teaching English idioms?
2. What factors do teachers consider when selecting and adapting authentic materials?
3. Which materials do teachers perceive as most effective for teaching English idioms?
4. What challenges do teachers encounter when incorporating authentic materials into idiom instruction?
5. What examples and recommendations do teachers provide regarding classroom use?

2. Literature Review

2.1. Authentic materials in EFL teaching

Authentic materials are generally understood as spoken, written or multimodal resources originally created for communication beyond the language classroom. Examples include newspapers, interviews, songs, films, public announcements and online content. Gilmore (2007) notes that authenticity is a complex concept in language education and raises questions about the relationship between real-world language, learner needs, text difficulty and task design. Buendgens-Kosten (2014) likewise explains that authenticity may relate not only to the origin of a text but also to how it is used and experienced in a learning context.

The pedagogical value of authentic materials lies partly in exposing learners to language in context. They can demonstrate how expressions operate in particular situations and connect classroom work with communication beyond the textbook. However, authenticity is not a guarantee of learning. Teachers need to consider learners' proficiency, interests, age and lesson purpose. The Common European Framework of Reference for Languages recognises both unedited authentic texts and authentic texts selected, graded or edited to suit learners' characteristics (Council of Europe, 2001). Carefully planned adaptation can therefore make real-world resources more accessible while retaining their communicative value.

2.2. Idioms, figurative meaning and cultural context

Idioms are conventional multiword expressions whose meanings are often not fully predictable from their individual components. Learners may rely on context, prior knowledge and figurative interpretation to understand them. Boers and Demecheleer (2001) show that cross-cultural differences can affect learners' interpretation of imageable English idioms, highlighting the importance of the images and cultural assumptions learners associate with figurative expressions.

The context in which an idiom occurs can help learners infer its intended meaning. A film scene, song lyric or television interaction may provide information about the speakers, their relationship and the communicative purpose of an expression. Boers, Eyckmans and Stengers (2007) suggest that exploring the imagery and motivation behind idioms can contribute to more meaningful learning than memorising expressions without explanation. Authentic materials may thus be useful because they present idioms alongside visual, verbal and situational information. Teachers still need to guide learners so that they do not rely exclusively on literal interpretation or assume that every cultural reference will be familiar.

3. METHODOLOGY

3.1. Research design

The study employed a descriptive questionnaire-based design combining quantitative and qualitative information. Closed-ended questions provided numerical data about teachers' reported practices, selection criteria, perceptions and challenges. Two open-ended questions invited the respondents to describe classroom examples and identify support that could help them use authentic materials more effectively. The design documents teachers' perspectives; it does not measure changes in learners' idiom knowledge or establish the causal effectiveness of particular materials.

3.2. Participants and data collection

The dataset presented for this study comprises responses from 78 English language teachers in Albania. The questionnaire was distributed online. The available dataset also provides further demographic information such as the participants' years of teaching experience and the educational level that they currently teach.

3.3. Data analysis

Closed-ended responses were summarized using frequencies and the number of the participants. Responses to the two open-ended questions were reviewed and grouped according to recurring topics, including examples of materials and activities, access to resources, technology, time and student participation.

3.4. Scope and limitations of the data

The findings represent teachers' self-reported practices and perceptions. They are not based on direct classroom observations or measured student learning outcomes. The available dataset also does not specify the sampling procedure, response rate, questionnaire piloting or ethical approval arrangements. These details should be added if documented. The results should therefore be interpreted as descriptive insights into the participating teachers' perspectives, rather than representative claims about all Albanian EFL teachers.

4. RESULTS AND FINDINGS

4.1. The use of authentic materials

Teachers reported different frequencies of using authentic materials when teaching English idioms. Almost three in ten (29.5%, n = 23) indicated that they used them during every lesson. A further 10.3% (n = 8) used them every two to three sessions, while 29.5% (n = 23) selected "sometimes". The remaining 30.8% (n = 24) reported using them rarely; no respondent selected "never". Thus, all respondents reported at least some use, although frequency varied.

Table 1. Frequency of using authentic materials

Response	Number of teachers	Percentage
During every lesson	23	29.5%
Every 2–3 sessions	8	10.3%
Sometimes	23	29.5%
Rarely	24	30.8%
Never	0	0.0%
Total	78	100.0%

Regarding types of resources, newspapers, magazines and online articles and songs and music videos were each selected by 50 teachers (64.1%). Online videos followed (55.1%, n = 43), while social media content was selected by 28 teachers (35.9%). Movies and film extracts, podcasts and interviews, and television shows and series were each selected by 21 teachers (26.9%).

Table 2. Types of authentic materials used (multiple responses)

Response	Number of teachers	Percentage
Movies and film extracts	21	26.9%
Newspapers, magazines and online articles	50	64.1%
Podcasts and interviews	21	26.9%
TV shows and series	21	26.9%
Songs and music videos	50	64.1%
Online videos	43	55.1%
Social media content	28	35.9%
I do not use authentic materials	0	0.0%

Note. Multiple selections were permitted; percentages do not sum to 100%.

The range of resources suggests that teachers draw on both written and audiovisual sources. The prominence of songs, articles and online videos indicates that authentic materials are not limited to film or television. These findings are consistent with the open-ended examples, in which respondents described using songs, YouTube clips, social media posts and a television extract.

Students' English proficiency was the most frequently selected factor in material selection (91.0%, n = 71), followed by students' age (73.1%, n = 57). Relevance to lesson objectives was selected by 55.1% (n = 43), students' interests and preferences by 44.9% (n = 35), linguistic complexity by 17.9% (n = 14), and cultural content by 9.0% (n = 7).

Table 3. Factors considered when selecting materials (multiple responses)

Response	Number of teachers	Percentage
Students' age	57	73.1%
Students' English proficiency level	71	91.0%
Students' interests and preferences	35	44.9%
Linguistic complexity of the material	14	17.9%
Cultural content	7	9.0%
Relevance to lesson objectives	43	55.1%

Note. Multiple selections were permitted; percentages do not sum to 100%.

The emphasis on proficiency and age suggests that teachers are attentive to learner suitability. The low selection rate for cultural content is noteworthy because idioms may be connected to cultural knowledge. This result does not establish that teachers ignore cultural explanations; it indicates only that relatively few selected cultural content as a factor in this question.

Regarding adaptation, 35.9% (n = 28) reported that they always adapted authentic materials, 26.9% (n = 21) often did so, 9.0% (n = 7) sometimes did so and 28.2% (n = 22) rarely did so. Most respondents therefore reported adapting materials at least sometimes, although a substantial group indicated that they rarely did so.

Table 4. Adaptation of authentic materials

Response	Number of teachers	Percentage
Always	28	35.9%
Often	21	26.9%
Sometimes	7	9.0%
Rarely	22	28.2%
Total	78	100.0%

4.2. Teachers' perceptions of effectiveness

Songs and music videos were most frequently identified as effective for teaching English idioms, selected by 71 teachers (91.0%). Movies and film extracts followed, with 64 selections (82.1%). Podcasts and interviews were selected by 28 teachers (35.9%); online videos and newspapers, magazines and online articles each received 21 selections (26.9%); and television shows and series were selected by 14 teachers (17.9%).

Table 5. Materials perceived as most effective (multiple responses)

Response	Number of teachers	Percentage
Movies and film extracts	64	82.1%
Podcasts and interviews	28	35.9%
Online videos	21	26.9%
Newspapers, magazines and online articles	21	26.9%
Songs and music videos	71	91.0%
TV shows and series	14	17.9%

Note. Multiple selections were permitted; percentages do not sum to 100%.

The strong preference for songs and film extracts may be related to the contextual and multimodal information these resources provide. Songs can make expressions memorable through rhythm and repetition, while film extracts can show the circumstances in which an idiom is used. These are plausible pedagogical explanations, not effects directly tested by this questionnaire. A difference is also visible between reported use and perceived effectiveness: movies were selected by 26.9% as a resource used in class but by 82.1% as effective. The data do not explain this gap.

Teachers' overall experience was positive. Fifty-seven respondents (73.1%) described their experience as very positive, and 21 (26.9%) described it as positive. No respondents reported a negative or very negative experience, and none indicated having no experience using authentic materials for this purpose. These responses show favourable perceptions, but they are not evidence that student comprehension or retention improved.

Table 6. Overall experience with authentic materials

Response	Number of teachers	Percentage
Very positive	57	73.1%
Positive	21	26.9%
Negative	0	0.0%
Very negative	0	0.0%
No experience	0	0.0%
Total	78	100.0%

4.3. Challenges and difficulties

The most frequently reported challenge was the additional time required to prepare activities based on authentic materials, selected by 71 teachers (91.0%). Limited classroom time was identified by 35 teachers (44.9%); 28 (35.9%) reported difficulty finding age-appropriate materials; and 21 (26.9%) indicated difficulty finding materials suitable for students' English proficiency. Limited access to technology or the internet was selected by seven teachers (9.0%). No respondent selected the option that the language in authentic materials was too difficult for students to understand.

Table 7. Challenges encountered (multiple responses)

Response	Number of teachers	Percentage
Finding materials suitable for students' English proficiency	21	26.9%
Preparing activities requires additional time	71	91.0%
Finding age-appropriate materials	28	35.9%
Limited access to technology or the internet	7	9.0%
Limited classroom time	35	44.9%
Language is too difficult for students	0	0.0%

Note. Multiple selections were permitted; percentages do not sum to 100%.

The prominence of preparation time suggests that locating a resource is only one part of using it. Teachers may also need to identify idioms, check meanings and context, select suitable extracts, prepare tasks and plan

follow-up activities. Limited classroom time may make it difficult to complete these stages while meeting other lesson objectives. Responses concerning age and proficiency further indicate that selecting an appropriate resource requires attention to learner characteristics.

The low percentage for technological access suggests that this was less frequently reported than preparation and classroom time among these respondents. It should not be interpreted as proof that technological barriers are absent from Albanian schools. Similarly, the absence of selections for excessive language difficulty does not demonstrate that all authentic materials are linguistically accessible; it means that no respondent selected this challenge from the options provided.

4.4. Findings from the open-ended questions

4.4.1. Examples of materials and classroom activities

The first open-ended question asked teachers to describe an authentic material they had used to teach an English idiom and explain how it was used. Responses referred to YouTube videos, songs, a television extract, short video clips, social media posts, podcasts, interviews, articles and traditional songs. One teacher described using a short YouTube video to introduce “It’s raining cats and dogs”; students watched the video, learned the meaning and then produced their own sentences. Another respondent reported using a clip from the television series Friends to teach “break the ice”, describing the activity as enjoyable and useful for explaining the expression.

A further response described playing a song containing an idiom. Another teacher used short video clips and social media posts, asking students to identify idioms in context, discuss their meanings and create original sentences. This example combines noticing, interpretation and productive use. A respondent also mentioned traditional rounds and folk songs, including “Alabama Gal”, while other answers referred briefly to podcast interviews and articles.

One answer mentioned flashcards. Flashcards can be useful teaching aids, but they are not necessarily authentic materials in themselves; their status depends on whether they reproduce or support work with an original real-world source. The responses therefore include both authentic sources and supplementary classroom resources. Overall, they suggest that teachers use materials not only to present idioms but also to create opportunities for contextual interpretation and sentence production.

4.4.2. Support needed for more effective use

The second open-ended question asked what would help teachers use authentic materials more effectively. Responses repeatedly referred to greater access to suitable videos, pictures, real-life examples, podcasts, texts and practical teaching resources. Some respondents mentioned the need for available materials and different classroom activities, while others highlighted student participation.

Technological facilities and internet access were also mentioned, together with the need for additional classroom time. These suggestions correspond with the quantitative finding that preparation time was the most frequently reported challenge and that limited classroom time was another common difficulty. The qualitative responses add detail to the numerical results: teachers’ needs concern not only access to materials but also the time, facilities and activities required to use them purposefully.

5. Discussion

The findings present a generally positive picture of teachers’ attitudes towards authentic materials, while also revealing practical constraints on their use. All respondents indicated at least some use, but frequency varied: approximately three in ten used them during every lesson and a similar proportion reported using them rarely.

Authentic resources are therefore present in participants' reported teaching practices, but they are not integrated with the same regularity by all teachers.

The prominence of songs, articles and online videos as materials used, and of songs and film extracts as materials perceived to be effective, points to the value teachers place on varied forms of language input. These media can present idioms within a broader context and provide clues unavailable when an expression is taught only as an isolated phrase. This interpretation is consistent with research emphasising context and imagery in idiom comprehension (Boers & Demecheleer, 2001; Boers et al., 2007). Nevertheless, the present study did not test learners' comprehension and cannot establish which material produces the greatest learning gains.

A particularly relevant finding concerns material selection. Teachers most frequently considered students' proficiency and age, whereas cultural content was selected by only 9.0%. This contrast deserves attention in idiom instruction. Selecting a resource at an appropriate language level is essential, but idioms may also carry cultural associations and pragmatic meanings. Teachers may benefit from selection criteria that explicitly consider both linguistic accessibility and the cultural or situational information needed to interpret an expression. The low percentage should be treated as a prompt for reflection, not proof that teachers do not address culture.

The reported adaptation practices are also important. More than one-third of teachers always adapted materials and a further group often did so. This is consistent with the view that authentic resources may need to be selected, shortened or supported with tasks to match learners' needs (Council of Europe, 2001; Gilmore, 2007). Adaptation should preserve the original communicative context while making the target idiom and relevant clues accessible.

The most substantial difficulty was the time required to prepare activities. Positive attitudes alone may therefore be insufficient to ensure regular classroom use. Teachers need time to locate suitable resources, identify target expressions and prepare meaningful tasks. The open-ended answers reinforce this point by calling for practical resources, varied activities, additional classroom time and, in some cases, better technological facilities. Shared collections of age- and level-appropriate clips, songs and texts, accompanied by ready-to-use idiom activities, could be one practical response.

Taken together, the findings suggest that authentic materials can be a useful component of idiom instruction when their use is purposeful. A lesson might begin with a short extract, ask learners to identify an idiom, guide them to infer its figurative meaning from the situation, discuss relevant cultural or pragmatic references, and then ask them to use the expression in a new context. This sequence connects exposure with interpretation and production and reflects teachers' examples of identifying idioms, discussing meanings and creating sentences.

6. Practical Implications

Several practical implications emerge.

First, teachers may benefit from selecting materials through a balanced set of criteria: learner age, proficiency, interests, lesson objectives, linguistic complexity and cultural relevance.

Second, materials should be accompanied by tasks that guide learners beyond literal translation. Questions about who is speaking, what is happening and why an expression is appropriate can help learners interpret idioms in context.

Third, teachers can use short extracts rather than entire films, programs or songs when classroom time is limited.

Finally, schools and professional communities could support teachers by sharing curated resources and lesson activities and by ensuring access to suitable technology and preparation time.

7. Limitations and Recommendations for Further Research

This study is based on questionnaire responses and reflects teachers' self-reported practices and perceptions. It does not include classroom observations, student interviews or tests of idiom comprehension and it cannot establish the direct effect of authentic materials on learning outcomes. The available dataset does not include detailed participant demographics or information about the sampling procedure, which limits generalisation. The open-ended responses provide useful examples but are brief and do not offer an in-depth account of each teacher's practice.

Further research could combine teacher questionnaires with classroom observations and interviews to examine how authentic materials are selected, adapted and used during lessons. Studies involving students could investigate whether contextualised exposure supports recognition, interpretation, retention and appropriate use of idioms. Future research could also compare different types of materials or examine more closely how teachers address the cultural references associated with English idiomatic expressions.

8. Conclusion

This study explored how Albanian EFL teachers report using authentic materials to teach English idioms, the factors they consider when selecting resources, their perceptions of effectiveness and the challenges they encounter. Teachers reported using a range of written and audiovisual materials, particularly songs and music videos, newspapers and online articles, and online videos. Students' English proficiency and age were the most frequently selected considerations when choosing resources, while songs and music videos were most often perceived as effective.

Teachers' overall experiences were positive, but the preparation time required to develop activities emerged as a major challenge, followed by limited classroom time and difficulties finding age-appropriate resources. The open-ended responses illustrated how songs, video clips, television extracts and social media posts can be used to introduce idioms and encourage learners to interpret and produce them. Teachers also identified a need for more suitable resources, practical activities, classroom time and technological support.

The findings suggest that authentic materials are valued by the participating teachers, but their pedagogical contribution depends on thoughtful selection and task design. In idiom instruction, it is particularly important to connect figurative meaning with the communicative situation and, where relevant, the cultural references behind an expression. Supporting teachers with accessible resources and time to prepare contextualised activities may help make authentic materials a more consistent and purposeful part of English language teaching.

References

Boers, F., & Demecheleer, M. (2001). Measuring the impact of cross-cultural differences on learners' comprehension of imageable idioms. ELT Journal, 55(3), 255–262. https://doi.org/10.1093/elt/55.3.255

Boers, F., Eyckmans, J., & Stengers, H. (2007). Presenting figurative idioms with a touch of etymology: More than mere mnemonics? Language Teaching Research, 11(1), 43–62. https://doi.org/10.1177/1362168806072460

Buendgens-Kosten, J. (2014). Authenticity. ELT Journal, 68(4), 457–459. https://doi.org/10.1093/elt/ccu034

Council of Europe. (2001). Common European framework of reference for languages: Learning, teaching, assessment. Cambridge University Press.

Gilmore, A. (2007). Authentic materials and authenticity in foreign language learning. Language Teaching, 40(2), 97–118. https://doi.org/10.1017/S0261444807004144

Peacock, M. (1997). The effect of authentic materials on the motivation of EFL learners. *ELT Journal, 51*(2), 144–156. https://doi.org/10.1093/elt/51.2.144

F. (2005). *Designing authenticity into language learning materials*. Intellect Books.

Balenović, K., & Proroković, J. (2023). Foreign language vocabulary development: Media-driven learning in the informal context. *Suvremena lingvistika, 49*(96), 175–201. https://doi.org/10.22210/suvlin.2023.096.01

Al-Hamdun, S., & Al Mozari, S. (2024). Exploring the contribution of film and music in learning English idioms. *Research Studies in English Language Teaching and Learning*, *2*(1), 12–22. https://doi.org/10.62583/rseltl.v2i1.33

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ARTIFICIAL INTELLIGENCE IN FINANCIAL DECISION-MAKING AND INTERNATIONAL DIPLOMACY

Arzu Al
Ege Gündüz
Professor, ORCID: 0000-0002-3287-3661, Marmara Unıversıty, Faculty of Political Science, International Relations, International Political Economy, İstanbul, Türkiye
ORCID: 0009-0000-0312-7160, Marmara Unıversıty, Faculty of Political Science, International Relations, International Political Economy, İstanbul, Türkiye

Abstract

In the 21st century, artificial intelligence, which has developed in parallel with rapid technological advancements, has become a tool increasingly utilized not only by individuals and corporations but also by states. Governments have begun to employ artificial intelligence particularly in the processes of financial decision-making and the development of economic diplomacy. Within this context, states can enhance their economic diplomacy through AI and conduct trade negotiations with the support of artificial intelligence-based analytical tools.

Furthermore, when making international investment decisions, governments can analyze the domestic markets, as well as the political and economic dynamics, of potential host countries through artificial intelligence systems. Another significant area in which AI is utilized by states is the management and mitigation of financial crises. Through artificial intelligence, governments are able to conduct financial risk analyses and identify financial vulnerabilities, thereby developing predictive crisis scenarios. In this way, states can take early preventive measures and respond more effectively to potential financial crises. The integration of artificial intelligence into the global financial competition by states has not only reshaped the field of economics but has also significantly influenced the discipline of international relations. The contemporary global competition in artificial intelligence is largely centered between the United States and China, and this study provides a comparative analysis of the policies developed by these two states in the field of AI as well as their efforts to expand their spheres of influence. While the United States seeks to strengthen its position through research and development activities carried out by multinational corporations and innovative technology startups, thereby creating a Western-oriented technological sphere centered around itself, China aims to position itself at the core of a structure focused on developing countries and the Global South by supporting its domestic companies through a state-capitalist model. Given that this competitive order is primarily shaped by the rivalry between two major powers, this study aims to contribute to the literature by analyzing the phenomenon within the framework of neorealist theory, while also incorporating the perspective of algorithmic governance theory, considering that the process is increasingly driven by algorithms and data.

Keywords: Artificial intelligence, international diplomacy, financial decision-making.

YAPAY ZEKÂ İLE FİNANSAL KARAR ALMA VE ULUSLARARASI DİPLOMASİ

Özet

21. yüzyılda teknolojik gelişmelere paralel olarak gelişen yapay zekâ bireylerin ve şirketlerin olduğu kadar devletlerin de başvurduğu bir araç hâline gelmiştir. Devletler özellikle finansal karar alma ve ekonomik diplomasi geliştirme esnasında yapay zekâ kullanımına başvurmaktadır. Devletler bu kapsamda yapay zekâ aracılığıyla ekonomik diplomasi geliştirebilmekte ticari müzakerelerini yapay zekâdan destek alarak gerçekleştirebilmektedir. Ayrıca devletler uluslararası yatırım yapacakları zaman yatırım yapılacak ülkenin iç pazarını, politik ve iktisadi dinamiklerini yapay zekâ aracılığıyla analiz edebilmektedir. Yapay zekânın devletler için bir başka önemli kullanım alanı ise finansal krizlere müdahale olmuştur. Devletler yapay zekâ

aracılığıyla finansal risk analizi yapabilir ve finansal kırılganlıkları tespit ederek tahmini kriz senaryoları oluşturabilmektedir. Bu sayede devletler finansal krizlere erken önlem alarak müdahale edebilmektedir. Devletlerin yapay zekâ kullanımıyla finansal küresel rekabet sürecine dâhil olması ekonomi bilimini şekillendirdiği kadar uluslararası ilişkiler bilimini de şekillendirmiştir. Uluslararası yapay zekâ mücadelesi ABD ve Çin arasında gerçekleşmekte olup her iki devletin yapay zekâ özelinde geliştirdiği politikalar ve etki alanlarını genişletme çabaları karşılaştırmalı olarak analiz edilmiştir. ABD bu süreci çok uluslu şirketlerinin yürüttüğü araştırma geliştirme çalışmaları ve yeni girişimler üzerinden geliştirerek kendisinin merkezde yer aldığı Batılı devletler eksenli alan oluşturmaya çalışırken Çin ise devlet kapitalizmi modeliyle yerli şirketlerine teşvikler sağlayarak gelişmekte olan ülkeler ve küresel güney eksenli yapının merkezinde olmaya çalışmaktadır. Bu rekabet düzeninin iki büyük güç arasında gerçekleşmesi sebebiyle çalışma neorealist teori ve algoritmalar ile veriler aracılığıyla gerçekleşmesi sebebiyle algoritmik yönetişim teorisi ekseninde analiz edilerek literatüre katkıda bulunmak hedeflenmiştir.

Anahtar Kelimeler: Yapay zekâ, uluslararası diplomasi, finansal karar alma.

1.Giriş

Bu çalışmada "Yapay zekâ, ekonomik diplomasi kapsamında uluslararası finansal karar alma süreçlerini nasıl dönüştürmektedir?" sorusuna yanıt aranmıştır. Yapay zekâ kullanımının 2020 yılından itibaren yaygınlaşması yalnızca bireylerin günlük işlemleri esnasında karar alma sürecini kolaylaştırmamış devletlerin politikalarının şekillenmesinde de önemli bir unsur olmuştur. Uluslararası sistemin askeri ve ekonomik diplomasi temelli güç ağları dönüşüm geçirerek yapay zekâ ekseninde veri tabanlı boyuta evrilmiştir. Bu doğrultuda dijitalleşme çağında sert güç ve yumuşak güç kavramlarının yanına veri gücü kavramı da eklenmiştir. Devletler yapay zekâ tabanlı algoritmalarını kullanarak risk analizi, finansal gözetim, politika üretimi ve ekonomik planlama yapma imkânına sahiptir. Yapay zekâ kullanımından önce politika yapım süreci geçmiş olayların analizi ve uzman görüşleri ekseninde gerçekleşirken yapay zekâ kullanımının yaygınlaşmasıyla birlikte politika yapım süreci büyük veri, tahmin modelleri ve algoritmik analizin bir sentezi şeklinde gerçekleşme imkânına erişmiştir (OECD, 2025). Yapay zekânın politika yapım sürecinde kullanılması siyasal yönetişimin de dijitalleşmeye başladığını göstermektedir. Bu noktada karşımıza çıkan önemli bir sorun ise alınan kararların ne kadar güvenilir olduğudur. Söz konusu güvenilirlik sorunu yapay zekâ tabanlı alınan finansal kararların şeffaflığı, hesap verebilirliği ve kurumsal güven krizine yöneliktir (Andrews, 2022, ss. 2-4). Bu bağlamda yapay zekâ kullanımıyla alınan finansal kararların algoritmik süreçlerle açıklanıp açıklanamayacağı kararın şeffaflığına yönelik, yanlış karar alınması durumunda ise sorumluluğun politikacılara mı yoksa yapay zekâya mı ait olacağı ise hesap verebilirlik doğrultusunda eleştirilere neden olmaktadır. Alınan finansal kararlara yönelik potansiyel eleştiriler ise yapay zekâ ile politika şekillendirmenin meşruiyetine yönelik eleştirileri de beraberinde getirmektedir. Yapay zekâ aracılığıyla finansal karar alma ve politika belirleme süreci her ne kadar beraberinde meşruiyet sorununu getirse de devletlerin dış politikalarını şekillendirmede önemli bir unsur olarak yer alma potansiyeline sahiptir. Özellikle devletlerin dış politikalarında kriz meydana gelmesi durumunda ekonomik yaptırım tahmini, risk analizi ve kriz simülasyonu gibi imkânlar yapay zekâ kullanımını politika yapıcılar için vazgeçilmez kılmaktadır.

2.Kavram Olarak Yapay Zekâ ve Ekonomik Diplomasi

2020 yılından itibaren yapay zekâ kullanımının dünya genelinde yaygınlık kazanması finansal karar alma sürecinde de yapay zekâ kullanımını artırmıştır. Finansal karar alma kapsamında yapay zekâ kullanımı yalnızca özel sektörle sınırlı kalmamış olup devletler de yapay zekâ kullanımına başvurmaktadır. Diğer taraftan devletlerin finans ve ticaret gibi ekonomi çatısı altında yer alan konularda belirli dış politikalar oluşturması, müzakereler yürütmesi veya yaptırımlar uygulaması ekonomi diplomasisi çerçevesinde değerlendirilmektedir.

2.1.Yapay Zekâ Kavramı

Makinelerin, insan zihin yapısını örnek alarak öğrenme, analiz etme, problem çözme ve karar alma gibi bilişsel süreçleri uygulamasına olanak sağlayan teknolojik sistemler literatürde yapay zekâ olarak tanımlanmaktadır (İşcan ve Durgun Kaygısız, 2024, s. 203). Yapay zekânın gösterdiği gelişim devletlerin finansal karar almalarında ve politikalarını şekillendirmelerinde önemli bir unsur olarak yer almaktadır. Devletler yapay zekâ kullanımıyla makroekonomik tahmin üretme, bütçe planlama, harcamaları izleme ve finansal raporlama araçlarıyla kamu finansmanını yönetebilmektedir. Ayrıca Uluslararası Ödemeler Bankası'nın (Bank for International Settlements) 2025 yılında hazırlamış olduğu bir rapora göre yapay zekâ artık yalnızca özel sektörün yararlandığı bir araç olmaktan çıkmış, kamu otoriteleri için de bir politika üretim aracı hâline gelmiştir. Özellikle merkez bankaları, finansal düzenleyiciler ve denetleyici kurumlar yapay zekâ kullanarak risk analizi, politika belirleme, iktisadi analiz ve finansal karar alma süreçlerinde etkin bir rol oynamaktadır (BIS, 2025, ss. 4-11).

2.2. Ekonomik Diplomasi Kavramı

Klasik anlamda diplomasi devletler arasındaki ilişkileri düzenleyen siyasi ve hukuki antlaşmalar bütünü veya müzakere sanatı olarak ifade edilmektedir. Geleneksel diplomasi askeri ittifaklar ve siyasi müzakereler çerçevesinde değerlendirilmekte olup ekonominin de diplomasinin bir parçası hâline gelmesiyle ekonomik diplomasi kavramı literatürde yer almaya başlamıştır (Keyman, t.y.). Ticaret, finans ve ekonomik devletçilik gibi kavramları tek çatı altında toplayan ekonomik diplomasi kavramı hükûmet yetkilileri, dışişleri bakanlığı veya bakanlığın temsilcilerinin yürüttüğü ekonomik müzakereler ve ekonomi politikaları süreçlerini ifade etmektedir. Ticari ve finansal süreçleri bir arada yürütmeyi olanaklı kılan ekonomik diplomasi ticari boyutta bir devletin başka bir devletle veya Dünya Ticaret Örgütü (DTÖ) gibi uluslararası örgütlerle yapılan müzakereler kapsamında belirli ticari normların belirlenmesini veya standartların oluşturulmasını ifade etmektedir. Finansal boyutta ise ekonomik diplomasi bir devletin başka bir devletle veya Uluslararası Para Fonu (IMF) ve Dünya Bankası (WB) gibi uluslararası örgütlerle yapılan müzakereler sonucunda alınan finansal kararları kapsamaktadır. Ayrıca devletler ekonomik diplomasi kapsamında finansal ambargolara veya ödemeler sistemi kısıtlamalarına başvurarak birbirleri üzerinde yaptırıma başvurabilmektedir (Okan, 2019, s. 10). Yakın tarihte söz konusu duruma en uygun örneklerden bir tanesi, Rusya'nın 2022 yılında Ukrayna'yı işgal etmesinin ardından AB'nin (AB) 2022/345 sayılı Konsey Tüzüğü ile yedi Rus bankasına özel finansal mesajlaşma hizmeti sağlanmasını yasaklaması, yani bu bankaları SWIFT (Society for Worldwide Interbank Financial Telecommunication) sisteminden çıkarmasıdır (Avrupa Birliği Konseyi, 2022). Rusya gibi ihracat gelirlerinin ağırlıklı kısmını petrol satışından sağlayan bir devlet için küresel ödeme sistemlerinden çıkarılmak en önemli gelir kaynaklarından bir tanesinin kapanması anlamına gelmektedir. Rusya-Ukrayna Savaşı'nda Batılı devletlerin Rusya'ya uyguladığı bir diğer yaptırım ise Visa ve Mastercard'ın Rusya'daki faaliyetlerini durdurmasıdır. Bu sayede Rus bankalarının kartları uluslararası geçerliliğini kaybetmiştir (Gündüz, 2025, s. 104). Ekonomi diplomasisi kapsamında devletlerin birbirlerine uyguladığı bir diğer yaptırım örneği ise ABD'nin İran'a yönelik finans ve enerji sektörü yaptırımlarıdır. ABD Hazine Bakanlığı Yabancı Varlıklar Kontrol Ofisi (OFAC) tarafından yürütülen yaptırımlar kapsamında İran'ın finans sektörü 2020 yılında, petrol ve petrokimya sektörleri ise 2024 yılında yaptırım kapsamına alınmıştır. 23 Ocak 2026 tarihli yaptırım kararıyla İran petrolü ve petrol ürünlerinin uluslararası piyasalara erişimini sağlayan sekiz kuruluş ve dokuz gemi yaptırım kapsamına alınmıştır (U.S. Department of State, 2026). Bu sayede İran'ın petrol ihraç gelirleri ve deniz taşımacılık gelirleri sınırlandırılmaya çalışılmıştır (OFAC, 2026).

3. Teorik Çerçeve

Çalışma kapsamında devletlerin yapay zekâ ve buna bağlı olarak ekonomi diplomasisi geliştirerek uluslararası sistem içerisinde güç rekabetinde olması neorealist teori perspektifinden analiz edilecektir. Algoritmik yönetişim teorisi ile ise devletlerin bu süreçleri veri temelli otomatikleştirilmiş sistemlerle nasıl gerçekleştirdiği sorusuna yanıt aranacaktır.

3.1. Neorealist Teori

Uluslararası ilişkiler disiplininde devlet davranışlarını açıklamak için öne sürülen teorilerden bir tanesi neorealist teoridir. Neorealist teorinin temeli ilk defa Kenneth Waltz tarafından 1979 yılında yayınlanan "Theory of International Politics" adlı kitapta atılmıştır. Waltz bu çalışmada doğrudan neorealizm kavramını kullanmamakla birlikte uluslararası siyasetin yapısını devlet davranışlarının meydana getirdiği sistem üzerinden açıklamaktadır. Uluslararası sistemin yapısına yönelik ilk temeller çalışmanın "İndirgemeci Teoriler ve Sistemik Teoriler" bölümünde açıklanmıştır. Waltz klasik realist teoriden farklı olarak insan doğasının kötü olması anlayışının yerine uluslararası sistemin yapısının kötü olduğu anlayışını ortaya koymaktadır. Uluslararası ilişkilerin temel aktörünün devlet olduğu anlayışı klasik realizme paralel olarak devam etmekle birlikte devletlerin birbirleriyle etkileşim içerisinde olduğu, anarşik yapının bulunduğu davranışları şekillendiren yapısal düzen uluslararası sistem olarak ifade edilmektedir. Uluslararası sistemin yapısı devletleri rekabete zorlamakta, ittifak oluşumlarını teşvik etmektedir (Waltz, 1979, ss. 60-67).

Çalışmanın beşinci bölümü olan "Politik Yapılar" bölümünde Waltz uluslararası sistemi anarşi, fonksiyonel benzerlik ve güç dağılımı kavramlarıyla inşa etmektedir. Uluslararası sistem yapısı gereği anarşik olup bu yapı devletlerin güç mücadelesi alanıdır. Devletler arasındaki rekabetin ve savaşların esas nedeni de uluslararası sistemin anarşik yapısından kaynaklanmaktadır. Bu anarşik yapı içerisinde devletlerin varlıklarını sürdürebilmeleri de güç kazanmalarına bağlıdır (Waltz, 1979, ss. 79-88).

Waltz'un ileri sürmüş olduğu neorealist teori çerçevesinde büyük güçlerin ekonomi diplomasisi bağlamında yapay zekâ geliştirme rekabetleri, ekonomi diplomasisi aracılığıyla birbirlerine uyguladıkları yaptırımlar ve yatırım rekabetinin neorealist teori çerçevesinde analiz edilmesinin uygun olacağı düşünülmektedir. Uluslararası anarşik yapı içerisinde devletlerin birbirleriyle olan güç mücadelesi ve yaptırımlar neorealist teori kapsamında devletlerin hangi motivasyonla hareket ettiğini değerlendirecek olup devletlerin bu gücü ve yaptırımları nasıl uyguladığını anlamak için algoritmik yönetişim teorisinin de incelenmesi gelişmelerin daha açık bir şekilde analiz edilmesi için oldukça önem arz etmektedir. Bu durumun sebebi ise uluslararası anarşik düzende güç mücadelelerinin algoritmik yönetişim araçlarıyla uygulanan dijital jeopolitik mekanizmalar olmalarıdır.

3.2. Algoritmik Yönetişim Teorisi

Akademik literatürde oldukça yeni bir kavram olan algoritmik yönetişim teorisinin kökeni ilk defa Antoinette Rouvroy ve Thomas Berns'in 2013 yılındaki "Algorithmic Governmentality and Prospects of Emancipation" başlıklı çalışmasında yer almaktadır. Çalışma kapsamında teorinin çıkış noktası yönetişim biçimlerinin değişiminden kaynaklanmaktadır. Klasik manada devlet yönetişimi devletin hukuki yapısı altında politikacılar karar alırken politikacıların aldıkları bu kararlar vatandaşları yönetmekteydi. Ancak veri teknolojisinin gelişimine bağlı olarak politikacılar kararlarını verilerin çıktıları kapsamında önceden tahmin edilen davranışlara göre almaktadır. Bu sebeple küreselleşen dünyada devletler veri akışlarını yönetmeye başlamıştır. Söz konusu veri akışları vatandaşların davranışlarını şekillendirebileceği gibi devletlerin dış politikalarını şekillendirmelerini de olanaklı kılmaktadır. Bu noktada devletlerin politik karar alma süreçleri dönüşüm geçirmiştir. Geçmişte politik karar alma süreci iktidarın ideolojisi ve çıkarlarının bütünüyken günümüzde veriler ve bu veriler üzerinden yapılan tahminlerin sonucu hâline gelmiştir. Bu sebeple politik karar alma süreci de otomatikleşmiş bir hâle evrilmiştir (Rouvroy ve Berns, 2013, ss. 165-178). Otomatikleşen karar alma süreci sayesinde devletler riskli yatırım taraması, finansal yaptırım, terör finansmanı izleme ve ticaret güvenliği gibi alanlarda belirli düzeyde öngörü sahibi olabilmektedir. Ayrıca devletler veri risk profilleri aracılığıyla SWIFT analizi geliştirebilir, yatırım güvenlik incelemeleri yapabilir, OFAC risk modellemeleri geliştirebilir ve yapay zekâ destekli yaptırımlar uygulayabilme imkânına erişmiştir.

Algoritmik yönetişim teorisi yalnızca politik bacağı olan bir teori olmamakla birlikte hukuksal bağlantı kurmadan teorinin net bir şekilde açıklanması mümkün değildir. Karen Yeung'un 2018 yılında hazırlamış olduğu "Algoritmik Regülasyon: Kritik Bir Sorgulama" başlıklı makalesinde ise algoritmik yönetişim sürecinin sadece teknik bir süreç olmadığı günümüzde davranışları yönlendiren bir yönetim mekanizması

hâline geldiği ve bu sayede regülasyon sürecinin nasıl çalıştığı üzerinde durulmuştur. Bu kapsamda algoritmik regülasyonun ilk etabında devletler tarafından sensörler, dijital izler ve platformlar aracılığıyla sürekli olarak bireylerin verileri toplanabilmektedir. Bu veriler toplandıktan sonra ise yapay zekâ tabanlı algoritmik modellemeler aracılığıyla veriler otomatik olarak işlenmektedir. Bireylere ilişkin veriler işlendikten sonra ise davranış modülasyonu ortaya koyulmaktadır. Yeung bu süreci davranış yönlendirici algoritmik yönetim modeli olarak açıklamaktadır. Bu yönetim modeli sayesinde toplumsal düzenlemeler gerçekleştirilebilmektedir (Yeung, 2018, ss. 508-515).

Yeung'un hazırlamış olduğu bu çalışma verilerin işlenmesi sonucunda bireylerin davranışlarını yönlendiren bir yönetim mekanizmasına yönelik bir çalışma olup söz konusu yönetim mekanizması devletlerin makro ölçüde politika geliştirmelerine de olanak sağlama imkânına sahiptir. Algoritmik regülasyon kapsamında devletler karşı devletin davranışlarına yönelik analiz çıkarıp (Hangi yatırım güvenlik tehdidine sebep olacaktır? Hangi sektör riskli? Hangi finansal akış engellenmeli? gibi sorulara cevap bulunacaktır.) yatırım analizi yapma, yaptırım hedefi belirleme ve ticaret akışlarını izleme gibi davranış yönlendirici politikalar uygulayabilmektedir. Bu gelişmeler dikkate alındığında yapay zekâ destekli finansal karar alma mekanizmaları uluslararası diplomaside yalnızca analitik araçlar olarak yer almamakta olup ekonomik aktörlerin davranışlarını da şekillendiren algoritmik regülasyon mekanizmaları hâline gelmiştir. Türkçe literatürde Çalışkan (2026) da yapay zekânın devlet ve devlet üstü düzeylerde kullanımını algoritmik yönetişim ve küresel düzen bağlamında ele almaktadır.

4.Araştırmanın Yöntemi

Bu çalışmada yapay zekâ ile finansal karar alma ve ekonomi diplomasisinin yürütülmesi süreci, devletlerin uyguladığı politikalar, olası fırsatlar ve tehditler nitel araştırma yöntemiyle analiz edilmiştir. Çalışmanın çıkış sorusu olan yapay zekânın ekonomik diplomasi kapsamında uluslararası finansal karar alma süreçlerini nasıl dönüştürdüğünü analiz etmek için ABD ve Çin üzerinden karşılaştırmalı örnek olay incelemesi yapılmıştır. Analizin ABD ve Çin üzerinden yürütülmesinin nedeni ise iki ülkenin küresel yapay zekâ rekabetinde önde gelmeleri, dünyanın en büyük iki ekonomisine sahip olmaları, yürüttükleri teknoloji politikaları ve uluslararası etki alanlarının geniş olmasıdır. Karşılaştırma iki ülkenin yapay zekâ ekosistemlerinin kurumsal yapısı, ekonomik diplomasi araçları ve finansal karar alma süreçlerinde veri temelli teknolojilerin kullanımı kapsamında üç farklı boyut üzerinden yapılmıştır. Çalışmada kullanılan veriler doküman analizi yöntemiyle uluslararası kuruluşların hazırlamış oldukları raporlar, akademik çalışmalar, devletlerin yapay zekâ çalışmaları, resmi politika belgeleri ve finansal düzenleyici kurumların yayınlarından elde edilmiştir. Özellikle Uluslararası Ödemeler Bankası (BIS, 2025), OECD (2025 ve 2026), Çin Ulusal Finansal Düzenleme İdaresi (NFRA, 2026) ve Stanford Üniversitesi'nin hazırlamış oldukları çalışmalar ile ABD ve Çin'in yapay zekâ geliştirmelerine ve politikalarına yönelik çalışmalardan temel veriler alınmıştır. Devletlerin birbirlerine uyguladıkları finansal yaptırımlar ve ekonomi diplomasisi boyutunun incelenmesi için OFAC (2026) gibi kaynaklardan elde edilen veriler kullanılmıştır. Çalışmada elde edilen veriler tematik ve karşılaştırmalı analiz yöntemiyle kullanılmış ve bu doğrultuda devletler adına yapay zekâ kullanımının uluslararası yatırım kararı alma, finansal kriz yönetimi, ekonomi diplomasisi yürütme ve yaptırım uygulama kapsamında uluslararası güç dengesindeki etkisi incelenmiştir. Analiz sürecini teorilerle desteklemek adına neorealist teorinin devletler arasındaki güç rekabeti yaklaşımı, algoritmik yönetişim teorisinin ise veri ve algoritma temelli karar alma süreçlerinin devletlerin politikalarını nasıl şekillendirdiği üzerinden çalışma yürütülmüştür.

5. Uluslararası Diplomaside Yapay Zekâ ile Finansal Karar Alma

Yapay zekâ tabanlı patent geliştirme ülkeler arasında yeni bir rekabet alanı hâline gelmiştir. Stanford AI Index 2025 raporunun 2010-2023 dönemine ilişkin patent verilerine göre 2023 yılı itibarıyla küresel yapay zekâ patentlerinin ülkelere göre dağılımında birinci sıra %69.7 oran ile Çin'e ait iken ikinci sıra %14.16 oran ile ABD'ye aittir (Stanford University, 2025, s. 44). Bu verilerden de görüleceği üzere tarihsel süreçte teknolojik gelişmelerin kökeni ABD ve Avrupa eksenli olmasına rağmen 21. yüzyılda Çin'in uyguladığı devlet kapitalizmi politikaları ve teknoloji yatırımları Çin'in yapay zekâ rekabetinde önde olmasını sağlamıştır.

5.1. Yapay Zekâ ve Ekonomik Diplomasi

Devletler yapay zekâ tabanlı politikalarını geliştirmek adına dışişleri bakanlıkları üzerinden veri diplomasisine yönelik geliştirmeler hazırlamaktadır. Veri diplomasisi, veri biliminden gelen kavram ve uygulamaların sosyal bilimler, uluslararası ilişkiler ve diplomatik müzakerelerle bütünleştirilmesini ifade etmektedir (Baştan ve Karagül, 2021, s. 790). Veri diplomasisi sayesinde devletler müzakere süreçlerini kendileri adına daha hızlı ve maksimum fayda elde edecek şekilde gerçekleştirerek küresel rekabette öne geçmek için çalışmalarını yürütmektedir. Veri diplomasisi literatürde henüz yeni bir alan olmakla birlikte dışişleri bakanlıklarının üzerinde çalıştığı bir konudur; bazı dışişleri bakanlıkları stratejik iletişim için departmanlar kurmaktadır (Baştan ve Karagül, 2021, s. 790). Bu gelişmelere paralel olarak dijitalleşen dünyada veri diplomasisi ülkelerin diplomatik gücü hâline dönüşmüştür. Özellikle ekonomi diplomasisine başvurulacağı esnada yapay zekâ kullanım kapasitesi gelişmiş ülkeler finansal akışları izleme, küresel sermaye hareketlerini analiz edebilme ve yaptırımları daha etkili tasarlama yetkinliğine erişmiştir. Ayrıca devletler yapay zekâ üzerinden yatırım çekme stratejisi geliştirebilmekte ve yapay zekâ tabanlı regülasyonlar oluşturarak belirli kısıtlamalar ve politikalar oluşturabilmektedir (Farrell ve Newman, 2019, ss. 62-78).

5.2. Yapay Zekâ ve Uluslararası Yatırım Kararları

Uluslararası yatırımlar, sermayenin bir ülkeden başka bir ülkeye aktarılması yoluyla gerçekleştirilen ekonomik faaliyetlerdir. Bu yatırımlar kapsamında doğrudan yabancı yatırımlar çok uluslu bir şirketin (ÇUŞ) başka bir ülkede faaliyetlere başlaması veya başka ülkedeki yerli bir firmayı satın alması şeklinde gerçekleştirilebilmektedir. Devletler ÇUŞ'ların ülkelerine sağlayacakları para akışı, istihdam olanakları ve teknoloji transferi gibi faktörler sebebiyle ÇUŞ'ları ülkelerine çekmek için teşvikler sunabilir ve uygun çevre koşulları oluşturabilmektedir (Kurtaran, 2007, s. 367).

ÇUŞ'lar merkezlerinin bulunduğu devletlerin de desteğini alarak yabancı ülkelere doğrudan yabancı yatırımları gerçekleştirirken normal yatırım koşulları altında maliyet, pazar büyüklüğü ve politik risklerini göz önünde bulundurmaktadır. Günümüzde ise teknolojik gelişmelere paralel olarak yapay zekâ uluslararası yatırımları şekillendiren stratejik bir araç hâline gelmiştir. Yapay zekâ kullanımı doğrudan yabancı yatırımlar özelinde üç farklı kanal üzerinden gerçekleşmektedir. Bunlardan ilki yapay zekâ kullanımının ÇUŞ'ların veri işleme kapasitelerini artırma, operasyonel verimlilik sağlama ve maliyet düşürme gibi üretkenlik artışını sağlayacak avantajlar sunmasıdır. Diğer kanal ise yapay zekâ aracılığıyla hedef pazarların belirlenebilmesi, risk analizi yapılması ve yatırım tahmini oluşturulmasına olanak sağlayan pazar öngörüsü elde etmedir. Bu sayede ÇUŞ'lar için piyasadaki belirsizlik durumu ortadan kalkarak daha sağlıklı yatırım kararı almak mümkün hâle gelmektedir. Sonuncu kanal ise yatırımın içeriğini, lokasyonunu ve zamanlamasını belirleyecek olan stratejik karar alma sürecidir. Bu doğrultuda "Nereye, ne zaman ve nasıl bir yatırım yapılacaktır?" sorularına yanıt aranabilmektedir (Yang vd., 2026, ss. 4-6). Uluslararası yatırımlarda yapay zekâ kullanımı rekabet düzeyini artırırken, yatırım kararlarının daha hızlı bir şekilde alınmasına olanak sağlamaktadır. Devletler ise uluslararası diplomasi kapsamında yapay zekâ kullanımını teşvik ederek daha fazla yatırımcı çekebilmekte ve ekonomik diplomasi gücü kazanabilmektedir. Buradan hareketle devletlerin yapay zekâ kullanımını teşvik eden politikalar üretmesi yapay zekânın ekonomi diplomasisi aracı hâline geldiğini göstermektedir.

Diğer bir taraftan yapay zekâ firmalarına yönelik girişim sermayesi yatırımları süreç içerisinde ciddi artış göstermiş olup 2012 yılında yapay zekâ firmalarına yapılan yatırımlar 8.3 milyar USD seviyesinde iken 2025 yılında 258.7 milyar USD seviyesine yükselmiştir. Ayrıca 2025 yılında toplam girişim sermayesi yatırımlarının yaklaşık %61'i yapay zekâ yatırımlarından meydana gelmektedir. Bu istatistiklerden de görüleceği üzere yapay zekâ artık finansal anlamda sadece bir analiz aracı değil ayrıca ekonomik değer üreten bir yatırım fırsatı hâline gelmiştir. Yapay zekâ firmalarına yönelik küresel girişim sermayesi yatırımlarının yaklaşık %75'i ABD'de yerleşik firmalara gitmekte; ABD'yi %6 ile AB27, %5 ile Çin ve %5 ile Birleşik Krallık takip etmektedir. Bu oranlar devletlerin inovasyon stratejilerini ve ekonomik diplomasiyi nasıl şekillendirdiğine yönelik izlenim oluştururken yapay zekâ şirketlerine yönelik girişim sermayesi yatırımlarının

devletlerin ekonomik rekabet gücüne yönelik çıkarımlar yapmayı olanaklı kıldığı görülmektedir (OECD, 2026).

Yapay zekânın uluslararası yatırım kararları kapsamında bir diğer etkisi yatırım tercihlerini dönüştürmesidir. Bu doğrultuda yapay zekâ üretim süreçlerinde maliyet düşürme, veri analitiği oluşturma ve otomasyon sağlama gibi kolaylıklarıyla yatırımcıların ilgisini çekmektedir. Bununla birlikte Lahmeri'nin OECD ülkeleri üzerine çalışması, yapay zekâ yatırımlarının kısa vadede ihracat performansını baskılayabildiğini, buna karşılık ihracattaki oynaklığı azaltarak istikrar sağlayıcı bir rol oynadığını göstermektedir (Lahmeri, 2025, s. 267).

5.3. Finansal Krizler ve Yapay Zekâ Kullanımı

Makroekonomik kırılganlıklar klasik modellerle tam olarak tespit edilememekte olup yapay zekâ tabanlı erken uyarı sistemlerine başvuran ülkeler finansal krizleri erkenden tespit etmeye çalışmaktadır. Devletler erken uyarı sistemleri sayesinde yabancı yatırım riskini azaltmak, dış ekonomik stratejilerini güçlendirmek ve jeoekonomik karar alma süreçlerine veri temelli katkı sağlamaya çalışmaktadır. Söz konusu uygulamayı en etkin şekilde uygulayan ülkelerin başında ABD ve Çin gelmektedir. ABD'nin dış yatırım risk stratejisini güçlendirmeye yönelik bir çalışmada, makro-finansal göstergeler, piyasa mikro yapısı sinyalleri ve alternatif verilerden oluşan geniş veri setleriyle çalışan yapay zekâ tabanlı bir erken uyarı sistemi önerilmiştir. Dönüştürücü (transformer) ve çizge sinir ağı modellerini gradyan artırma yöntemleriyle birleştiren bu sistem, lojistik regresyon ve Random Forest gibi karşılaştırma modellerine göre daha yüksek doğruluk, daha az yanlış alarm ve daha erken sinyal üretmiştir (Kafi vd., 2025, ss. 19-26). Çin ise finans sektöründe risk tespiti ve yönetimi sağlamak adına yapay zekâ kullanımını kurumsal politikaları vasıtasıyla desteklemeye çalışmaktadır. NFRA'nın 2026 yılında hazırladığı düzenlemeye göre bankacılık ve sigortacılık sektörlerinde risklerin yapay zekâ aracılığıyla izlenmesi, erken uyarı sistemleri geliştirilmesi ve düzenleyici kurumların denetim kapasitelerinin güçlendirilerek gerekli zamanlarda müdahale edilmesi hedeflenmektedir. Bu sayede Çin yapay zekâyı finansal piyasalarda sadece bir erken uyarı sistemi değil aynı zamanda finansal istikrarı sürdürmek adına bir araç olarak kullanmaktadır (NFRA, 2026).

5.4. Yapay Zekâ ve Küresel Ekonomik Güç Dengesinin Değişimi

Son yıllarda karar alıcıların politika yapımında yapay zekâyı ekonomik diplomasi aracı olarak kullanmaları uluslararası yapı üzerindeki büyük güçlerin rekabetinin dönüşüm geçirdiğini göstermektedir. Söz konusu dönüşüm süreci üretken yapay zekâ düzeni olarak ifade edilmekte olup yapay zekânın ekonomik büyümeyi hızlandırması, uluslararası rekabeti şekillendirmesi ve bu kapsamda uluslararası güç dengesine yön vermesi beklenmektedir (Cohen ve Lee, 2023). Bu doğrultuda gelişmiş yapay zekâ teknolojisine sahip olan ülkeler ekonomik rekabette avantaj elde etmesi beklenmektedir. Devletlerin elde ettiği iktisadi avantajlar diplomatik ilişkileri ve güç dinamiklerini yeniden şekillendirme potansiyeline sahiptir. Yapay zekâ kullanımının gittikçe yaygınlaştığı günümüz dünyasında uluslararası sistem üzerindeki küresel ekonomik rekabet ABD ve Çin arasında gerçekleşen küresel yönetişim mücadelesinin yansıması hâline gelmiştir. Söz konusu mücadele özellikle ÇUŞ'lar üzerinden gerçekleştirilmekte olup ABD menşeili Microsoft, Alphabet (Google) ve Meta platformları ile Çin menşeli Alibaba, Tencent gibi ÇUŞ'lar arasındaki rekabet küresel ekonomik yapıyı geliştirmekle birlikte şekillendirmektedir. ABD'de ilk yapay zekâ şirketleri 1991 yılından itibaren faaliyet göstermeye başlarken Çin'de ise 1996 yılında yapay zekâ şirketleri faaliyete başlamıştır (Çakan ve Göküş, 2025, s. 155).

İki büyük gücün arasındaki yapay zekâ rekabeti klasik manada teknoloji rekabeti olmanın ötesine geçerek küresel güçlerin ekonomik ve politik mücadele alanı hâline gelmiştir. Bu bağlamda ABD ve Çin kendi politikalarını geliştirmek için yapay zekâ kullanımına başvurmaktadır. ABD'nin yapay zekâ sektörüne yaklaşımı Big Tech şirketlerinin araştırma ve geliştirme çalışmaları üzerinden ileri teknoloji yatırımlarının gerçekleştirilmesi ve müttefik ülkelerle teknoloji blokları oluşturmaya yöneliktir. ABD bu politikasıyla özel sektör üzerinden geliştirdiği yapay zekâ teknolojisini kendisinin merkezinde bulunduğu bir ekosisteme dönüştürmeyi ve Çin'in küresel rekabetteki etkisini sınırlamaya çalışmaktadır. Diğer taraftan Çin ise devlet kapitalizmi modelini koruyarak yerli yapay zekâ şirketlerine destekler ve teşvikler sağlamaktadır. Çin'in

geliştirdiği bu modelde devlet destekli araştırma geliştirme süreçleri, askeri sivil teknoloji entegrasyonu ve hızlı endüstriyel uygulama sayesinde Çin'in merkezde olduğu küresel güney ülkeleriyle iş birliği yapabileceği bir düzen hazırlanmaktadır (Dinic, 2025).

6. Sonuç

Dijitalleşme ve küreselleşmenin birbiriyle ortak paydada gelişim gösterdiği 21. yüzyılda yapay zekâ kullanımı devletlerin iktisadi politikalarını şekillendirmiştir. Yapay zekânın ekonomik diplomasi alanında kullanılması devletler arasındaki ticari müzakerelerde karşı devletin ticari potansiyelinin analiz edilmesi, kur riski ve dış ticaret açığı gibi unsurların tahmin edilmesi bağlamında devletlere avantaj sağlamaktadır.

Yapay zekânın ekonomik alandaki bir diğer kullanım alanı finansal krizlerin erken tespiti ve yönetimidir. Özellikle yapay zekânın makine öğrenmesi yöntemiyle incelenen makro göstergeler ve uluslararası finansal piyasalardan elde edilen veriler aracılığıyla kriz simülasyonları üzerinden analiz yapılması mümkün olmaktadır. Bu sayede devletler potansiyel finansal krizlerde ne gibi durumlar yaşanacağını öngörme imkânına sahip olarak erkenden önlem alabilmektedir.

Sonuç olarak ABD ve Çin arasında yapay zekâ rekabeti uluslararası sistemde büyük güçler arasındaki mücadelenin teknolojik boyutunu ortaya koymaktadır. Bu rekabet düzeninin veri akışları ve algoritmik yönetişim üzerinden devletlerin dış politikaları ve stratejik önceliklerini etkilemesi rekabetin jeopolitik yönünü de doğrulamaktadır. Bu durum büyük güç rekabetini temel alan neorealist teorinin yapay zekâ ile finansal karar alma ve diplomasi geliştirme süreçlerini açıklama konusundaki önemini göstermektedir.

Kaynakça

Andrews, P. (2022). *A trust framework for government use of artificial intelligence and automated decision making*. arXiv. https://doi.org/10.48550/arXiv.2208.10087

Avrupa Birliği Konseyi. (2022). Council Regulation (EU) 2022/345 of 1 March 2022 amending Regulation (EU) No 833/2014 concerning restrictive measures in view of Russia's actions destabilising the situation in Ukraine. *Official Journal of the European Union, L 63*, 1-4. http://data.europa.eu/eli/reg/2022/345/oj

Bank for International Settlements [BIS]. (2025). *The use of artificial intelligence for policy purposes: Report submitted to the G20 Finance Ministers and Central Bank Governors*. BIS. https://www.bis.org/publications/use-artificial-intelligence-policy-purposes.pdf

Baştan, Y. ve Karagül, S. (2021). Diplomasinin dönüşümü ve dijital diplomasi. *TroyAcademy, 6*(3), 777-803. https://doi.org/10.31454/troyacademy.959312

Cohen, J. ve Lee, G. (2023, 14 Aralık). *The generative world order: AI, geopolitics, and power*. Goldman Sachs. https://www.goldmansachs.com/insights/articles/the-generative-world-order-ai-geopolitics-and-power

Çakan, Ş. N. ve Göküş, M. (2025). Yapay zekada iki küresel güç: ABD ve Çin'in yapay zeka stratejileri üzerine bir inceleme. *Bilgi Sosyal Bilimler Dergisi, 27*(2), 142-163. https://doi.org/10.54838/bilgisosyal.1799701

Çalışkan, A. S. (2026). Yapay zekâ ve küresel noopolitik düzen: Algoritmik yönetişim, BM ve Noopoliticus. *Divan: Disiplinlerarası Çalışmalar Dergisi, 31*(60), 41-65. https://doi.org/10.20519/divan.1489047

Dinic, L. (2025, 1 Ağustos). *U.S. and Chinese AI strategies: Competing global approaches*. China-US Focus. https://www.chinausfocus.com/finance-economy/us-and-chinese-ai-strategies-competing-global-approaches

Farrell, H. ve Newman, A. L. (2019). Weaponized interdependence: How global economic networks shape state coercion. *International Security*, *44*(1), 42-79. https://doi.org/10.1162/isec_a_00351

Gündüz, E. (2025). *Yeni küreselleşmede fintek etkisi*. TESAM Yayınları.

İşcan, H. ve Durgun Kaygısız, A. (2024). Yapay zekâ: Alt dalları ve uygulama alanları. *Aksaray Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 16*(4), 201-234. https://doi.org/10.52791/aksarayiibd.1574207

Kafi, A., Arefin, S. M. S., Sultana, N., Hossain, M. S., Rafi, M. A., Rahman, M. M. ve Zakaria, R. M. (2025). AI-powered early warning systems for emerging market crises: Enhancing U.S. foreign investment risk strategy. *Journal of Economics, Finance and Accounting Studies*, *7*(5), 17-29. https://doi.org/10.32996/jefas.2025.7.5.3

Keyman, E. F. (t.y.). Diplomasi. *TÜBİTAK Ansiklopedi* içinde. Erişim tarihi: 24 Şubat 2026, https://ansiklopedi.tubitak.gov.tr/ansiklopedi/diplomasi

Kurtaran, A. (2007). Doğrudan yabancı yatırım kararları ve belirleyicileri. *Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *10*(2), 367-382.

Lahmeri, H. (2025). Artificial intelligence and export performance: Insights from OECD countries. *Uluslararası İşletme ve Ekonomi Çalışmaları Dergisi, 7*(4), 258-271. https://doi.org/10.54821/uiecd.1786964

National Financial Regulatory Administration [NFRA]. (2026, 18 Haziran). *Guanyu yinhangye baoxianye rengong zhineng anquan kaifa yingyong de zhidao yijian* [Bankacılık ve sigortacılık sektörlerinde yapay zekânın güvenli geliştirilmesi ve uygulanmasına ilişkin yol gösterici görüşler]. https://www.nfra.gov.cn/cn/view/pages/ItemDetail.html?docId=1261784

OECD. (2025). *Governing with artificial intelligence: The state of play and way forward in core government functions*. OECD Publishing. https://doi.org/10.1787/795de142-en

OECD. (2026). *Venture capital investments in artificial intelligence through 2025* (OECD Policy Briefs). OECD Publishing. https://doi.org/10.1787/a13752f5-en

Office of Foreign Assets Control [OFAC]. (2026). *Iran sanctions*. U.S. Department of the Treasury. Erişim tarihi: 24 Şubat 2026, https://ofac.treasury.gov/sanctions-programs-and-country-information/iran-sanctions

Okan, C. (2019). *Ekonomik diplomasi aracı olarak devlet ve hükümet başkanlarının yurtdışı ziyaretlerinin uluslararası ticarete etkisi: Türkiye analizi* [Yayımlanmamış yüksek lisans tezi]. İstanbul Üniversitesi Sosyal Bilimler Enstitüsü.

Rouvroy, A. ve Berns, T. (2013). Algorithmic governmentality and prospects of emancipation (L. Carey-Libbrecht, Çev.). *Réseaux, 177*(1), 163-196. https://doi.org/10.3917/res.177.0163

Stanford University. (2025). *Artificial Intelligence Index Report 2025*. Stanford Institute for Human-Centered Artificial Intelligence. https://hai.stanford.edu/ai-index/2025-ai-index-report

U.S. Department of State. (2026, 23 Ocak). *Sanctions on illicit petroleum traders to support the people of Iran* [Basın açıklaması]. https://www.state.gov/releases/office-of-the-spokesperson/2026/01/sanctions-on-illicit-petroleum-traders-to-support-the-people-of-iran

Waltz, K. N. (1979). *Theory of international politics*. Addison-Wesley.

Yang, Z., Wu, F. ve Yue, Z. (2026). Artificial intelligence technology and firms' OFDI: Evidence from China. *International Review of Economics & Finance, 106*, 104920. https://doi.org/10.1016/j.iref.2026.104920

Yeung, K. (2018). Algorithmic regulation: A critical interrogation. *Regulation & Governance, 12*(4), 505-523. https://doi.org/10.1111/rego.12158

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FROM STORIES TO MEMORY: STORYTELLING IN SHORT-FORM VIDEO MARKETING AND COGNITIVE BRAND OUTCOMES IN THE FASHION INDUSTRY

Nurgül Güneş
Evrim Gemici
0009-0009-6835-778X, Istanbul Health and Technology University, Faculty of Economics, Administrative and Social Sciences, Business Administration, Istanbul, Türkiye.
0000-0002-0573-1086, Istanbul Health and Technology University, Faculty of Economics, Administrative and Social Sciences, Business Administration, Istanbul, Türkiye.

Abstract

The growing popularity of short-form video platforms has transformed how fashion brands communicate with consumers, increasing the strategic importance of storytelling as a means of capturing attention and creating memorable brand experiences. Although prior research has examined storytelling, digital marketing, and consumer engagement extensively, limited attention has been given to the mechanisms through which storytelling in short-form video content contributes to cognitive branding outcomes in the fashion industry. Addressing this gap, this conceptual study proposes an integrative framework that examines the relationships between storytelling in short-form videos, brand awareness, and brand recall. Drawing on Narrative Transportation Theory and the identity-based consumption literature, the framework proposes emotional engagement as the underlying mediating mechanism through which storytelling influences brand outcomes, while consumer identity congruence is introduced as a boundary condition that strengthens these relationships. By integrating previously fragmented research streams, the study contributes to the digital branding literature by offering a theoretically grounded perspective on how narrative communication in short-form video environments may enhance consumers' cognitive responses to fashion brands. The proposed framework also provides practical insights into fashion marketers seeking to design storytelling strategies that foster stronger brand recognition and memorability and offers a foundation for future empirical research.

Keywords: Storytelling, Short-Form Video Marketing, Brand Awareness, Brand Recall, Emotional Engagement, Consumer Identity Congruence, Narrative Transportation Theory, Fashion Marketing.

INTRODUCTION

The widespread adoption of short-form video platforms has transformed the way brands communicate with consumers (Nesterenko et al., 2023). Platforms such as TikTok, Instagram Reels, and YouTube Shorts have reshaped digital marketing by encouraging concise, visually engaging, and highly interactive content that competes for consumers' attention within only a few seconds (Dong et al., 2024; Islam & Kabir, 2025). As attention spans continue to decline and consumers are exposed to an unprecedented volume of digital content, brands face increasing pressure to develop communication strategies that not only capture attention but also create memorable experiences (Bowen Shi & Hyoungtae Kim, 2025; Vedechkina & Borgonovi, 2021). In this environment, storytelling has become an increasingly valuable marketing approach because it enables brands to present products and brand identities through meaningful narratives rather than isolated promotional messages (Bharti et al., 2024; Crespo et al., 2023).

The strategic value of storytelling is particularly evident in the fashion industry, where purchasing decisions are influenced not only by functional product attributes but also by symbolic meanings, emotional experiences, and identity expression (Faschan et al., 2020; McNeill & Venter, 2019). Fashion brands increasingly rely on short-form videos to communicate lifestyle aspirations, brand values, and authentic consumer experiences through compact narrative formats (Cao et al., 2021). Rather than merely showcasing products, these videos create emotionally engaging micro-stories that help consumers associate brands with particular lifestyles and

self-images (Dong et al., 2024). By increasing brand recognition and memorability in fiercely competitive digital environments, these narratives have the potential to improve cognitive branding outcomes (Chen et al., 2021).

Existing research (e.g., Crespo et al., 2023; Qasim & Tayyab, 2025) has established the importance of storytelling in strengthening consumer engagement and improving marketing effectiveness across a variety of digital contexts. Recent studies have also demonstrated the effectiveness of storytelling within short-form video environments. For example, Demir & Gür (2025) showed that authentic narrative-driven influencer marketing on Instagram significantly enhances followers' purchase intentions, while Zhang et al. (2025) found that audiovisual storytelling elements in TikTok videos increase consumer engagement. Beyond storytelling, research on short-form video marketing has predominantly focused on user engagement, content virality, platform algorithms, and purchase intentions (Dong et al., 2024; Zhu et al., 2022). Likewise, branding research (e.g., Bergkvist & Taylor, 2022; Thoma & Koziak, 2025) has devoted considerable attention to the determinants of brand awareness and brand recall. Although these streams of research have generated valuable insights, they have largely evolved independently, resulting in a fragmented understanding of how storytelling embedded in short-form video marketing contributes to consumers' cognitive responses toward fashion brands.

More importantly, limited attention has been paid to the underlying mechanisms through which storytelling influences brand awareness and brand recall in short-form video environments. While previous studies acknowledge that storytelling often evokes emotional responses and that consumers tend to respond more favorably to brands reflecting their identities and values (Han & Choi, 2019; Rather et al., 2022), these perspectives have rarely been integrated into a unified conceptual framework. Consequently, the psychological process through which storytelling translates into cognitive branding outcomes, as well as the conditions under which this process becomes stronger, remains insufficiently theorized, particularly within the fashion industry.

To address these gaps, this study proposes an integrative conceptual framework that examines how storytelling in short-form video marketing is associated with brand awareness and brand recall in the fashion industry. The framework draws on Narrative Transportation Theory (Cao et al., 2021) and the identity-based consumption literature (AlQahtani, 2025; McNeill & Venter, 2019) to explain both the process through which storytelling may influence cognitive branding outcomes and the conditions under which these relationships are likely to become stronger. Specifically, emotional engagement is proposed as the mediating mechanism linking storytelling to brand awareness and brand recall, whereas consumer identity congruence is introduced as a moderating condition that strengthens consumers' emotional responses to narrative-based communication.

This study contributes to digital marketing and branding literature in three ways. First, it extends the emerging literature on short-form video marketing by shifting attention beyond commonly examined engagement metrics, such as views, likes, and shares, toward cognitive branding outcomes that are central to long-term brand performance. Second, it integrates Narrative Transportation Theory and identity-based consumption into a single conceptual framework, providing a more comprehensive understanding of how storytelling may influence consumers' cognitive responses through emotional engagement while accounting for differences in consumer identity congruence. Third, by focusing on the fashion industry, the study highlights how storytelling strategies embedded in short-form video content can support branding efforts in markets where symbolic consumption, self-expression, and emotional value play a central role.

The proposed framework also offers practical implications for marketing practitioners. Rather than relying primarily on product-oriented promotional content, fashion brands may benefit from designing short-form video campaigns that communicate authentic and emotionally engaging stories aligned with consumers' identities and values. Such an approach has the potential to strengthen brand recognition and memorability while fostering more meaningful relationships between consumers and brands in increasingly competitive digital environments.

The remainder of this paper is organized as follows. The next section reviews the theoretical foundations of storytelling, Narrative Transportation Theory, and identity-based consumption, and develops the study's propositions. The subsequent section describes the conceptual research design and presents the proposed

framework. Finally, the paper discusses the theoretical and managerial implications of the framework, acknowledges its limitations, and outlines directions for future empirical research.

THEORETICAL BACKGROUND AND PROPOSITION DEVELOPMENT

Theoretical Foundations

The proposed conceptual framework is grounded in two complementary theoretical perspectives: Narrative Transportation Theory and Identity-Based Consumption Theory. Together, these theories provide a coherent explanation of both the psychological process through which storytelling influences consumer responses and the conditions under which these effects are likely to become stronger within short-form video marketing. Narrative Transportation Theory suggests that individuals become mentally and emotionally immersed in a story when they perceive it as engaging, coherent, and personally meaningful (Green & Brock, 2000). During this process of narrative transportation, attention shifts from critically evaluating persuasive messages toward experiencing the narrative itself, increasing emotional involvement and facilitating information processing and memory formation (Lundqvist et al., 2013). In marketing contexts, this perspective implies that storytelling can shape consumers' cognitive responses not merely by presenting product information but by creating immersive experiences that make brands more recognizable and memorable (Baig et al., 2025).

While Narrative Transportation Theory explains how storytelling may influence consumer cognition, it offers limited insight into why the same narrative may generate different responses across consumers. To address this limitation, the present study incorporates Identity-Based Consumption Theory. This perspective argues that consumers are more likely to engage with brands whose values, personalities, and symbolic meanings are consistent with their own identities or desired self-concepts (Acar et al., 2024). Consequently, storytelling is expected to be more persuasive when consumers perceive a strong alignment between the brand narrative and their own identities.

Viewed together, these theoretical perspectives provide a comprehensive foundation for the proposed conceptual model. Narrative Transportation Theory explains the psychological mechanism through which storytelling facilitates cognitive branding outcomes, whereas Identity-Based Consumption Theory identifies consumer identity congruence as an important boundary condition that may strengthen this process. Building upon these complementary perspectives, the following sections develop the study's propositions concerning the relationships among storytelling in short-form video marketing, emotional engagement, brand awareness, and brand recall.

Storytelling in Short-Form Video Marketing and Cognitive Brand Outcomes

Storytelling has become an increasingly important communication strategy in short-form video marketing because it enables brands to convey complex meanings within highly constrained timeframes (Crespo et al., 2023; Malik et al., 2025). Unlike traditional promotional messages that primarily emphasize product features, storytelling embeds products within narratives that communicate experiences, emotions, and symbolic meanings (Dong et al., 2024; Faschan et al., 2020). This distinction is particularly relevant in short-form video environments, where brands have only a few seconds to attract attention and create memorable impressions (Cao et al., 2021).

Narrative Transportation Theory provides a useful explanation for why storytelling is expected to influence cognitive branding outcomes. According to the theory, individuals who become immersed in a narrative allocate greater cognitive and emotional attention to the story than to the persuasive intent underlying the message (Green & Brock, 2000). Rather than processing isolated marketing claims, consumers mentally experience the events and emotions presented in the narrative, leading to deeper information processing and stronger memory formation. Within short-form video marketing, even brief narratives can trigger transportation when they present coherent, emotionally meaningful, and visually engaging stories that capture consumers' attention during rapid content consumption (Büyükdağ & Kitapci, 2021; Chen et al., 2021).

This process is particularly important in the fashion industry. Fashion brands rarely compete solely with functional product characteristics; instead, they communicate symbolic meanings related to lifestyle, identity,

creativity, and self-expression (Faschan et al., 2020; McNeill & Venter, 2019). Short-form videos provide an effective medium for translating these symbolic meanings into concise visual narratives (Yin, 2024) . By integrating products into authentic stories rather than presenting them as isolated commercial messages, fashion brands are more likely to create memorable brand experiences that remain accessible in consumers' memory (Bharti et al., 2024).

From a branding perspective, storytelling is therefore expected to strengthen two closely related cognitive outcomes: brand awareness and brand recall. Brand awareness reflects consumers' ability to recognize or identify a brand when they encounter relevant cues, whereas brand recall refers to their ability to retrieve the brand from memory without such cues (Bergkvist & Taylor, 2022; Thoma & Koziak, 2025). Because narrative-based communication encourages deeper cognitive processing than purely informational messages, consumers are more likely to establish stronger memory associations with brands embedded in engaging stories (Green, 2022). Consequently, storytelling in short-form video marketing is expected to increase both the accessibility and the retrievability of brand-related information. Based on this reasoning, the following propositions are advanced:

Proposition 1a. Storytelling in short-form video marketing is positively associated with brand awareness in the fashion industry.

Proposition 1b. Storytelling in short-form video marketing is positively associated with brand recall in the fashion industry.

Emotional Engagement as the Mediating Mechanism

While storytelling is expected to directly enhance cognitive branding outcomes, its persuasive value is further amplified through emotional engagement, which encourages consumers to process brand-related information more deeply (Malik et al., 2025; Tyng et al., 2017). Consistent with Narrative Transportation Theory, individuals who become immersed in a narrative are not merely exposed to marketing messages; they experience emotions, characters, and situations embedded within the story (Tchernev et al., 2023). This immersive experience increases emotional involvement, making brand communication more personally meaningful and cognitively salient (Grazzini et al., 2021).

Emotional engagement therefore represents a key psychological mechanism linking storytelling to brand-related memory. Narrative-based communication invites consumers to feel curiosity, empathy, inspiration, or excitement rather than simply receive product information (Rao et al., 2024). These emotional responses encourage greater cognitive elaboration and strengthen consumers' attention to the brand, thereby increasing the likelihood that brand-related information will be encoded and retained in memory (Green, 2022; Tyng et al., 2017). Consequently, storytelling is expected to influence brand awareness and brand recall not only directly, but also indirectly by fostering emotionally engaging experiences.

The mediating role of emotional engagement is particularly relevant within the fashion industry. Fashion consumption is closely associated with symbolic value, identity expression, and affective experiences, making consumers especially responsive to emotionally rich brand narratives (Faschan et al., 2020). Short-form video marketing provides an ideal environment for creating such experiences because visual storytelling, music, editing styles, and narrative structure can rapidly evoke emotional responses within a limited viewing time (Büyükdağ & Kitapci, 2021; Cao et al., 2021). When consumers become emotionally engaged with these narratives, they are more likely to recognize the brand during subsequent encounters and to retrieve it from memory when making purchase-related decisions (Chung & Lee, 2020; Egamberdieva & Egamberdieva, 2024). Accordingly, emotional engagement is proposed as a key psychological mechanism through which storytelling in short-form video marketing contributes to cognitive branding outcomes.

Proposition 2a. Emotional engagement mediates the relationship between storytelling in short-form video marketing and brand awareness in the fashion industry.

Proposition 2b. Emotional engagement mediates the relationship between storytelling in short-form video marketing and brand recall in the fashion industry.

Consumer Identity Congruence as a Boundary Condition

Although storytelling has the potential to generate emotional engagement, consumers are unlikely to respond to brand narratives in the same way. Identity-Based Consumption Theory suggests that consumers are more receptive to brands that reflect or reinforce their actual or desired self-concepts (Acar et al., 2024). Consequently, the effectiveness of storytelling depends not only on the quality of the narrative itself but also on the extent to which consumers perceive the brand story as personally relevant and consistent with their identities (Kaur & Anand, 2021).

This perspective is particularly applicable to the fashion industry, where products function as symbolic expressions of lifestyle, personality, and social identity rather than merely fulfilling functional needs (Faschan et al., 2020; McNeill & Venter, 2019). Fashion consumers often evaluate brands according to the meanings they communicate and the identities they represent (AlQahtani, 2025). As a result, storytelling is more likely to generate strong emotional responses when consumers perceive that the narrative reflects their own values, aspirations, or desired lifestyles (Ciocodeică et al., 2025; Kim & Sullivan, 2019).

Consumer identity congruence is therefore expected to strengthen the emotional impact of storytelling. When consumers recognize themselves in a brand's narrative, they are more likely to become emotionally immersed in the story, experience stronger narrative transportation, and develop richer cognitive associations with the brand (Chen et al., 2021). Conversely, when consumers perceive little alignment between the narrative and their identities, even well-designed stories may generate only limited emotional engagement, thereby dampening the indirect cognitive response (Kaur & Anand, 2021). Thus, identity congruence does not directly create brand awareness or brand recall; rather, it enhances the effectiveness of the psychological process through which storytelling influences these outcomes. Accordingly, consumer identity congruence is proposed as a boundary condition that strengthens the indirect influence of storytelling on cognitive branding outcomes by reinforcing consumers' emotional engagement with narrative-based communication.

Proposition 3a. Consumer identity congruence positively moderates the relationship between storytelling in short-form video marketing and emotional engagement, such that the relationship is stronger when consumer identity congruence is high.

Proposition 3b. The indirect positive relationship between storytelling in short-form video marketing and (a) brand awareness and (b) brand recall through emotional engagement is stronger when consumer identity congruence is high.

METHODOLOGY

Research Design

This study adopts a conceptual research design to develop a theoretically grounded framework explaining the relationships among storytelling in short-form video marketing, emotional engagement, consumer identity congruence, and cognitive branding outcomes in the fashion industry. Unlike empirical studies, conceptual research does not seek to test hypotheses through primary data collection (Jaakkola, 2020). Instead, it advances knowledge by synthesizing existing theoretical perspectives, identifying relationships among established constructs, and proposing a coherent framework that can guide future empirical investigation (Kozlenkova et al., 2025).

A conceptual approach is particularly appropriate for the present study because research examining storytelling within short-form video marketing remains fragmented across several disciplines, including digital marketing, branding, consumer behavior, and fashion marketing. Although these research streams provide valuable insights individually, their integration remains limited. Accordingly, the present study brings together complementary theoretical perspectives to explain how storytelling may contribute to brand awareness and brand recall through emotional engagement and under varying levels of consumer identity congruence.

Literature Review Approach

The proposed framework was developed through a review of the literature. Relevant studies were identified across the fields of digital marketing, branding, consumer psychology, fashion marketing, and social media communication. Particular attention was given to research addressing storytelling, short-form video marketing, brand awareness, brand recall, emotional engagement, Narrative Transportation Theory, and Identity-Based Consumption Theory.

Rather than conducting a systematic review, the objective of the literature review was to integrate complementary theoretical perspectives that have traditionally been examined in isolation. This integrative approach enabled the identification of key constructs, the clarification of their conceptual relationships, and the development of theoretically grounded propositions concerning storytelling and cognitive branding outcomes within the fashion industry.

Development of the Conceptual Framework

Building upon the theoretical foundations presented in the previous section, the proposed framework conceptualizes storytelling in short-form video marketing as the primary antecedent of cognitive branding outcomes. The model proposes that storytelling enhances brand awareness and brand recall indirectly through emotional engagement, while consumer identity congruence strengthens the influence of storytelling on consumers' emotional engagement with brand narratives.

The framework integrates Narrative Transportation Theory and Identity-Based Consumption Theory into a single conceptual model. Narrative Transportation Theory explains the psychological process through which storytelling promotes deeper cognitive processing and memory formation, whereas Identity-Based Consumption Theory explains why consumers differ in their emotional responses to brand narratives. By combining these complementary perspectives, the proposed framework offers a theoretically grounded explanation of how storytelling may contribute to brand-related cognitive outcomes in contemporary digital environments.

Figure 1 presents the proposed conceptual framework.

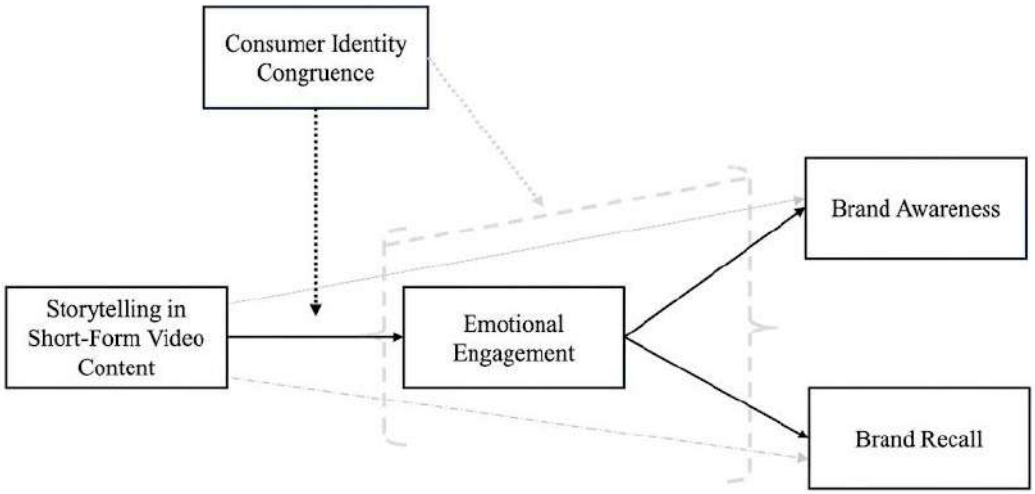


Figure 1: Conceptual framework

Source: Developed by the authors based on Narrative Transportation Theory and Identity-Based Consumption Theory

DISCUSSION AND CONCLUSION

This study proposed a conceptual framework explaining how storytelling in short-form video marketing influences cognitive branding outcomes, specifically brand awareness and brand recall, within the fashion industry. By integrating Narrative Transportation Theory and Identity-Based Consumption Theory, the framework posits that storytelling exerts both direct and indirect effects on cognitive outcomes, with emotional engagement operating as the key mediating psychological mechanism and consumer identity congruence serving as a critical boundary condition.

Theoretical Contributions

The proposed framework advances the literature on digital marketing, storytelling, and branding in four key ways: Existing research on short-form video marketing has predominantly focused on immediate behavioral outcomes, such as engagement metrics (likes, shares, comments) or purchase intentions (Wahid & Gunarto, 2022). By shifting attention toward brand awareness and brand recall, this model emphasizes longer-term cognitive representations that are central to sustainable brand equity in dynamic digital environments (Colicev et al., 2018; Hollebeek & Macky, 2019). The model synthesizes Narrative Transportation Theory and Identity-Based Consumption Theory into a unified conceptual framework. Rather than treating storytelling solely as a creative communication tactic, this integration explains the underlying psychological mechanisms while simultaneously defining the identity-related boundary conditions that govern its persuasive efficacy. Although storytelling is widely recognized as an effective communication tool (Crespo et al., 2023; Lundqvist et al., 2013), the underlying psychological pathways linking it to cognitive memory structures in short-form video formats have received limited conceptual attention. Positioning emotional engagement as a mediator provides a more nuanced explanation of how narrative transportation translates into deeper cognitive elaboration and brand retrieval (Glaser & Reisinger, 2022; Thomas & Grigsby, 2024). Consistent with Identity-Based Consumption Theory, the framework highlights that consumers do not respond to brand narratives uniformly (Rather et al., 2022). By introducing consumer identity congruence as a moderator, the study extends direct-effect paradigms and explains why narrative communication is particularly potent when aligned with consumers' self-concepts, values, and lifestyle aspirations (Kaur & Anand, 2021).

Practical Implications

The fashion industry provides a rich context for this framework because fashion products function as symbolic expressions of identity and lifestyle rather than mere functional items (Faschan et al., 2020; Lyu, 2025). For brand managers and digital marketers, the framework suggests that relying solely on product-centric promotional appeals is insufficient in short-form video environments. Instead, marketers should focus on crafting authentic, narrative-driven content that resonates with target consumers' self-identity. Evoking curiosity, empathy, and excitement through visual storytelling, music, and narrative structure fosters emotional engagement, which in turn enhances brand recall and recognition during purchase decisions (Büyükdağ & Kitapci, 2021; Cao et al., 2021).

Limitations and Directions for Future Research

As a conceptual study, this research has limitations that offer valuable avenues for future inquiry. Primarily, the proposed direct, mediating, and moderating relationships are theoretically derived propositions that have not yet been empirically validated. Future research is encouraged to test these propositions using quantitative (e.g., experimental designs, structural equation modeling) or mixed-method approaches. Furthermore, while this model is tailored to the symbolic context of fashion, its conceptual logic may extend to other lifestyle-driven industries where symbolic consumption and identity play a central role, such as cosmetics, luxury goods, sports apparel, and tourism. Future empirical studies should test the boundary conditions of this framework across diverse industry sectors, cultural contexts, and evolving short-form video platforms. Finally, exploring additional psychological mediators (e.g., perceived authenticity or brand trust) could further enrich our understanding of how storytelling builds enduring cognitive brand relationships.

REFERENCES

Acar, A., Büyükdağ, N., Türten, B., Diker, E., & Çalışır, G. (2024). The role of brand identity, brand lifestyle congruence, and brand satisfaction on repurchase intention: a multi-group structural equation model. *Humanities and Social Sciences Communications*, *11*(1), 1102. https://doi.org/10.1057/s41599-024-03618-w

AlQahtani, F. A. (2025). Mapping the Digital Self: The Role of Self-Image Congruence and Brand Authenticity in Shaping Purchasing Behavior, with Insights into Sustainability in Online Commerce. *European Journal of Sustainable Development*, *14*(1), 81. https://doi.org/10.14207/ejsd.2025.v14n1p81

Baig, T. A., Razak, Q., Qadeem, S. E. Y., & Zahur, H. (2025). The Psychology of Narrative in Marketing: Brand Communication through Story Telling. *Research Journal for Social Affairs*, *3*(6), 577–589. https://doi.org/10.71317/RJSA.003.06.0485

Bergkvist, L., & Taylor, C. R. (2022). Reviving and Improving Brand Awareness As a Construct in Advertising Research. *Journal of Advertising*, *51*(3), 294–307. https://doi.org/10.1080/00913367.2022.2039886

Bharti, R., Khatri, U., & Duralia, O. A. (2024). Examining the Role of Digital Marketing in Shaping Consumer Communication and Behavior. *Feedback International Journal of Communication*, *1*(4), 192–201. https://doi.org/10.62569/fijc.v1i4.76

Bowen Shi, & Hyoungtae Kim. (2025). The Impact of Short Video Platform Marketing Strategies on the Acceleration of the Consumer Decision-Making Cycle. *Frontiers in Business and Finance*, *2*(01), 50–56. https://doi.org/10.71465/fbf258

Büyükdağ, N., & Kitapci, O. (2021). Antecedents of consumer-brand identification in terms of belonging brands. *Journal of Retailing and Consumer Services*, *59*, 102420. https://doi.org/10.1016/j.jretconser.2020.102420

Cao, X., Qu, Z., Liu, Y., & Hu, J. (2021). How the destination short video affects the customers' attitude: The role of narrative transportation. *Journal of Retailing and Consumer Services*, *62*, 102672. https://doi.org/10.1016/j.jretconser.2021.102672

Chen, L., Halepoto, H., Liu, C., Kumari, N., Yan, X., Du, Q., & Memon, H. (2021). Relationship Analysis among Apparel Brand Image, Self-Congruity, and Consumers' Purchase Intention. *Sustainability*, *13*(22), 12770. https://doi.org/10.3390/su132212770

Chung, S., & Lee, S. Y. (2020). Cognitive processing of corporate social responsibility campaign messages: the effects of emotional visuals on memory. *Media Psychology*, *23*(2), 244–268. https://doi.org/10.1080/15213269.2019.1591999

Ciocodeică, D.-F., Chivu (Popa), R.-G., Popa, I.-C., Mihălcescu, H., & Barghier, I. (2025). Hedonic and Impulsive Consumer Behavior Stimulated by Social Media: Implications for Sustainable Fashion Marketing. *Sustainability*, *17*(11), 5198. https://doi.org/10.3390/su17115198

Colicev, A., Malshe, A., Pauwels, K., & O'Connor, P. (2018). Improving Consumer Mindset Metrics and Shareholder Value through Social Media: The Different Roles of Owned and Earned Media. *Journal of Marketing*, *82*(1), 37–56. https://doi.org/10.1509/jm.16.0055

Crespo, C. F., Ferreira, A. G., & Cardoso, R. M. (2023). The influence of storytelling on the consumer–brand relationship experience. *Journal of Marketing Analytics*, *11*(1), 41–56. https://doi.org/10.1057/s41270-021-00149-0

Demir, S., & Gür, D. (2025). The Impact of Influencer Marketing on Female Consumers' Online Impulse Buying Intentions. *Uluslararası İktisadi ve İdari İncelemeler Dergisi*, (47), 169–186. https://doi.org/10.18092/ulikidince.1597669

Dong, X., Liu, H., Xi, N., Liao, J., & Yang, Z. (2024). Short video marketing: what, when and how short-branded videos facilitate consumer engagement. *Internet Research*, *34*(3), 1104–1128. https://doi.org/10.1108/INTR-02-2022-0121

Egamberdieva, F., & Egamberdieva, S. (2024). Cognitive and Neurolinguistic Aspects of Advertising Discourse Perception. *International Journal of Industrial Engineering, Technology & Operations Management*, *2*(2), 52–58. https://doi.org/10.62157/ijietom.v2i2.60

Faschan, M., Chailan, C., & Huaman-Ramirez, R. (2020). Emerging adults' luxury fashion brand value perceptions: A cross-cultural comparison between Germany and China. *Journal of Global Fashion Marketing*, *11*(3), 207–231. https://doi.org/10.1080/20932685.2020.1761422

Glaser, M., & Reisinger, H. (2022). Don't Lose Your Product in Story Translation: How Product–Story Link in Narrative Advertisements Increases Persuasion. *Journal of Advertising*, *51*(2), 188–205. https://doi.org/10.1080/00913367.2021.1973623

Grazzini, L., Acuti, D., & Aiello, G. (2021). Solving the puzzle of sustainable fashion consumption: The role of consumers' implicit attitudes and perceived warmth. *Journal of Cleaner Production*, *287*, 125579. https://doi.org/10.1016/j.jclepro.2020.125579

Green, M. (2022). An exploration of the 'Get Ready with Me' (GRWM) culture within YouTube today and how it performs heteronormative femininity. *QMiP Bulletin*, *1*(33), 30–35. https://doi.org/10.53841/bpsqmip.2022.1.33.30

Green, M. C., & Brock, T. C. (2000). The role of transportation in the persuasiveness of public narratives. *Journal of Personality and Social Psychology*, *79*(5), 701–721. https://doi.org/10.1037/0022-3514.79.5.701

Han, T.-I., & Choi, D. (2019). Fashion Brand Love: Application of a Cognition–Affect–Conation Model. *Social Sciences*, *8*(9), 256. https://doi.org/10.3390/socsci8090256

Hollebeek, L. D., & Macky, K. (2019). Digital Content Marketing's Role in Fostering Consumer Engagement, Trust, and Value: Framework, Fundamental Propositions, and Implications. *Journal of Interactive Marketing*, *45*(1), 27–41. https://doi.org/10.1016/j.intmar.2018.07.003

Islam, M. M., & Kabir, M. A. (2025). The Impact Of Short Video Content And Social Media Influencers On Digital Marketing Success: A Systematic Literature Review Of Smartphone Usage. *Innovatech Engineering Journal*, *1*(02), 01–17. https://doi.org/10.70937/faet.v1i02.46

Jaakkola, E. (2020). Designing conceptual articles: four approaches. *AMS Review*, *10*(1–2), 18–26. https://doi.org/10.1007/s13162-020-00161-0

Kaur, H., & Anand, S. (2021). Actual versus ideal self: An examination of the impact of fashion self congruence on consumer's fashion consciousness and status consumption tendencies. *Journal of Global Fashion Marketing*, *12*(2), 146–160. https://doi.org/10.1080/20932685.2020.1856705

Kim, Y.-K., & Sullivan, P. (2019). Emotional branding speaks to consumers' heart: the case of fashion brands. *Fashion and Textiles*, *6*(1), 2. https://doi.org/10.1186/s40691-018-0164-y

Kozlenkova, I. V., Warren, C., Kotha, S., Boghrati, R., & Palmatier, R. W. (2025). Conceptual Research: Multidisciplinary Insights for Marketing. *Journal of Marketing*, *89*(4), 1–20. https://doi.org/10.1177/00222429241302814

Lundqvist, A., Liljander, V., Gummerus, J., & van Riel, A. (2013). The impact of storytelling on the consumer brand experience: The case of a firm-originated story. *Journal of Brand Management*, *20*(4), 283–297. https://doi.org/10.1057/bm.2012.15

Lyu, J. (2025, May 14). Matching the Narrative Fragments and Customer Identity Fragments in Omni-Channel Fashion Retail. *Designing Retail & Services Futures Colloquium 2025: Sustainable Retail and Services Futures*. https://doi.org/10.21606/drsf.112

Malik, N. I., Ramzan, M. M., Malik, Z., & Tariq, I. (2025). The Rise of Reels: Analyzing the Communicative Power of Short-Form Videos on Social Media. *Qlantic Journal of Social Sciences*, *6*(2), 138–145. https://doi.org/10.55737/qjss.vi-ii.25350

McNeill, L., & Venter, B. (2019). Identity, self-concept and young women's engagement with collaborative, sustainable fashion consumption models. *International Journal of Consumer Studies*, *43*(4), 368–378. https://doi.org/10.1111/ijcs.12516

Nesterenko, V., Miskiewicz, R., & Abazov, R. (2023). Marketing Communications in the Era of Digital Transformation. *Virtual Economics*, *6*(1), 57–70. https://doi.org/10.34021/ve.2023.06.01(4)

Rao, U., Mazhar Ali, & Rubab, S. (2024). Unveiling the Power of Storytelling: A Comparative Analysis of Consumer vs. Brand Narratives in Shaping Favorable Attitude Toward Brands Through Emotions and Cognition. *International Journal of Management Research and Emerging Sciences*, *14*(3). https://doi.org/10.56536/ijmres.v14i3.609

Rather, R. A., Hollebeek, L. D., VO-THANH, T., Ramkissoon, H., Leppiman, A., & Smith, D. (2022). Shaping customer brand loyalty during the pandemic: The role of brand credibility, value congruence, experience, identification, and engagement. *Journal of Consumer Behaviour*, *21*(5), 1175–1189. https://doi.org/10.1002/cb.2070

Tchernev, J. M., Collier, J., & Wang, Z. (2023). There and Back Again? Exploring the Real-Time Cognitive Journey of Narrative Transportation. *Communication Research*, *50*(3), 312–337. https://doi.org/10.1177/00936502211018577

Thoma, D., & Koziak, J. (2025). Nostalgic Advertising Enhances Brand Name Recall by Reactivating Brand-Related Autobiographical Memories, Especially for Familiar and Personally Relevant Brands. *Psychology & Marketing*, *42*(12), 3306–3318. https://doi.org/10.1002/mar.70042

Thomas, V. L., & Grigsby, J. L. (2024). Narrative transportation: A systematic literature review and future research agenda. *Psychology & Marketing*, *41*(8), 1805–1819. https://doi.org/10.1002/mar.22011

Tyng, C. M., Amin, H. U., Saad, M. N. M., & Malik, A. S. (2017). The Influences of Emotion on Learning and Memory. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.01454

Vedechkina, M., & Borgonovi, F. (2021). A Review of Evidence on the Role of Digital Technology in Shaping Attention and Cognitive Control in Children. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.611155

Wahid, R. M., & Gunarto, M. (2022). Factors Driving Social Media Engagement on Instagram: Evidence from an Emerging Market. *Journal of Global Marketing*, *35*(2), 169–191. https://doi.org/10.1080/08911762.2021.1956665

Yin, H. (2024). From Virality to Engagement: Examining the Transformative Impact of Social Media, Short Video Platforms, and Live Streaming on Information Dissemination and Audience Behavior in the Digital Age. *Advances in Social Behavior Research*, *14*(1), 10–14. https://doi.org/10.54254/2753-7102/2024.18644

Zhang, Z., Qiu, K., & Ye, Y. (2025). Influence of audiovisual features of short video advertising on consumer engagement behaviors: Evidence from TikTok. *Journal of Business Research*, *201*, 115662. https://doi.org/10.1016/j.jbusres.2025.115662

Zhu, S., Karagioules, T., Halepovic, E., Mohammed, A., & Striegel, A. D. (2022). Swipe along. *Proceedings of the 13th ACM Multimedia Systems Conference*, 123–135. https://doi.org/10.1145/3524273.3528186

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

HOW CAN THE SAME ISSUE LEAD TO DIVERGENT POLITICAL OUTCOMES? IMMIGRATION-SPECIFIC CRIME ATTRIBUTION AND ITS EFFECTS ON SUPPORT FOR EXECUTIVE POWER AND GUN CONTROL POLICY

Nazım ERYILMAZ
The University of Kansas, Department of Political Science, Lawrence, US
ORCID ID: https://orcid.org/0009-0006-3107-1575

Abstract

Just as in every other aspect of life, people attribute different causes to various phenomena, and their political preferences and behaviours are shaped accordingly. The reasons people attribute to crime – a significant social problem – (individuals, groups, or other sociologically based causes) will also shape their preferences regarding policy and governance; however, little attention is paid to who is held responsible for crime and how political responses will change accordingly. This study focuses on two distinct dimensions that inform crime perception: crime salience and crime attribution. The first refers to the belief regarding the extent to which crime is a significant national issue, while the second pertains to the notion that immigrants increase crime. I argue that these two dimensions sufficiently capture distinct political processes and yield different political outcomes.

Using data from the 2024 American National Election Studies (ANES), this study demonstrates that immigration-specific crime attribution influences executive centralization and support for gun regulation in distinct ways. The perspective offered by this study provides important insights into whether crime-related perceptions will generate uniform security-seeking responses or diverse political responses. Support for executive centralization is analyzed using ordinary least squares (OLS), while support for stricter gun regulation is estimated using logistic regression. The study also controls for partisanship, race, gender, trust in government, and presidential approval.

The study finds that immigrant-specific crime attribution is positively correlated with support for executive centralization and negatively correlated with support for stricter gun regulation. In contrast, diffuse crime salience produces a non-systematic effect. The findings indicate that higher levels of immigrant-specific crime attribution correspond to higher levels of support for executive centralization but lower levels of support for stricter gun regulation.

The study contributes to the literature on political behaviour, public opinion, and democratic backsliding. Additionally, the study highlights the implication that crime should be considered not only in terms of how significant it is perceived to be but also in terms of to whom responsibility is attributed.

Keywords: Crime Attribution; Crime Salience; Executive Centralization; Gun Regulation; Political Behaviour.

Introduction

A 2024 survey reveals that American voters are divided on the extent to which crime is a major problem for the country and what criminal justice approach should be adopted to address it: 81% of Trump supporters argue that the current criminal justice system is not tough enough, while only 40% of Biden supporters share that view.[1] Although this study was conducted while the Biden administration was still in office – and Biden supporters might therefore view any national issue more tolerably than Republicans – one wonders: is partisanship the only factor shaping people's political positions on crime? Society may demand strong leadership and policy-related toughness in the face of perceived insecurity. Existing literature emphasizes that

[1] https://www.pewresearch.org/politics/2024/06/06/crime-policing-and-the-2024-election/ (Accessed on May 1st, 2026)

a general sense of insecurity may lead people to rely more on authority and shape their political behavior accordingly (Davis & Silver, 2004; Huddy et al., 2007; Stenner, 2005). To what extent does the source of this threat influence these demands? The argument presented in this study is that perceptual differences, supported by a quest for cultural homogeneity in response to the aforementioned threat, lead to divergent institutional and policy preferences. Although people continue to view crime as a significant problem, their attribution of the cause of this problem can influence political behavior. The set of political attitudes resulting from a general perception of crime-related insecurity may differ when it is perceived as originating from an outgroup. Therefore, in this study, I examine whether different types of crime-related attributional perceptions produce distinct institutional and policy-related outcomes.

According to attribution theory, when people interpret specific events, they primarily form reactions based on their perceptions of the causes behind those events. People want to know the causes of specific events; engaging in a search for causes actually provides the individual with the opportunity to bring order to, and simplify, complex and potentially chaotic perceptual and behavioral unknowns. Unstable, uncertain, and uncontrollable phenomena can be made controllable by the actor through the identification of causal relationships, thereby enabling the formation of a judgment regarding them (Graham, 1991). The factor one perceives as the cause of any problem has, in a sense, now emerged; the problem has become knowable; and personal behavior will be shaped accordingly (Joslyn & Haider-Markel, 2017). In an earlier study, Haider-Markel and Joslyn (2001) wrote, "Political thinking is full of causal mysteries. Particular linkages of cause and effect can induce specific dynamics in the mass public, whether attitudinal or behavioral" (Haider-Markel and Joslyn, 2001, p. 537). This study will focus on how the "demystification" sought by the subject (individual) according to attribution theory drives divergent political reactions through the targeting of specific groups in the context of crime. The study will examine how this dynamic takes shape in the context of diffuse crime (general, not concentrated on one group) and immigrant-attributed crime.

Literature Review

In examining the literature on how the perception of insecurity fuels authoritarian tendencies, there are studies indicating that the perception of threat – particularly that stemming from terrorism – leads to divergent political behaviors among different groups (Huddy et al., 2005). One of the most important triggers highlighted here is that in-group anxiety, particularly when it stems from the out-group, is generally amplified by in-group cues (Brader et al., 2008). Under these conditions, it is emphasized that the public may support more security-oriented measures, potentially pushing democratic ideals to the background. In other words, the perception of insecurity can lead to a search for authoritarian measures (Hetherington & Suhay, 2011). In another study, by distinguishing between individual threat perception and societal threat perception, it was found that the latter produces a greater negative impact on governmental trust (Schlipphak, 2024). A paper on punitive policies toward out-groups shows that as the population of the minority out-group increases, the in-group tends to punish criminals within that group more severely (Ousey & Unnever, 2012). Authoritarian tendencies reflect a process in which immigration is perceived as a cultural threat by the in-group and is further amplified by immigration itself. In this regard, it has been noted that perceptions of cultural threats are more strongly associated with authoritarianism than instrumental concerns such as the protection of economic interests (Norris & Inglehart, 2019). A similar study argues that ethnic antagonism itself negatively affects Republican Americans' commitment to democratic norms. One of the most striking findings in this regard is the increase in support for strong leaders and their ability to bend the rules when necessary (Bartels, 2020). The primary factor driving this is the need for the president to make faster decisions, particularly during crises, which in turn fuels the expansion of presidential power (Marshall, 2008).

One of the areas where the perception of social insecurity plays a role – aside from the expansion of executive power – is gun control policy. According to a study investigating why people support handgun bans, those who hold negative stereotypes about gun ownership and those who believe that the responsibility to protect one's home from crime lies with the police tend to adopt a more anti-gun stance (Kleck et al., 2009). Another study shows that proximity to the location of mass shootings, the recurrence of such incidents, their intensity, and their recency constitute significant support for gun control (Newman & Hartman, 2019). A separate group

of studies reveals that security threats stemming from out-groups, the method of violence, or the urban/rural divide do not constitute significant support for gun control; however, gender does produce a significant effect in this regard (McKee, 2017; Oraka et al., 2019). While some studies highlight that as trust in the government increases, there is less resistance to gun control regulations among conservatives (Ryan et al., 2022), others show that focusing events such as mass shootings further polarize partisans, leading Democrats to support gun control regulations more strongly while making Republicans less supportive (Barney & Schaffner, 2019).

As people form their attitudes toward the violent act itself, they generate different causal explanations in their interpretations of the event, and thus interpret the event through this lens. In their study examining what shapes causal attributions regarding the 2007 Virginia Tech and 2011 Tucson shootings, Joslyn and Haider-Markel (2013) highlight two key motives: people's causal reasoning is shaped by (a) partisanship and (b) a motivation to alleviate the mental burden of the events. The first is reflected as follows: while Democrats attribute the event to environmental factors, Republicans tend to focus more on the shooter as an individual. Regarding the second motive, it is predicted that less educated individuals will focus more on the perpetrator himself, while the educated will focus on social and political conditions. Another study argues that gun owners undergo a self-serving cognitive attribution process following a mass shooting; these individuals are reluctant to view the gun as a cause of the mass shooting and therefore support gun-control-related policy changes to a lesser extent (Joslyn & Haider-Markel, 2017). Haider-Markel and Joslyn (2001) examine how framing influences attributions regarding mass shootings. They found that framing has a conditional effect on people's views regarding gun policy following a mass shooting; therefore, individuals' existing political leanings and levels of knowledge amplify the impact of alternative gun-related information. Frames serve not to persuade those with opposing views to adopt a different perspective, but rather to reinforce existing views. Thus, for example, the effect of framing is observed when it reinforces people's partisanship-filtered causal reasonings. Existing literature shows that people resort to various causal attributions during moments of insecurity and interpret events through these filters. However, we need to give more thought to the nature of the drive generated by insecurities of an "outgroup" origin in such attributions. The immigration and outgroup politics angles will offer considerable insights into how the authority seeking and policy-related demands generated by *an insecurity without a subject* differ from those generated by *the same insecurity attributed to a subject*.

Theory

Political attitudes will differ depending on the extent to which people perceive crime as a significant problem, and on whom or which group this issue is attributed. This corresponds precisely to the difference between salience and attribution. According to Wlezien (2001), salience is a concept used to "designate the importance individual voters attach to different issues" (Wlezien, 2001, p. 1). Thus, it is undoubtedly natural for people to develop a political stance regarding issues they pay more attention to, worry about, and form opinions on; however, this stance will differ when a subject is assigned to the problem. Unlike salience, crime attribution assigns a perpetrator to the problem, as the public has now formed an opinion regarding the source of the problem. At this point, the positioning of immigrants as an outgroup at the center of the problem – that is, their being viewed as the cause of rising crime rates – actually falls within the scope of attribution theory. As noted above, people evaluate events based on the causal reasoning they construct rather than the event itself (Joslyn & Haider-Markel, 2017).

Here, I focus on two dynamics: crime as a diffuse issue and crime as an immigrants-related issue. Both of these dynamics give rise to different sets of behaviors. First, if we evaluate crime solely along the salience axis, we can expect people to demand greater executive authority to resolve this increasingly significant problem. This is because, when feeling threatened, the belief that faster action is needed – without any institutional oversight – will drive the demand for a leader who is not constrained by such oversight (Hetherington & Suhay, 2011). Since this is a general problem, we can also expect the public to prefer more regulation in their policy choices. Gun control support is a policy area that can be evaluated precisely within this framework. For when people perceive a general insecurity related to crime, they may have demands specifically regarding the reduction of gun ownership or the increased monitoring of the gun acquisition process (Verrecchia et al., 2021). When considered alongside support for expanding executive authority, it is suggested that the necessary steps

regarding gun control must be taken swiftly at the national level, and that public expectations may emerge for relevant authorities to implement more public safety measures (Ziller & Helbling, 2021). Undoubtedly, in the interest of public safety, people may want the president to have more authority and for gun ownership to be regulated.

So what kind of shift might occur in political attitudes when crime becomes an issue perceived to be originating from a specific group? This corresponds to the dynamic of crime as an issue related to immigrant background. Here, we are no longer dealing with a situation where the cause of crime is unclear, but rather one where a causal relationship is established and the perpetrator is identified. Crime ceases to be a general public safety issue and is interpreted through identity-linked attribution, since the social group to which the crime is attributed is an outgroup, the "other." This can lead to the emergence of identity-based reactions. Furthermore, the search for authority observed in the first mechanism – where crime is viewed as *a general public issue* – may also be activated here. Joslyn and Haider-Markel (2017) demonstrate that gun owners construct self-serving causal attributions and, therefore, prefer alternative causal explanations rather than regulations that would prevent gun ownership. Thus, the study argues, a gun is not merely a purchase but a socio-cultural investment; consequently, rather than abandoning it, they seek the cause of the problem not in the gun itself but in a more alternative context. Therefore, it becomes difficult to expect these individuals to adopt a more objective position regarding gun-related policy regulations. For many political and cultural reasons, people's policy stances can be steered in specific directions.

In this second dimension, I believe that when crime is attributed to a specific group, immigrants in this case, an identity-based self-protection drive may emerge. This is because when the crime-linked insecurity is perceived as a general public issue and the subject has not been identified, the search for authority could be stronger, and the likelihood of a general consensus forming in society regarding gun regulation higher. However, in the second mechanism – that is, when the insecurity originates from an outgroup – the uncertainty about when the crime might occur, coupled with the demand for the state to impose even more restrictive measures on individual gun ownership against the "usual suspect," may not be as strong as in the first mechanism. Causal attribution ultimately adds a sense of urgency to the problem here. While salience provides information about the problem's importance, attribution makes the problem seem as though it could "knock on the door" or "be encountered on the street" at any moment.

I believe that drawing on two distinct areas – support for executive authority and support for gun control regulations – has the potential to offer important insights into the divergent behavioral outcomes caused by these two mechanisms. First, we can conceptually define support for executive authority as endorsing the idea that the leader in power should operate without any institutional constraints, while support for gun control regulations can be seen as supporting greater monitoring and stricter restrictions on gun ownership. So, when crime is attributed to a particular group, do these two dimensions interact together, or do they operate in opposing ways? If people view crime as a general security problem, I expect this will result in support for both increased executive authority and gun regulation policies. However, if crime is instead framed as an identity-driven attribution – immigrants are the cause – we may observe the opposite dynamic. In other words, we might see a greater drive toward individual gun ownership. Analyzing crime attribution will undoubtedly provide significant insights into changes in people's political attitudes, policy support, and their relationships with authority.

In this study, I hypothesize that the perception of outgroup-linked attribution generates a stronger demand for executive centralization than general diffuse crime concerns, as a means of circumventing democratic norms. I argue that the primary driver of this demand is the perception of an identity-linked crime responsibility, which consequently leads to a search for faster solutions without getting bogged down in institutional gridlocks. As regards to identity-linked attributional perception in support for gun regulation, I hypothesize that the distinction between general crime and outgroup-originated crime creates differences in the demand for regulation. I hypothesize that while people may be more supportive of regulation when crime is framed as a general public safety issue – which is viewed as a public safety concern – support for gun regulation decreases when outgroup-originated crime is involved, and people become more supportive of individual gun ownership.

In other words, the issue shifts from being a public safety concern to an attributional dynamic centered on the protection of identity and preparedness against the "other." In short;

H1: Compared to general crime concern, attributing crime to immigrants increases support for the president bypassing Congress and the courts.

H2: Attributing crime to immigrants reduces support for gun regulation.

H3: General crime concern increases support for gun regulation.

H4: Among Republicans, compared to Democrats, attributing crime to immigrants leads to greater opposition to gun regulation.

Research Design

The research question at the center of this study is: Compared to diffuse crime salience, how does immigration-focused crime attribution differently influence support for the expansion of executive power and gun control regulations? Here, I treat diffuse crime salience and immigration-focused crime attribution as two distinct dimensions of crime perception. The primary theoretical approach I rely on is Attribution Theory. According to this theory, drawing particularly from the field of social psychology, people attribute causality when interpreting or perceiving behaviors or events, and their resulting reactions are shaped by this attribution (Kelley & Michela, 1980; Manusov & Spitzberg, 2008). In this specific study, Attribution Theory provides significant insight because I am attempting to demonstrate how people's political attitudes change when they attribute the phenomenon of crime to a specific group (immigrants). In contrast, diffuse crime salience is conceptualized as a general state of national insecurity. Because it affects virtually everyone in society, it gives rise to a general sense of fear and an inability to fulfill the necessities of daily life (Cullen et al., 1985). Classifying crime perception in this way (immigrant-specific vs. diffuse) offers a fundamental insight from the perspective of this study's theoretical approach; while crime is indeed considered significant in terms of these two constructs, when people attribute crime to a specific group, they not only seek greater authority but also, paradoxically, shift into a survival mode on an individual level – which has policy-related implications – because what is at stake is not only general security but also identity.

Data and Measurement

In this study, I am using data from the American National Elections Studies (ANES) 2024. The dataset is collected in a two-stage process: pre-election (5,521 individuals) between August 3, 2024, and November 5, 2024, and post-election (4,964 individuals from the pre-election sample) between November 7, 2024, and February 17, 2025. Executive bypass support and party alignment are measured in the pre-election phase, while immigrant crime attribution, crime salience, and gun regulation support are measured in the post-election phase. Therefore, since these predictors were not measured within the same wave, rather than directly addressing the dynamic proposed by the study from a causal perspective – where higher immigrant crime attribution is associated with higher executive bypass support and lower gun regulation support – it is more accurate to view this relationship as a meaningful correlation. Those who hold immigrants responsible for rising crime are associated with higher levels of executive bypass support and lower levels of gun regulation support. The IVs I focused on in the study (immigration-origin crime belief and general crime salience) are measured using the following two indicators from ANES:

Immigration-specific crime attribution mesaurement

> *"(Do you [agree strongly, agree somewhat, neither agree nor disagree, disagree somewhat, or disagree strongly /disagree strongly, disagree somewhat, neither agree nor disagree, agree somewhat, or agree strongly] with the following statement?)*
>
> *'Immigrants increase crime rates in the United States.'"*
>
> *The value labels (5-point Likert scale) are as follows: 1. Agree strongly 2. Agree somewhat 3. Neither agree nor disagree 4. Disagree somewhat 5. Disagree strongly.*

Crime Salience

> *"How important is the following issue in the country today? [Extremely important, very important, moderately important, slightly important or not at all important / Not at all important, slightly important, moderately important, very important or extremely important]?*
>
> *Crime"*
>
> *The value labels (5-point importance scale) are as follows: 1. Extremely important 2. Very important 3. Moderately important 4. Slightly important 5. Not at all important.*

The issue of whether the question regarding the attribution of crime to immigrants primes the respondents may arise. However, what I am trying to measure here is whether people currently hold immigrants responsible for rising crime; in other words, they hold a belief in this direction, and this belief may not necessarily be based on objective crime rates data. Although the current wording of the question could be considered leading, the measurement logic is primarily based on the extent to which people believe this statement. Attributional conviction rather than neutral assessment of crime is what this study pays attention to.

The DVs I focus on in this study (support for executive power centralization and support for gun regulation) are measured using the following indicators from ANES:

Executive Power Centralization Support

> *"HELPFUL/HARMFUL IF PRES DIDN'T HAVE TO WORRY ABOUT CONGRESS/COURTS"*
>
> *The value labels (7-point scale) are as follows: 1. Extremely helpful 2. Moderately helpful 3. A little helpful 4. Neither helpful nor harmful 5. A little harmful 6. Moderately harmful 7. Extremely harmful*

Gun Regulation Support

> *"Do you think the federal government should make it more difficult for people to buy a gun than it is now, make it easier for people to buy a gun, or keep these rules about the same as they are now?"*
>
> *The value labels (3-category scale) are as follows: 1. More difficult 2. Easier 3. Keep these rules about the same*
>
> Finally, to capture the partisanship effect, I use the party identification indicator from ANES.
>
> *"Generally speaking, do you usually think of yourself as [a Democrat, a Republican / a Republican, a Democrat], an independent, or what?"*
>
> *The value labels (3-category scale) are as follows: 1. Democrat 2. Republican 3. Independent*

I will perform two basic models. The first model will be derived from a 7-point ordinal scale and rescaled to a 0–1 scale. Therefore, as the scale increases from 0 to 1, it indicates greater executive support; in its original form, higher values actually correspond to lower support. Since the scaling is continuous, OLS (Ordinary Least Squares) will be used in the model. In the measurement of gun regulation support, support for further restricting gun ownership is coded as 1, while support for maintaining current regulations or relaxing them is coded as 0. Therefore, this will be modeled using logistic regression.

The study also includes certain control variables. These are gun ownership, ideological inclinations, race/ethnicity, gender, trust in government, and presidential approval. Although the initial models include partisanship to test H4, I will also incorporate these controls to further strengthen the reliability of my findings. By controlling for these variables, I will be able to demonstrate that people's attitudes toward executive authority and policy regulations are indeed driven by the belief that immigrants increase crime.

Empirical Findings

The theoretical expectations tested in this study are strongly supported. Most importantly, by demonstrating how "outgroup-focused issue attribution" generates divergent responses in the context of institutional and policy support, this study makes a meaningful contribution to the literature on political behavior. Figure 1 shows that immigrant crime attribution has a significant effect on support for executive bypass. In other words, those who believe that the increase in crime is driven by immigrants also support executive centralization. This is because attributing crime to a specific group generates a greater demand for executive power centralization than simply making crime salient. However, while the effect of general crime salience is positive, it is not statistically significant. Consequently, when the insecurity is attributed to a domestic subject sharing the same social space, the issue becomes a more urgent and significant matter for people, leading them to demand greater centralization. The predictors of Republican affiliation, government trust, and presidential approval, however, are significantly inversely correlated with support for executive bypass.

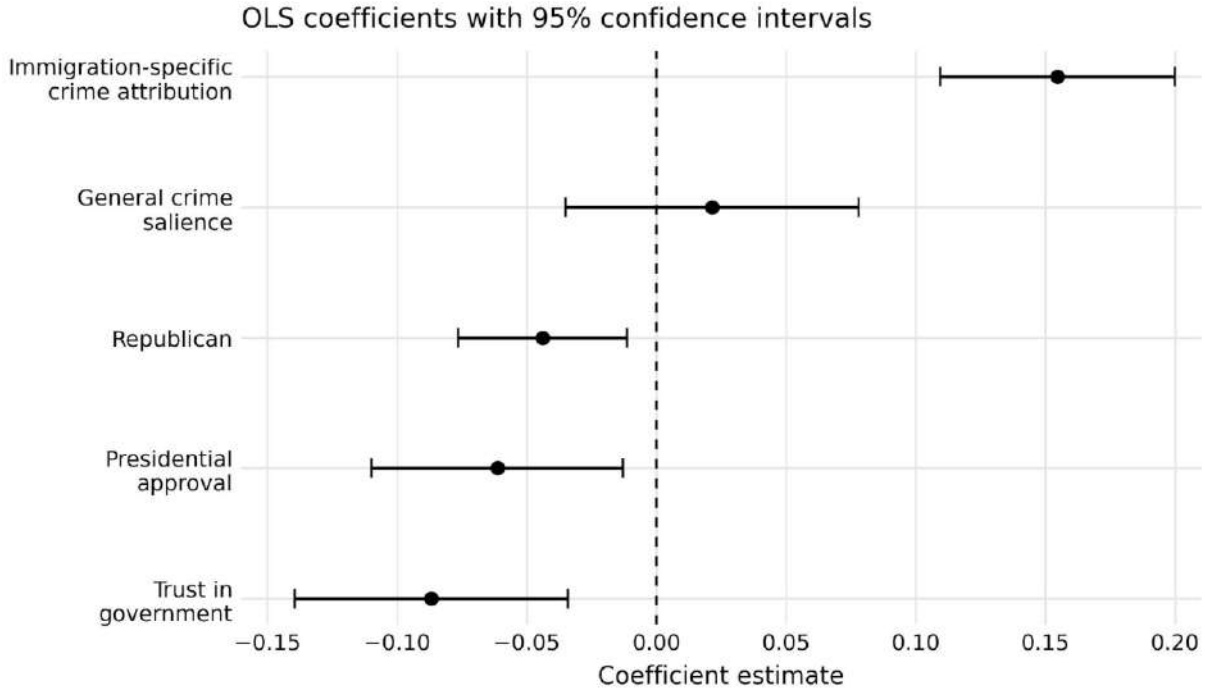


Figure 1. Predictors of Executive Power Centralization Support

Figure 2 shows the odds ratios for predictors of support for gun regulation. Attributing crime to immigrants significantly reduces support for gun regulation. In other words, among people who believe that crime is largely attributed to immigrants, support for imposing more restrictions on gun ownership decreases significantly. Crime salience, however, does not produce a similarly significant effect on support for gun regulation. While support for gun regulation is lower among Republicans, it is notably high among women. Similarly, trust in government and presidential approval are positively correlated with support for gun regulation.

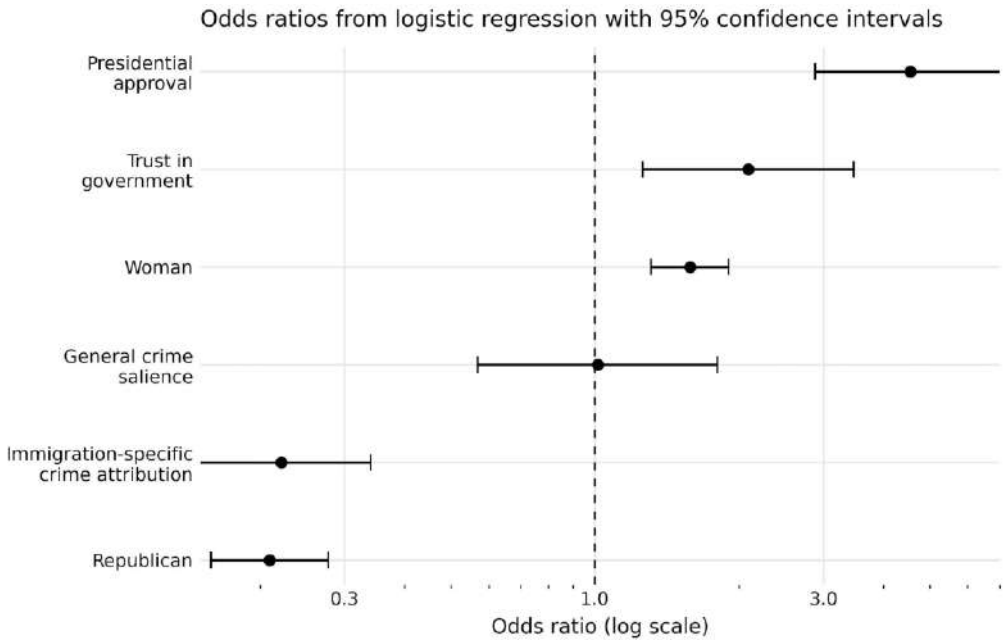


Figure 2. Predictors of Gun Regulation Support

Figure 3 illustrates the divergent political behavior outcomes resulting from the attribution of crime to immigrants. The left panel shows that executive support increases under conditions where crime is attributed to immigrants; the predicted outcome rises above 0.45. The right panel, however, shows that predicted probability of support for gun regulation decreases as immigration crime attribution increases. This figure reveals that crime is not actually evaluated within a general public security context; otherwise, people would exhibit the same directional political behavior across both dimensions. However, concerns about identity targeting not only call for greater authority but also demonstrate that self-protection (in other words, individual gun ownership) holds such utmost importance that it cannot be entirely entrusted to another authority.

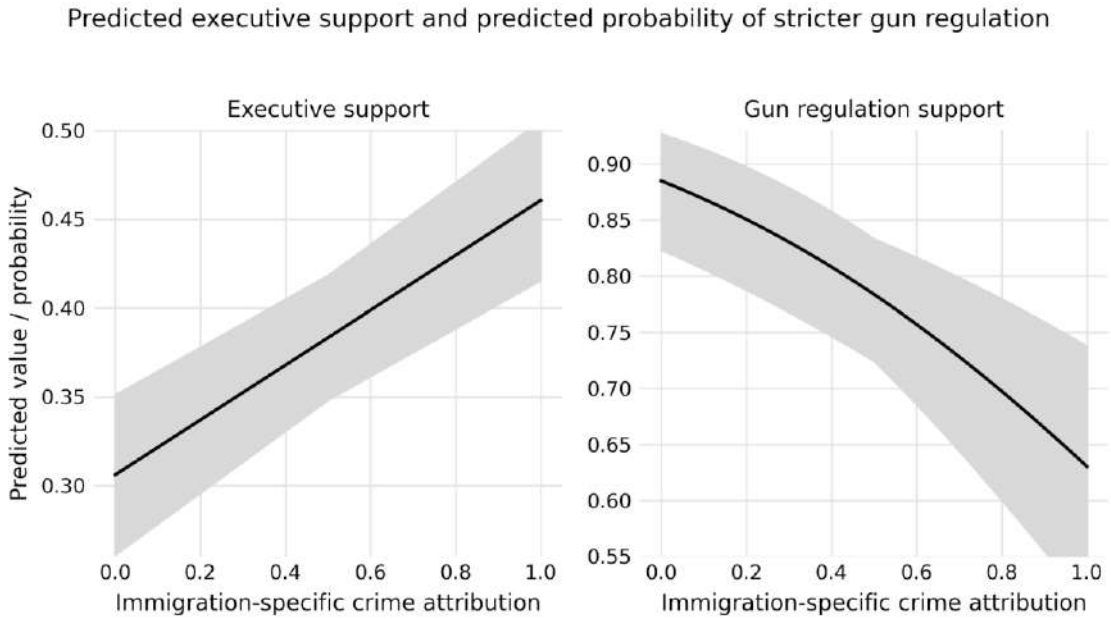


Figure 3. Divergent Effects of Immigration-Specific Crime Attribution

Figure 4 shows how support for gun regulation varies by party affiliation among people who believe that immigrants increase crime. Democrats have higher support for gun regulation compared to Republicans. Party

identification does not actually produce an inverse effect on support for gun regulation; when crime is attributed to immigrants, support for gun regulation decreases in both groups, and a demand for fewer barriers to gun ownership emerges. Therefore, the expectation that support for regulation would decrease more among Republicans, as hypothesized in this study (H4), is not meaningfully supported by this observational finding.

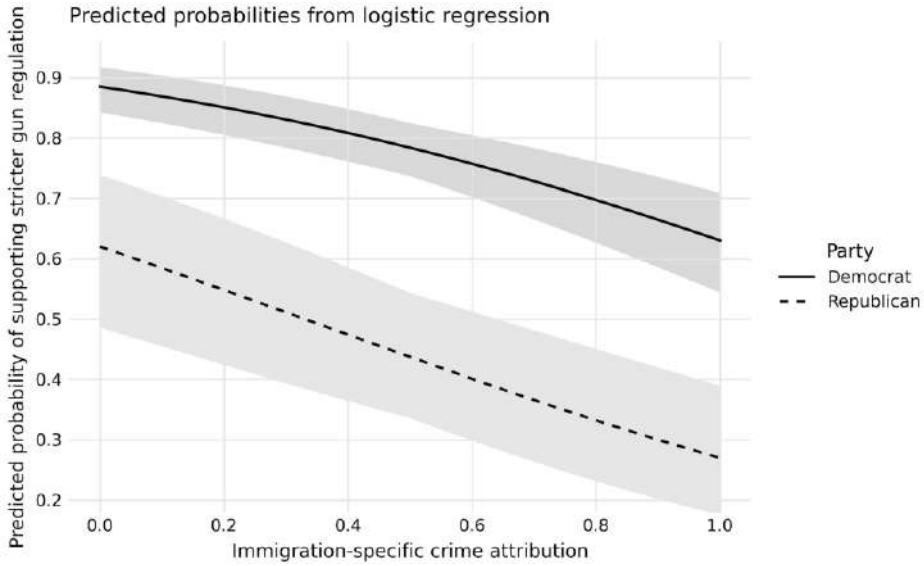


Figure 4. Immigration Crime Attribution and Gun Regulation Support by Party

In the first model presented in Table 1, the results show that the effects of diffuse crime and immigrant crime attribution on executive support are positive. However, this effect is not statistically significant for diffuse crime. In contrast, immigrant crime attribution retains a significant effect even when controls are added to the model. The conclusion drawn from this is that when people view crime as a general problem in the country, they provide the president with support to bypass Congress and the courts; however, this finding is not strong or meaningful. However, among those who believe the outgroup plays a major role in crime, executive bypass support increases significantly, a finding that supports H1. Another finding in the table is that executive bypass support is particularly high among Black non-Hispanic and Asian/Native Hawaiian-Pacific Islander categories compared to the reference White non-Hispanic category. As expected, as trust in the government increases, executive bypass decreases. Another interesting finding is that presidential approval (during the Biden administration) is significantly inversely correlated with executive bypass support. When controlling for interactions in the second model, the table shows that immigration crime attribution remains a significant and meaningful finding; however, contrary to expectations among Republicans, while it remains positive, it is not statistically significant. In the second model as well, crime salience does not have a statistically significant effect on executive bypass support. Both models demonstrate that the attribution of crime to immigrants strongly determines executive bypass support, but party identification does not make a significant difference.

Table 1. Immigration-Specific Crime Attribution, Executive Power Support, and Gun Regulation Support

	Executive Support OLS	Executive Support OLS + Interactions	Gun Regulation Logit	Gun Regulation Logit + Interactions
Immigration-specific crime attribution	0.155***	0.175***	-1.507***	-1.585***
	(0.023)	(0.030)	(0.219)	(0.327)
General crime salience	0.022	0.064+	0.013	-0.410
	(0.029)	(0.036)	(0.294)	(0.436)
Republican	-0.044**	0.100+	-1.565***	-2.377***
	(0.017)	(0.053)	(0.144)	(0.503)
Immigration attribution × Republican		-0.056		0.187
		(0.045)		(0.431)
Crime salience × Republican		-0.129*		0.836
		(0.060)		(0.594)
Trust in government	-0.087**	-0.087**	0.737**	0.738**
	(0.027)	(0.027)	(0.258)	(0.258)
Presidential approval	-0.061*	-0.065**	1.516***	1.531***
	(0.025)	(0.025)	(0.233)	(0.233)
Woman	0.001	0.001	0.457***	0.459***
	(0.010)	(0.010)	(0.095)	(0.095)
Nonbinary	0.105+	0.106+	0.749	0.741
	(0.059)	(0.059)	(0.687)	(0.695)
Other gender	-0.043	-0.036	-1.889	-1.884
	(0.119)	(0.119)	(1.318)	(1.312)
Black	0.111***	0.103***	-0.147	-0.097
	(0.017)	(0.018)	(0.182)	(0.185)
Hispanic	0.069***	0.067***	-0.074	-0.059
	(0.016)	(0.016)	(0.165)	(0.164)
Asian/NHPI	0.082**	0.078**	-0.013	0.008
	(0.027)	(0.027)	(0.259)	(0.260)
Native American/Other race	0.093	0.091	-2.034**	-2.010**
	(0.071)	(0.071)	(0.768)	(0.764)
Multiple races	-0.009	-0.011	-0.822**	-0.809**
	(0.028)	(0.028)	(0.265)	(0.266)
Num. Obs.	3095	3095	3109	3109
R^2	0.056	0.059		
Adj. R^2	0.052	0.054		
AIC	555.1	550.6	2909.7	2910.8
BIC	645.6	653.2	2994.3	3007.5

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

+ p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

OLS coefficients are reported for executive support. Logit coefficients are reported for gun regulation support. Standard errors in parentheses.

Support for gun regulation, however, drops significantly when the attribution of crime to immigrants is taken into account. Crime salience, however, does not produce a significant effect in this model either. Consequently, among people who believe that immigrants increase crime in the country, support for gun regulation drops significantly, as this situation is perceived not merely as a general public safety issue but as an identity-based attribution, leading to demands for more flexible gun laws. Thus, the findings support H2. However, H3 – the expectation that crime salience would lead to positive support for gun regulation among people – is not statistically supported. The odds ratio corresponding to the -1.507 coefficient is 0.22; this means that as the belief that immigration causes crime increases from 0 to 1, support for gun regulation drops by nearly 78 percent. In this model, support for gun regulation is significantly lower among Republicans; however, no significant difference is observed between Democrats and Republicans who attribute crime to immigrants. Therefore, H4 – the expectation that the negative relationship between immigrant crime attribution and support for gun regulation would be more significantly differentiated among Republicans compared to Democrats – is not empirically supported.

Limitations and Contributions

The study has a number of limitations. First, because the measurement predictors were collected at different time points, the theorized relationship should be interpreted as associational rather than causal. Also, although the study examines immigrant crime attribution, this predictor alone does not fully capture the insecurity perceived as originating from an outgroup. While some people believe that immigrants increase crime, is this belief based on their local experiences or on cues driven by elites? I am unable to measure this in this study. Another limitation is the absence of data on ideological stance and gun ownership. Due to the data unavailability, I cannot demonstrate the effects of these important predictors on the study's outcome variables. Future research addressing these limitations will yield more robust findings regarding the impact of crime attribution on political behavior.

In this study, I aim to determine the extent to which identity-specific attributional perception influences political preferences. I believe that outgroup-originated crime attribution alone is insufficient for understanding crime perception; rather, evaluating it in conjunction with the general perception of crime salience in the country will provide important insights into policy support dynamics. I argue that it is not so much the extent to which crime is perceived as a significant problem, but rather whether it is attributed to other groups that shapes political reactions. Therefore, I aim to assess the strength of the second dynamic in conjunction with the first. This study also makes a contribution to the literature on democratic backsliding through the lens of executive power expansion support, while simultaneously demonstrating that the same dynamic (outgroup crime attribution) generates an anti-regulatory reaction specifically regarding gun control regulation, thereby contributing to the public policy literature as well.

Conclusion

This study examines perception of outgroup crime attribution and focuses on how it influences people's political behavior and attitudes. As a significant individual source of insecurity in a social context, crime can trigger a search for authority among people. With the prevalence of crime, people may demand greater executive authority to resolve issues more quickly. In this study, I examine this dynamic by focusing on an immigrant-focused dimension of crime. Empirical findings indicate that people who believe immigrants play a significant role in rising crime levels are more in favor of centralizing executive power, while simultaneously showing less support for restricting individual gun ownership. Consequently, when the issue of crime is perceived as a general and salient problem without a specific subject, people view it as a general public safety issue and express support for greater regulation regarding gun ownership; however, when a subject is attributed to the problem – and that subject is an outgroup or "other" – identity concerns come into play, leading to demands for greater flexibility regarding individual gun ownership. The issue of public safety is becoming a matter of individual self-protection. Future research could better establish causal relationships using data obtained through methods such as survey experiments. Furthermore, when an increase in the attribution of crime to immigration is observed, questions regarding how people position themselves on immigration-related policy areas – such as deportation, the process by which immigrants obtain citizenship, and border security – could provide important insights. Finally, due to missing data, it is not possible to measure the isolated effects of gun ownership and ideological tendencies on the variables of interest. By including these measurements, the independent effect of crime attribution could be demonstrated more meaningfully.

Acknowledgement

The author gratefully acknowledges the support provided by the Ministry of National Education of the Republic of Türkiye during the preparation of this study.

References

Barney, D. J., & Schaffner, B. F. (2019). Reexamining the effect of mass shootings on public support for gun control. *British Journal of Political Science*, *49*(4), 1555-1565.

Bartels, L. M. (2020). Ethnic antagonism erodes Republicans' commitment to democracy. *Proceedings of the National Academy of Sciences*, *117*(37), 22752-22759.

Brader, T., Valentino, N. A., & Suhay, E. (2008). What triggers public opposition to immigration? Anxiety, group cues, and immigration threat. *American Journal of Political Science*, *52*(4), 959-978.

Cullen, F. T., Clark, G. A., Cullen, J. B., & Mathers, R. A. (1985). Attribution, salience, and attitudes toward criminal sanctioning. *Criminal Justice and Behavior*, *12*(3), 305-331.

Davis, D. W., & Silver, B. D. (2004). Civil liberties vs. security: Public opinion in the context of the terrorist attacks on America. *American Journal of Political Science*, *48*(1), 28-46.

Graham, S. (1991). A review of attribution theory in achievement contexts. *Educational Psychology Review*, *3*(1), 5-39.

Haider-Markel, D. P., & Joslyn, M. R. (2001). Gun policy, opinion, tragedy, and blame attribution: The conditional influence of issue frames. *Journal of Politics*, *63*(2), 520-543.

Hetherington, M., & Suhay, E. (2011). Authoritarianism, threat, and Americans' support for the war on terror. *American Journal of Political Science*, *55*(3), 546-560.

Huddy, L., Feldman, S., Taber, C., & Lahav, G. (2005). Threat, anxiety, and support of antiterrorism policies. *American Journal of Political Science*, *49*(3), 593-608.

Huddy, L., Feldman, S., & Weber, C. (2007). The political consequences of perceived threat and felt insecurity. *The ANNALS of the American Academy of Political and Social Science*, *614*(1), 131-153.

Joslyn, M. R., & Haider-Markel, D. P. (2013). The politics of causes: Mass shootings and the cases of the Virginia Tech and Tucson tragedies. *Social Science Quarterly*, *94*(2), 410-423.

Joslyn, M. R., & Haider-Markel, D. P. (2017). Gun ownership and self-serving attributions for mass shooting tragedies. *Social Science Quarterly*, *98*(2), 429-442.

Kelley, H. H., & Michela, J. L. (1980). Attribution theory and research. *Annual review of psychology*, *31*(1), 457-501.

Kleck, G., Gertz, M., & Bratton, J. (2009). Why do people support gun control?: Alternative explanations of support for handgun bans. *Journal of Criminal Justice*, *37*(5), 496-504.

Manusov, V., & Spitzberg, B. (2008). Attribution theory. *Engaging theories in interpersonal communication: Multiple perspectives*, 37-49.

Marshall, W. P. (2008). Eleven reasons why presidential power inevitably expands and why it matters. *BUL Rev.*, *88*, 505.

McKee, E. (2017). The Effects of Terrorism on Public Opinion of Gun Control in the United States.

Newman, B. J., & Hartman, T. K. (2019). Mass shootings and public support for gun control. *British Journal of Political Science*, *49*(4), 1527-1553.

Norris, P., & Inglehart, R. (2019). *Cultural backlash: Trump, Brexit, and authoritarian populism*. cambridge university press.

Oraka, E., Thummalapally, S., Anderson, L., Burgess, T., Seibert, F., & Strasser, S. (2019). A cross-sectional examination of US gun ownership and support for gun control measures: sociodemographic, geographic, and political associations explored. *Preventive medicine*, *123*, 179-184.

Ousey, G. C., & Unnever, J. D. (2012). Racial–ethnic threat, out-group intolerance, and support for punishing criminals: A cross-national study. *Criminology*, *50*(3), 565-603.

Ryan, J. B., Andrews, T. M., Goodwin, T., & Krupnikov, Y. (2022). When trust matters: The case of gun control. *Political Behavior*, *44*(2), 725-748.

Schlipphak, B. (2024). Threat perceptions, blame attribution, and political trust. *Journal of Elections, Public Opinion and Parties*, *34*(1), 59-78.

Stenner, K. (2005). *The authoritarian dynamic* (Vol. 10).

Verrecchia, P., Bush, M. D., & Hendrix, N. (2021). Is there a relationship between fear of crime and attitudes toward gun control? *Crime prevention and community safety*, *23*(3), 264-277.

Wlezien, C. (2001). On the salience of political issues. annual meeting of the Midwest Political Science Association, Chicago,

Ziller, C., & Helbling, M. (2021). Public support for state surveillance. *European Journal of Political Research*, *60*(4), 994-1006.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

COMPARATIVE ANALYSIS OF *CHLORELLA VULGARIS* CULTIVATION AT THE LABORATORY SCALE USING MUNICIPAL WASTEWATER FROM TWO ADVANCED BIOLOGICAL WASTEWATER TREATMENT PLANTS

Elif Bostanoğlu
Didem Balkanlı
Benan İnan
Sinan Kutluay
0009-0007-5232-8795, Istanbul Technical University,Department of Chemical Engineering, Istanbul, Türkiye.
0000-0003-2483-7617, Yildiz Technical University, Department of Bioengineering, Istanbul, Türkiye.
0000-0002-2315-3099, Yildiz Technical University, Department of Bioengineering, Istanbul, Türkiye.
0000-0002-4987-6789, Istanbul Technical University, Department of Chemical Engineering, Istanbul, Türkiye.

Abstract

A sustainable method that integrates wastewater treatment and biomass production is microalgal cultivation utilizing municipal wastewater (MWW). Microalgal growth and pollutant removal efficiency, however, may be impacted by differences in wastewater parameters. The laboratory-scale cultivation of *Chlorella vulgaris* utilizing MWW obtained from two advanced biological wastewater treatment plants (ABWWTP-1 and ABWWTP-2) was compared in this work. To ascertain the impact of wastewater concentration on microalgal growth, cultivation experiments were carried out at MWW ratios of 25%, 50%, 75%, and 100% (v/v) in conjunction with a BG-11 control. Throughout the cultivation process, specific growth rate, biomass productivity, and the removal efficiencies of chemical oxygen demand (COD), biochemical oxygen demand (BOD), total nitrogen (TN), and total phosphorus (TP) were assessed in addition to optical density at 680 nm (OD_{680}). A 100% (v/v) MWW ratio produced the best cultivation performance for both wastewater sources, suggesting that dilution was not required in the studied circumstances. With a specific growth rate of 0.104 d^{-1} and biomass productivity of 28 mg/(L·d), the maximal OD_{680} for ABWWTP-1 MWW was 0.90 after 27 days. The comparable removal efficiencies for COD, BOD, TN, and TP were 90%, 99%, 97%, and 96%, respectively. After 21 days of cultivation, ABWWTP-2 MWW produced biomass productivity of 36.7 mg/(L·d), a maximum OD_{680} of 0.47, and a specific growth rate of 0.114 d^{-1}. 78%, 98%, 95%, and 97% were the corresponding removal efficiencies. ABWWTP-2 MWW produced higher biomass productivity and a higher specific growth rate, while ABWWTP-1 MWW supported higher maximum optical density and more COD and TN removal. These results show that varied wastewater parameters affect microalgal growth and treatment effectiveness. The findings demonstrate *C. vulgaris*'s capability for producing biomass and treating wastewater simultaneously, highlighting the significance of choosing growth conditions based on wastewater properties and treatment goals.

Keywords: *Chlorella vulgaris* cultivation, Municipal wastewater, Biomass productivity, Nutrient removal, Wastewater treatment.

Introduction

Urbanization, industrialization, and population growth strain clean water supplies and raise the amount of wastewater generated. Microorganisms, suspended particles, nitrogen and phosphorus compounds, organic matter, and other contaminants are all found in municipal wastewater (MWW). If this effluent is released into bodies of water without proper treatment, it can lead to major environmental problems such as eutrophication, reduced dissolved oxygen levels, and the degradation of aquatic ecosystems. As a result, wastewater is increasingly recognized as a significant resource from which water, nutrients, energy, and other valuable

products can be recovered (Abdelfattah et al., 2023; Chai et al., 2021; Jones, van Vliet, Qadir, & Bierkens, 2021).

Conventional wastewater treatment methods are effective in removing organic matter and nutrients, but they have a number of drawbacks, such as high energy requirements for aeration, excessive sludge generation, the use of chemicals, and high operational costs. This has highlighted the need to consider wastewater treatment plants as resource recovery facilities, where materials, energy, and water are recovered, rather than just as pollutant removal systems. One of the biological approaches that can help facilitate this shift is microalgae-based wastewater treatment. Through photosynthesis, microalgae release oxygen into the surrounding environment, use the nitrogen and phosphorus found in wastewater for cellular growth, and aid in the removal of a variety of organic and inorganic pollutants. Biofuels, chemicals, agricultural products, animal feed, adsorbents, and catalytic materials are just a few of the applications for the microalgal biomass generated during this process. Another important benefit of using wastewater as a cultivation medium is that it reduces the need for artificial nutrient media and freshwater (Abdelfattah et al., 2023; Abuhasheesh et al., 2025; Akdag, Guven, Ersahin, & Ozgun, 2026; Mohsenpour, Hennige, Willoughby, Adeloye, & Gutierrez, 2021).

Much of the research on the use of microalgae for wastewater treatment has been conducted under laboratory conditions. It is easier to control variables such as light exposure, temperature, pH, mixing, and nutrient availability in a lab setting. In small culture volumes, culture development can also be monitored more closely.

The compatibility between the microalgal species and the wastewater source is as important for microalgal growth as the wastewater concentration. In municipal wastewater from various sources, the same microalgal species may exhibit different growth patterns. This is mainly due to variations in the organic matter, nitrogen, phosphorus, suspended particles, trace elements, salinity, and possible inhibitory components in wastewater. As a result, results from a single species or effluent source may not necessarily be directly applicable to other systems (Abdelfattah et al., 2023; Akdag et al., 2026; Mohsenpour et al., 2021).

Microalgal cultivation using wastewater offers a sustainable approach that combines biomass production with wastewater treatment. However, the characteristics of raw municipal wastewater (MWW) can vary considerably depending on influent composition, hydraulic load, and treatment plant operational conditions. These variations can directly affect the growth kinetics and pollutant removal performance of microalgal cultivation systems (Koçer, Inan, Özçimen, & Gökalp, 2023; Reyimu & Özçimen, 2017). In this study, the laboratory-scale cultivation performance of *C. vulgaris* was comparatively evaluated using municipal wastewater (MWW) obtained from two different advanced biological wastewater treatment plants, hereafter referred to as ABWWTP-1 MWW and ABWWTP-2 MWW. The objectives of the study were to determine the optimal MWW ratios and cultivation periods, evaluate the growth behavior and specific growth rate of *C. vulgaris*, assess biomass productivity, and determine the wastewater treatment performance of the cultivation process.

Materials and Methods

Raw municipal wastewater (MWW) samples were collected from the outlets of the grit chambers at two advanced biological wastewater treatment plants (ABWWTPs) for microalgal cultivation. The wastewater samples were autoclaved at 121 °C for 30 min to eliminate bacterial contamination. Laboratory-scale experiments were conducted in 100 mL erlenmeyer flasks with a working volume of 20 mL. Each culture medium consisted of 10% (v/v) microalgal inoculum, corresponding to 2 mL, while the remaining 18 mL consisted of MWW and distilled water at the selected dilution ratios. The experiments were conducted at a controlled ambient temperature of 25 °C under continuous orbital shaking at 180 rpm and LED illumination of 500–600 lx. Cultivation was performed at different MWW ratios of 100%, 75%, 50%, and 25%, along with a control group containing BG-11 medium (Reyimu & Özçimen, 2017; Tarhan, Koçer, Özçimen, & Gökalp, 2021). Optical density at 680 nm (OD_{680}) was measured daily using a UV–Vis spectrophotometer. Before and after cultivation, physicochemical parameters, including chemical oxygen demand (COD), biochemical

oxygen demand (BOD), total nitrogen (TN), total phosphorus (TP), pH, and temperature, were measured. The laboratory-scale microalgal cultivation setup and microscopic images of *C. vulgaris* are shown in Figure 1.

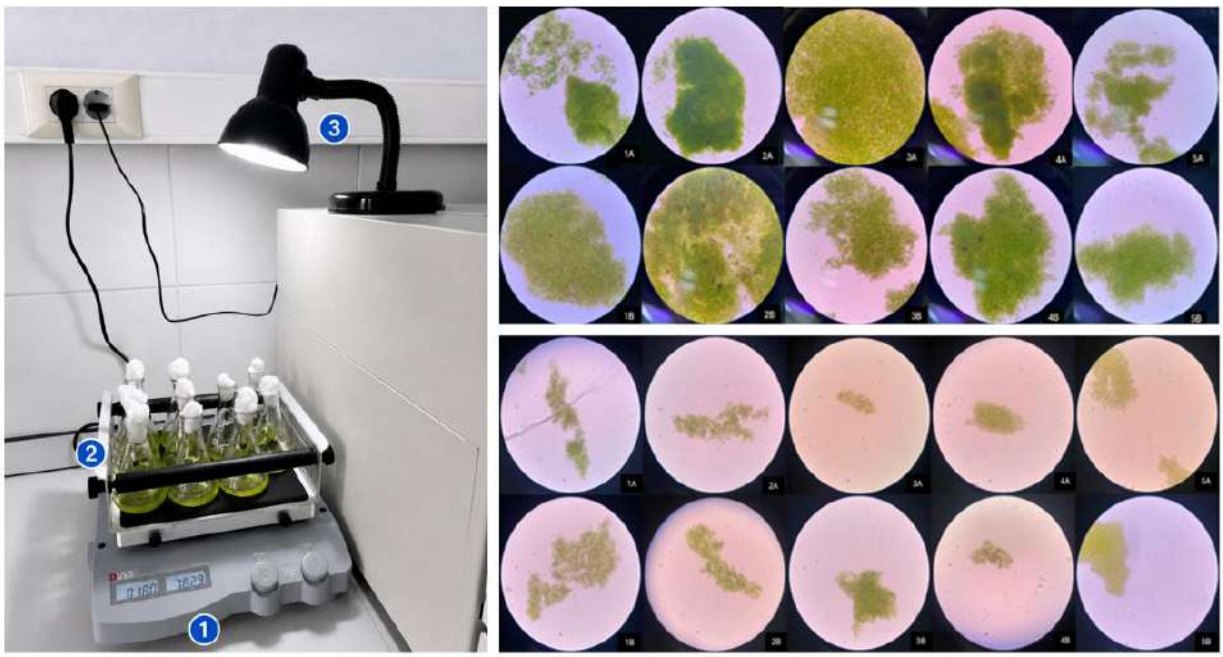


Figure 1. Laboratory-scale microalgal cultivation setup and microscopic images of *C. vulgaris*.

Findings and Discussion

Different MWW ratios were evaluated for the cultivation of *C. vulgaris*, along with a control group. The cultivation performance was assessed based on the OD_{680} values obtained throughout the cultivation period, specific growth rate, and dry microalgal biomass productivity. Figure 2 presents the growth curves of *C. vulgaris* based on OD_{680} measurements using ABWWTP-1 MWW and ABWWTP-2 MWW at different MWW ratios. Figure 3 presents the corresponding specific growth rate and dry microalgal biomass productivity obtained from these cultivation experiments. The best cultivation performance for ABWWTP-1 MWW was observed at a 100% (v/v) MWW ratio based on the combined evaluation of Figures 2 and 3. Under these conditions, the biomass productivity was 28 mg/(L·d), the specific growth rate was 0.104 d-1, the cultivation period was 27 days, and the maximum OD_{680} value reached 0.90. For ABWWTP-2 MWW, the best cultivation performance was observed at a 100% (v/v) MWW ratio. At the end of the 21-day cultivation period, the maximum OD_{680} value was 0.47. Under these conditions, the biomass productivity was 36.7 mg/(L·d), and the specific growth rate was 0.114 d^{-1}.These results demonstrate that MWW from both ABWWTP-1 and ABWWTP-2 effectively supported the growth of *C. vulgaris*. The optimal MWW ratio was consistent across the two wastewater sources, with *C. vulgaris* exhibiting its highest cultivation performance at a 100% (v/v) MWW ratio in both cases. Table 1 summarizes the optimal cultivation parameters obtained for the two wastewater sources.

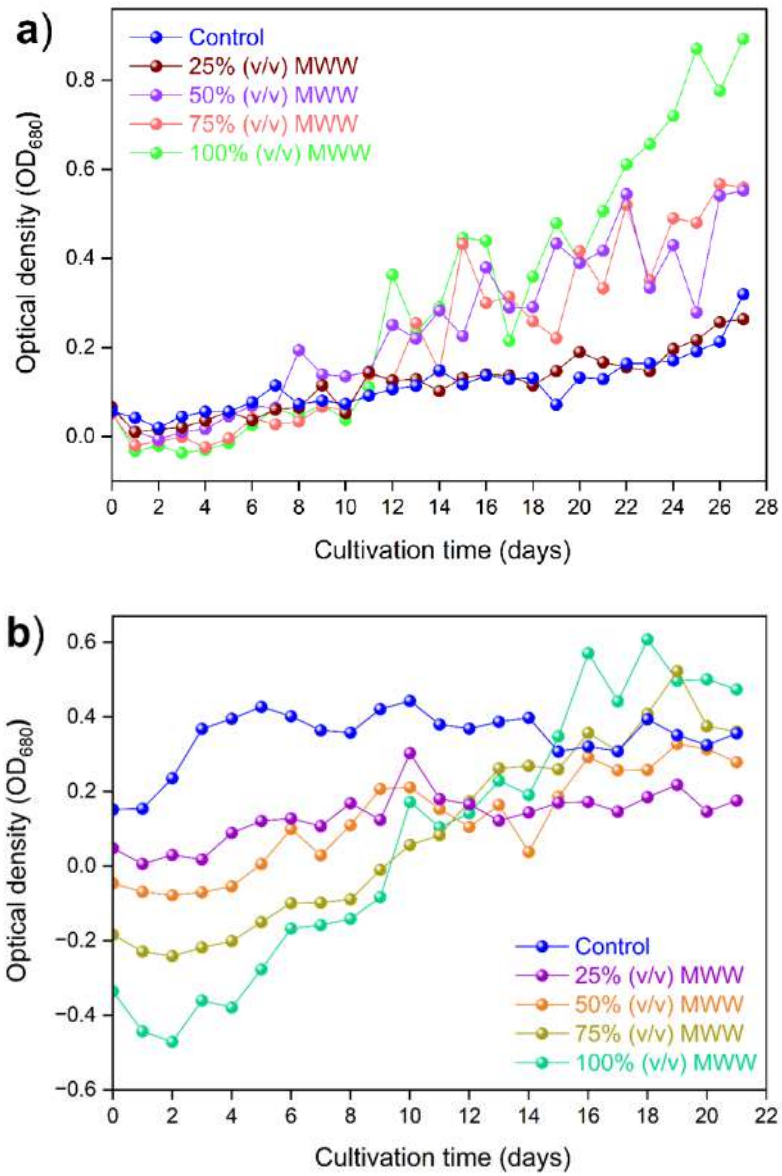


Figure 2. Growth curves of *C. vulgaris* based on OD_{680} measurements using ABWWTP-1 MWW (a) and ABWWTP-2 MWW (b) at different MWW ratios.

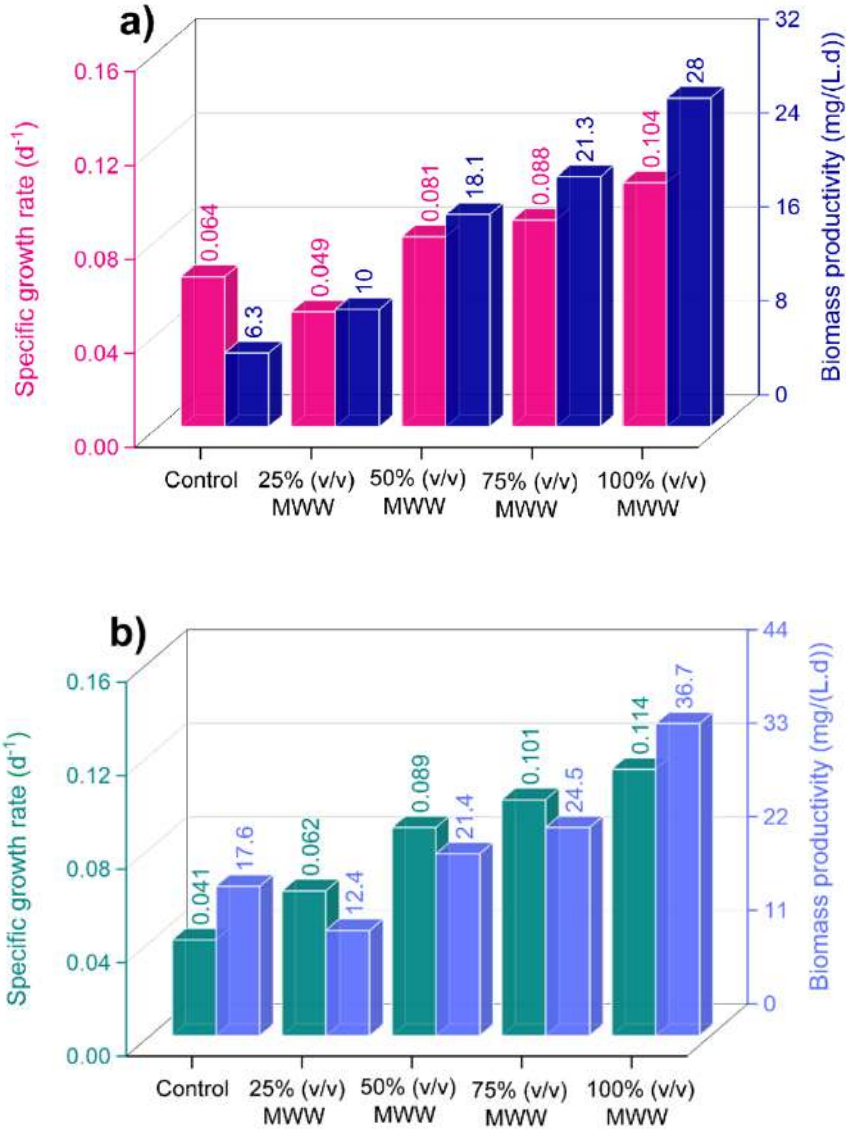


Figure 3. Microalgal biomass productivity and specific growth rate of *C. vulgaris* cultivated at different MWW ratios using ABWWTP-1 MWW (a) and ABWWTP-2 MWW (b).

Table 1. Comparison of the optimal cultivation conditions for *C. vulgaris* using ABWWTP-1 and ABWWTP-2 MWWs.

Parameters	**ABWWTP-1 MWW**	**ABWWTP-2 MWW**
MWW ratio	100% (v/v)	100% (v/v)
Maximum OD_{680}	0.90	0.47
Cultivation period	27 days	21 days
Specific growth rate	0.104 d^{-1}	0.114 d^{-1}
Microalgal biomass productivity	28 mg/(L.d)	36.7 mg/(L.d)

Table 2 displays the physicochemical characteristics and treatment efficiency values of treated water obtained following the cultivation of *C. vulgaris* utilizing ABWWTP-1 and ABWWTP-2 MWWs. Dilution to prevent inhibitory effects was not required for either ABWWTP-1 or ABWWTP-2 MWW. For COD, BOD, TN, and TP, treatment efficiencies of 90%, 99%, 97%, and 96% were thus obtained with ABWWTP-1 MWW; for COD, BOD, TN, and TP, treatment efficiencies of 78%, 98%, 95%, and 97% were obtained with ABWWTP-2 MWW. Biomass productivity and specific growth rate were higher in ABWWTP-2 MWW, despite *C. vulgaris* achieving higher maximum optical density and COD removal efficiency in ABWWTP-1 MWW. This implies that, despite having a higher beginning organic load, ABWWTP-2 MWW offered favorable circumstances for quicker biomass generation. BOD removal remained high in both wastewater sources, reaching 98% and 99% in ABWWTP-2 and ABWWTP-1 MWW, respectively, despite COD removal efficiency being lower in ABWWTP-2 MWW. While phosphorus removal was slightly higher in ABWWTP-2 MWW, nitrogen removal was also slightly higher in ABWWTP-1 MWW. These results show that *C. vulgaris* growth and nutrient removal were influenced differently by the wastewater source, underscoring the necessity to tailor wastewater-based microalgal cultivation to the specifics of each wastewater stream and the desired treatment goals.

Table 2. Changes in physicochemical parameters and treatment efficiency of the water after *C. vulgaris* cultivation in ABWWTP-1 and ABWWTP-2 MWWs.

ABWWTP-1 MWW results			
Parameters	**MWW**	**Treated water (100%MWW)**	**Treatment efficiency**
COD (mg/L)	377	38	90%
BOD (mg/L)	205	2.05	99%
TN (mg/L)	76.4	2.32	97%
TP (mg/L)	6.6	0.3	96%
pH	7.81	7.96	-
Temperature (°C)	16.0	19.3	-
ABWWTP-2 MWW results			
Parameters	**MWW**	**Treated water (100%MWW)**	**Treatment efficiency**

COD (mg/L)	732	162.6	78%
BOD (mg/L)	400	8	98%
TN (mg/L)	70.6	3.6	95%
TP (mg/L)	6.8	0.2	97%
pH	7.55	8.08	-
Temperature (°C)	18.1	21.8	-

Conclusion and Recommendations

This comparison investigation showed that depending on the wastewater source, *C. vulgaris* growth performance and MWW treatment effectiveness differed. Microalgal cultivation was effectively carried out using both ABWWTP-1 and ABWWTP-2 MWWs without the need for dilution to avoid inhibitory effects. Over a 27-day cultivation period, the specific growth rate and biomass productivity in ABWWTP-1 MWW were 0.104 d^{-1} and 28 mg/(L·d), respectively, with the highest OD_{680} reaching 0.90. The removal efficiencies for COD, BOD, TN, and TP were 90%, 99%, 97%, and 96%, respectively. By contrast, cultivation in ABWWTP-2 MWW produced a biomass productivity of 36.7 mg/(L·d) over 21 days, a specific growth rate of 0.114 d^{-1}, and a maximum OD_{680} of 0.47. The comparable removal efficiencies for COD, BOD, TN, and TP were 78%, 98%, 95%, and 97%, respectively. Overall, *C. vulgaris* culture was supported by both wastewater sources, which also significantly removed organic matter and nutrients. However, ABWWTP-2 MWW supported better specific growth rates and biomass production, while ABWWTP-1 MWW produced a higher maximum optical density and greater COD and TN removal efficiencies. These results underline the significance of adjusting cultivation conditions in accordance with the features of each wastewater source and the intended application, as well as the impact of wastewater properties on microalgal development and treatment performance.

Thanks and Information Note

The authors gratefully acknowledge the financial support provided by the Istanbul Technical University Research Foundation under ITU-BAP Project No. MYL-2025-47095. The authors also gratefully acknowledge the Istanbul Water and Sewerage Administration (ISKI) for providing the municipal wastewater samples and conducting the physicochemical analyses used in this study.

References

Abdelfattah, A., Ali, S. S., Ramadan, H., El-Aswar, E. I., Eltawab, R., Ho, S.-H., Schagerl, M. (2023). Microalgae-based wastewater treatment: Mechanisms, challenges, recent advances, and future prospects. Environmental science and ecotechnology, 13, 100205.

Abuhasheesh, Y., Ghazal, A., Tang, D. Y. Y., Banat, F., Hasan, S. W., & Show, P. L. (2025). Advances in Chlorella microalgae for sustainable wastewater treatment and bioproduction. Chemical Engineering Journal Advances, 22, 100715.

Akdag, Y., Guven, H., Ersahin, M. E., & Ozgun, H. (2026). Sustainable wastewater management using microalgae: A review of pilot and full-scale applications. Journal of Water Process Engineering, 81, 109324.

Chai, W. S., Tan, W. G., Munawaroh, H. S. H., Gupta, V. K., Ho, S.-H., & Show, P. L. (2021). Multifaceted roles of microalgae in the application of wastewater biotreatment: a review. Environmental Pollution, 269, 116236.

Jones, E. R., van Vliet, M. T. H., Qadir, M., & Bierkens, M. F. P. (2021). Country-level and gridded estimates of wastewater production, collection, treatment and reuse. Earth System Science Data, 13(2), 237-254.

Koçer, A. T., Inan, B., Özçimen, D., & Gökalp, İ. (2023). A study of microalgae cultivation in hydrothermal carbonization process water: Nutrient recycling, characterization and process design. Environmental Technology & Innovation, 30, 103048.

Mohsenpour, S. F., Hennige, S., Willoughby, N., Adeloye, A., & Gutierrez, T. (2021). Integrating micro-algae into wastewater treatment: A review. Science of The Total Environment, 752, 142168.

Reyimu, Z., & Özçimen, D. (2017). Batch cultivation of marine microalgae Nannochloropsis oculata and Tetraselmis suecica in treated municipal wastewater toward bioethanol production. Journal of Cleaner Production, 150, 40-46.

Tarhan, S. Z., Koçer, A. T., Özçimen, D., & Gökalp, İ. (2021). Cultivation of green microalgae by recovering aqueous nutrients in hydrothermal carbonization process water of biomass wastes. Journal of Water Process Engineering, 40, 101783.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

DETERMINATION AND EDUCATION OF AWARENESS REGARDING HEARING LOSS RISK FACTORS AND EARLY PREVENTION AMONG EXPECTANT MOTHERS

Havvanur TULUM
Ayşe Sanem ŞAHLI
0000-0001-7910-3325, Hacettepe University, Vocational School of Health Services, Audiometry Program, Ankara, Turkey.
0000-0001-5050-8994, Hacettepe University, Vocational School of Health Services, Hearing and Speech Education Unit, Ankara, Turkey.

Abstract

Since a significant proportion of hearing loss in infants is congenital and stems from pregnancy-related preventable factors, the awareness of pregnant women is of critical importance. Numerous prenatal risk factors, such as maternal infections, antibiotic use, and exposure to X-rays during pregnancy, are highly preventable through maternal awareness and protective measures. Accordingly, this study aimed to determine the baseline awareness levels of expectant mothers regarding the risk factors that may induce hearing loss during the prenatal period and beyond, and subsequently to evaluate the impact of a dedicated awareness training program on early prevention. The research was conducted within the scope of the TÜBİTAK 2209-A University Students Research Projects Support Program at Hacettepe University.

The study sample comprised a total of 40 expectant mothers allocated via random assignment into an intervention (experimental) group (n = 19) and a control group (n = 21). Initially, a "Sociodemographic Information Form" and the "Hearing Risk Factors and Early Prevention Awareness Scale for Expectant Mothers" were administered face-to-face as a pretest. In the Cronbach's alpha reliability analysis, a value of $\alpha \geq 0.70$ was adopted as the lower threshold for acceptable internal consistency. Pretest and posttest awareness scales were administered to both groups. While the control group received only the standard prenatal education curriculum, the intervention group received the "Early Prevention Training" via online meeting tools in addition to the standard curriculum.

Quantitative data analysis was performed using the SPSS software via independent and paired samples t-test techniques, with the statistical significance level set at $p < 0.05$. The baseline equivalence of the groups was verified via an independent samples t-test ($p = 0.771$). According to the paired samples t-test results, a statistically significant difference was observed between the pretest and posttest scores of the intervention group ($p = 0.001$), whereas no significant change was detected in the control group ($p = 0.418$). Furthermore, the posttest comparison between the groups revealed a statistically significant difference in favor of the intervention group ($p = 0.001$). In conclusion, it was demonstrated that hearing risk factors and early prevention training provided to pregnant women effectively increased their awareness levels, indicating that integrating such modules into standard prenatal education programs carries profound importance for preventive healthcare.

Keywords: pregnancy, pregnant women, early prevention, hearing, hearing loss, education.

Introduction

Congenital hearing loss occurs due to an impairment in the ear's ability to convert mechanical sound energy into electrical energy (Korver, 2017). While congenital hearing loss is seen in 0.1-0.2% of healthy newborns, this rate can rise to 4-5% in at-risk newborns (Chi et al, 2014). When the etiological distribution of congenital hearing loss is examined, it is noteworthy that approximately 50% is due to genetic causes, 25% to environmental causes, and 25% to unknown causes (Dobie & Hemes, 2004). Looking at the number of live births in our country, a steady decrease has been observed since 2014, and as of 2023, this number has fallen

below 1 million for the first time, reaching 958,408 (TÜİK, 2024). Despite the decrease in the number of live births, statistical data shows that there has been no decrease in the rate of babies born with hearing loss. In our country, approximately 1-3 out of every 1000 babies are born with hearing loss. A large proportion of hearing loss in infants and children is due to preventable causes, both congenital and pregnancy-related. In this context, the role of expectant mothers and mothers in preventing hearing loss is extremely important. The WHO (2016) reports that approximately 60% of hearing losses occur due to preventable causes. However, this rate can rise to 6% when temporary hearing losses are included due to childhood illnesses, ear infections, accidents, and certain medications (HSGM, 2024). Awareness training programs for expectant mothers aim to prevent and/or minimize the risks that can cause hearing loss, thus providing early preventive services. It is believed that this will lead to a positive decrease in the number of babies born with hearing loss.

Hearing loss can be caused by risk factors in the prenatal (before birth), perinatal (at birth), and postnatal (after birth) periods. It is assumed that the effects of these risks can be minimized through systematic and effective information sessions for pregnant women. The fact that these risks are preventable depending on the level of awareness and understanding of pregnant women, and the lack of comprehensive education for pregnant women regarding the hearing health of their babies, highlights the unique value of this research.

Pregnant women's awareness of risk factors for hearing loss plays a major role in the hearing health of their baby. When considering prenatal risk factors that can cause hearing loss, one example is the presence of maternal infection during pregnancy (Toxoplasmosis, rubella). Several factors can contribute to the development of premature birth, including a history of bacterial or viral meningitis caused by cytomegalovirus (cytomegalovirus , herpes , syphilis), mumps, herpes virus-related illnesses, physical head trauma resulting from accidents, falls, or similar situations, low birth weight in the baby, maternal diseases (hypothyroidism, hypertension, gestational diabetes, etc.), antibiotic use (aminoglycosides, isotretinoin, etc.), and exposure to X-ray radiation (Busa J., et al, 2007).

Some studies show that although individuals generally have a high level of knowledge about hearing problems, they lack knowledge about some important aspects related to the management and prevention of hearing loss (Di (Berardino et al, 2013). Studies aimed at protecting hearing health and raising public awareness about hearing loss have recently become widespread in our country through projects carried out in collaboration with the World Health Organization. In awareness campaigns conducted in our country regarding hearing health, it is seen that hearing loss and related speech delay are among the most common communication problems encountered in childhood, and therefore, it is necessary to organize training programs to increase the awareness of families on this issue (Tuz D. et al. 2020). Research shows that prenatal education programs significantly increase the knowledge levels of pregnant women (Turgut et al., 2017). However, these training programs mainly include general information about infant care such as the birthing process, parental roles, diapering, and breastfeeding. Enriching these trainings with content aimed at protecting against environmental risks that may cause hearing loss is crucial. Accordingly, the aim of our study is ***;*** Firstly, the aim is to assess the level of awareness and understanding of pregnant women regarding the risks that may cause hearing loss during the prenatal period and later. Subsequently, pregnant women will be provided with awareness training on protecting their baby's hearing health, and their awareness of hearing loss risk factors and early prevention will be evaluated after the training.

Materials and Methods

The study was designed as a quasi-experimental educational intervention using a pre-test-post-test design with a control group. The study comprised two independent groups: one experimental (intervention) group and one control group. The control group consisted of 21 participants, and the experimental group consisted of 19 participants. The research was conducted at the "Pregnancy School" within the Obstetrics and Gynecology Outpatient Clinic of Hacettepe University Hospital. Pregnant women are required to participate in a three-stage educational program to complete the standard training process. These trainings are completed on different dates and in mixed groups.

Both the experimental and control groups of participants in this study completed the standard training process.

First, all pregnant participants completed a "Sociodemographic Information Form" to determine their sociodemographic characteristics. The "Hearing Risk Factors and Early Prevention Awareness Scale for Expectant Mothers," prepared in line with the study's objective and expert opinion, was administered as a pre-test before the standard training and as a post-test after the training. Cronbach's Alpha reliability analysis was conducted to determine the scale's reliability, and the reliability was found to be $\alpha=0.82$ in the pre-test and $\alpha=0.94$ in the post-test. A Cronbach's Alpha value of $\alpha \geq 0.70$ is considered sufficient for the reliability of the measurement instrument (Pedersen and Lui, 2003). Therefore, the scale was accepted as a reliable measurement instrument.

Participants in the experimental group, unlike the control group, attended training on fetal hearing health during pregnancy. While the training was planned to be face-to-face, due to the mixed groups and the training sessions taking place on different dates, it was conducted online via the Teams application in three separate sessions. After the training, pregnant women were asked to complete a feedback form in a rating format. Additionally, all pregnant women received an informative brochure in digital format to ensure the information presented was retained and accessible. This training brochure, prepared as a clear and understandable summary of the awareness presentation, was distributed to all participating pregnant women via digital channels, with the aim of serving as a reminder for the experimental group and raising awareness for the control group. The content and visual design of the brochure were comprehensively reviewed and approved by the project consultant for academic validity and suitability for the project.

Finally, following the planned data collection applications and training intervention for the experimental and control groups, the data analysis and reporting process was initiated. The obtained data were analyzed using IBM SPSS Statistics 23 program. After data entry, frequency analyses were performed to determine the sociodemographic characteristics of the participants. The awareness levels of pregnant women were compared based on their pre-test and post-test total scores. Accordingly, the analysis methods deemed necessary for the purpose of the research were preferred in within-group or between-group calculations. An independent samples t-test was used to compare the differences between the pre-test and post-test scores of the experimental and control groups; a dependent samples t-test was used to analyze the variation within each group. In statistical analyses, the significance level was accepted as $p < 0.05$. The findings obtained after the analysis are comprehensively presented in the next section.

Findings and Discussion

The data collection process for the project was completed at the Antenatal Education School within the Obstetrics and Gynecology Polyclinic of Hacettepe University. Following interviews conducted between October and December, a control group of 21 individuals and an experimental group of 19 individuals were formed. After training sessions held in January, the data collection processes were completed, and the necessary analyses were carried out in accordance with the scope of the research. The findings obtained from these analyses are explained in detail in this section.

3.1. Analyses Regarding the Sociodemographic Data of the Groups

First, the data obtained using the "Sociodemographic Information Form," prepared to determine the sociodemographic characteristics of the participating pregnant women, were examined. Since the sociodemographic data obtained in the study have different variable structures, they are presented in two separate tables.

Table 2. Statistics on Age, Number of Pregnancies, and Gestational Week of Pregnant Women.

	Average	Standard Deviation
Age (years)	30.58	±4.47
Number of Pregnancies	1.43	±0.78
Pregnancy Week	23.55	±6.37

The mean age and standard deviation of the pregnant women were determined as 30.58 ±4.47. The mean and standard deviation for the number of pregnancies was 1.43 ±0.78, and the average number of weeks in pregnancy was found to be 23.55 ±6.37. This indicates that many of the pregnant women were experiencing their first pregnancy, and some were in their second pregnancy. Furthermore, the average number of weeks in pregnancy shows that the pregnant women were predominantly in the second trimester.
Regarding the educational attainment of pregnant women, the majority were found to have received university-level education (52.5%) and high school-level education (27.5%). When income levels were examined, it was determined that the majority belonged to the middle-income group, with no participants from the very low, low, or very high-income groups. This indicates a homogeneous distribution of the sample in terms of education and income levels. However, this has resulted in limitations regarding the impact of sociodemographic characteristics on awareness.

When the employment status of pregnant women was examined, it was observed that the number of working and non-working pregnant women was close to each other. The nature of the work performed during pregnancy, the number of weeks of pregnancy, and the differences in legal rights in the private or public sectors are some of the variables in the obtained data. Since these variables are outside the scope of the project, detailed analysis and examination were not deemed necessary; however, it is thought that the obtained data will contribute to determining the quality of the sample Responses regarding receiving education during pregnancy revealed that 70% of pregnant women had previously participated in an education program for pregnant women. However, the average number of pregnancies was 1.43, indicating a low standard deviation. The fact that a large proportion of the pregnant women in the sample were experiencing their first pregnancy suggests that the majority were in the middle trimester (second trimester) of their pregnancy indicates that participants may have interpreted this concept differently. It also suggests that the responses may have reflected the Hacettepe University Pregnancy School training already received, or that short-term information acquired about pregnancy may have been perceived as training.

When data on conditions that may pose a risk to the baby's hearing health during pregnancy were examined, it was observed that pregnant women were predominantly not in a high-risk group.

After determining the sociodemographic characteristics of pregnant women, the "Hearing Risk Factors and Early Prevention Awareness Scale for Expectant Mothers," prepared in line with the research objective and the opinions of project consultant Prof. Dr. Ayşe Sanem ŞAHLI, was used in pre-test and post-test applications. The scale consists of 13 items. Items are scored from 1 (strongly disagree) to 5 (strongly agree). The lowest possible score on the scale is 13, and the highest is 65. The level of awareness increases proportionally with the score. To determine the reliability of the scale, Cronbach Alpha reliability analysis was performed, and the reliability of the scale was found to be α=0.82 in the pre-test and α=0.94 in the post-test. Since the scale was prepared with expert opinion, its validity was deemed sufficient within the scope of the research. The findings related to the data obtained through the scale are presented below with their tables and explanations.

3.2. Examination of Similarities Between Experimental and Control Groups Before Intervention

The groups were assigned randomly without considering any specific criteria. Therefore, analysis was necessary to check whether the groups initially shared similar characteristics.

Table 3. T-test Results Regarding the Pre-Test Scores of the Groups

	N	Mean	Std . Deviation	Sig. (2-tailed)
Experimental group	19	42.73	8.19	771
Control group	21	43.47	7.72	771

The pre-test total scores of the experimental and control groups were compared using an independent samples t-test, and no statistically significant difference was found between the groups ($p=0.771$; $p>0.05$). This result indicates that the experimental and control groups had similar characteristics at the beginning of the study.

3.3. Evaluation of Changes Occurring Within the Experimental and Control Groups After the Intervention

In terms of the scope and nature of the project, data on the changes within each group, as well as comparisons between the groups themselves, are of great importance. First, it was examined whether the participants in the experimental group, who received the educational intervention, showed any changes before and after the intervention.

Table 4. T-test Results Regarding the Pre-Test and Post-Test Scores of the Experimental Group.

	N	Mean	Std . Deviation	Sig. (2-tailed)
Pre-test	19	42.73	8.19	,001
Final test	19	62.31	2.90	,001

The pre-test and post-test scores of the experimental group were compared using a dependent samples t-test, and a statistically significant difference was found between them ($p=0.001$; $p<0.05$). Based on the data obtained, an increase of approximately 20 points was observed in the average awareness scale scores of pregnant women after the educational intervention. This increase demonstrates the significant effect of the education on pregnant women and also confirms the hypothesis of the study. During the analysis process of the study, the same analyses were performed to determine whether there were any changes in the data of the control group. As indicated in Table 1, the control group received only the standard training consisting of 3 stages.

The pre-test and post-test scores of the control group were compared using a dependent samples t-test, and no statistically significant difference was found between the two values ($p=0.418$; $p>0.05$). The difference between the mean pre-test and post-test scores was determined to be 1.43. This result does not definitively evaluate the quality and effectiveness of the standardized training provided. The Hacettepe University Pregnancy School Program includes practical and theoretical training on topics such as pregnancy, preparation for childbirth, breathing exercises and prenatal yoga, postpartum period, breastfeeding, and newborn care. In this study, only the awareness levels of pregnant women regarding hearing risk factors and early prevention were addressed. Furthermore, a previous study on the change in knowledge levels of pregnant women who had received training at a pregnancy school showed that pregnancy school training had a significant impact on

increasing the knowledge levels of pregnant women (Turgut et al., 2017). These and similar studies undeniably demonstrate the necessity of expanding pregnancy schools and the importance of their contribution to the knowledge and awareness levels of pregnant women in terms of preventive health. According to the findings, the variations within the groups are clearly seen when looking at the results of the dependent samples t-test shown above.

3.4. Evaluation of the Impact of the Intervention on Intergroup Differentiation

Finally, to determine whether there was a significant difference between the experimental and control groups after the educational intervention, the groups' post-test scores were compared.

An independent samples t-test comparing the post-test scores of the experimental and control groups revealed a statistically significant difference between the two groups ($p=0.001$; $p<0.05$). Initially, a comparison of pre-test scores to assess group equality showed a difference of 0.74, which was not statistically significant when the p-value was considered. However, a comparison of the mean post-test scores showed a difference of 17.41. Therefore, it can be said that the educational intervention was a determining factor not only in the effect within the groups but also in the differentiation between the groups.

3.5. Evaluation of Participant Opinions Regarding Awareness Training

Following the awareness training, an evaluation form was used to identify the strengths and weaknesses of the training and to determine the opinions and suggestions of pregnant women regarding the training. The evaluation form, prepared using a 5-point Likert scale, was scored from 1 (strongly disagree) to 5 (strongly agree).

Looking at the evaluation form results, it is seen that opinions regarding the training are positive. In particular, all participants rated the 30-minute training duration as full marks.

Conclusion and Recommendations

Our study compared the pre-test and post-test scores of the experimental group using a dependent samples t-test, and a statistically significant difference was found between the two groups ($p=0.001$; $p<0.05$). Similarly, the pre-test and post-test scores of the control group were compared using a dependent samples t-test, and no statistically significant difference was found between the two groups ($p=0.418$; $p>0.05$). Therefore, the educational intervention clearly had a positive impact on the awareness levels of pregnant women.

Based on the findings, it was concluded that prenatal education programs should be expanded and their content enriched, and that education on hearing risk factors and early intervention for pregnant women has a positive impact on their awareness levels. It is believed that an increase in awareness will lead to a decrease in the number of newborns with congenital hearing loss. This is the primary expected effect of our project's implementation and expansion. However, not all congenital hearing losses are preventable, but minimizing time loss in audiological evaluation and intervention is of great importance. Parents' awareness of hearing health will facilitate this benefit.

The contribution of steps taken in the field of preventive health through these and similar projects to the existence of a healthy future in our country and in the world is undeniable. The results are significant not only in terms of hearing health. This will guide future research in terms of conducting necessary studies on preventable health problems that may be congenital or acquired.

Thanks and Information Note

This study was supported by the TÜBİTAK 2209-A University Students Research Projects Support Program under project number 1919B012408306.

References

Busa J, Harrison J, Chappell J, Yoshinaga-Itano C, Grimes A, Brookhouser PE, et al. (2007). Year 2007 position Statement: Principles and guidelines for early hearing detection and intervention programs. Vol. 120, Pediatrics. p. 898-921.

Chi DH, Sabo DL, Wilkins KB. (2014). Pediatric audiology and implantable hearing devices. In: Williams NS, Otey S (Eds .), Bailey's head and neck surgery - otolaryngology (5th ed., pp . 1507-1522). Lippincott Williams & Wilkins

Di Berardino, F., Forti, S., Iacona, E., Orlandi, GP, Ambrosetti, U., & Cesarani, A. (2013). Questionnaire. questionnaire. of ear and hearing management as measured using a specific questionnaire. European Archives of Oto- Rhino - Laryngology, 270(2), 449–453.

Dobie RA, Hemel S Van. (2004). Loss: Loss: Determining Eligibility for Social Security Benefits. Committee on Disability Determination for Individuals with Hearing Impairments. Dobie RA, editor. Washington, DC: National Academies Press.

HSGM (2024). International Week of the Deaf. Republic of Turkey Ministry of Health, General Directorate of Public Health, Department of Child and Adolescent Health. https://hsgm.saglik.gov.tr/tr/haberler-cocukergen/uluslararasi-isitme-engelliler-haftasi.html

Korver AM, Smith RJ, Van Camp G, Schleiss MR, Bitner-Glindzicz MA, Lustig LR, et al., (2017). loss. hearing loss . Nat Rev External Primers. 3: 16094.

Pedersen, S. and Liu, M. (2003). Teachers ' beliefs about issues in the implementation of a student-centered learning environment. Educational Technology Research and Development, 51(2), 57–76.

Turgut, N., Güldür, A., Çakmakçı, H., Şerbetçi, G., Yıldırım, F., Yumru, AE, Bebek, A., Gülova, SS (2017) A Study on the Knowledge Levels of Pregnant Women Receiving Education in the Pregnancy School. JAREN, 3(1), 1-8.

Tuz, D., Aslan, F., & Sennaroğlu, G. (2020). Hearing health awareness. Turkish Journal of Audiology and Hearing Research, 3(2), 13-17.

Turkish Statistical Institute (2024). Birth Statistics, 2023. General Directorate of Population and Citizenship Affairs, Ministry of Health. Ministry of Interior.

World Health Organization (WHO) (2016). Childhood hearing loss: Strategies for prevention and care..

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

PARENTAL AWARENESS OF THE EFFECTS OF SCREEN EXPOSURE ON CHILDREN'S HEARING, SPEECH AND LANGUAGE SKILLS

Özge Başak KARAKAYA
Ayşe Sanem ŞAHLI
0009-0009-2323-5009, Hacettepe University, Vocational School of Health Services, Audiometry Program, Ankara, Turkey.
0000-0001-5050-8994, Hacettepe University, Vocational School of Health Services, Hearing and Speech Education Unit, Ankara, Turkey.

Abstract

Early and prolonged exposure to screen-based devices has become an increasingly important concern for child health and development, as the first years of life represent a critical window for neuroplasticity, language acquisition, and speech development. This study aimed to determine the level of parental awareness regarding the effects of screen exposure on children's auditory perception, language, and speech skills, and to evaluate the impact of a structured face-to-face educational program designed to strengthen this awareness.

The research was conducted within the scope of the TÜBİTAK 2209-A University Students Research Projects Support Program at Hacettepe University, with the voluntary participation of 100 parents (N=100) of children aged 3-9 years. A pre-test/post-test design was employed: a socio-demographic information form and a parental awareness questionnaire were administered face-to-face in the first stage, followed in the same session by a structured educational program supported by brochures, information cards, and a podcast. A feedback form was applied after the training to record participants' post-training evaluations. Data were analyzed using SPSS, with descriptive statistics calculated for continuous and categorical variables.

Results showed that children's mean daily screen exposure was 3.54 ± 1.63 hours, considerably above the World Health Organization's recommended limit. Approximately two-thirds of parents reported perceiving a negative effect of screen exposure on auditory perception (64.0%), language skills (61.0%), and speech (63.0%), and 60.0% observed language development delays in their children. The educational program was rated as highly beneficial (80.0%), and all participants (100.0%) reported that they intended to limit, or had already limited, their children's screen time following the training. These findings demonstrate that even a brief, single-session educational intervention can measurably increase parental awareness and behavioral intention, providing evidence to inform awareness-raising policies in preschool education, primary healthcare, and family education settings in Türkiye.

Keywords: children, screen exposure, hearing, language, speech, development.

Introduction

Digital technology has become part of everyday life at a remarkable speed, and early contact with screen-based devices is a research topic of growing importance for child health and development (Şahlı, 2022). Monitoring studies consistently show that the age of first contact with such devices keeps falling while daily exposure keeps rising. A considerable proportion of young children already had access to tablets and smartphones in the early 2010s, and today this access is far more widespread (Common Sense Media, 2011). Exposure that starts early and becomes intensive also narrows the time children spend on activities that are indispensable for development, such as pretend play, peer interaction and reciprocal communication with parents.

The human brain works with only a small part of its functional capacity at birth, and the synaptic network between neurons is shaped rapidly by environmental interaction after birth. The first years of life therefore offer a unique window of neuroplasticity: a brain that receives appropriate sensory input builds new connections and expands its cognitive capacity, whereas structures exposed to deprived or mismatched stimuli may undergo synaptic deterioration (Şahlı, 2022). The 0-3 age range is considered the period in which maturation is fastest and environmental effects, positive or negative, leave the deepest traces. By the age of six the brain reaches about 90% of its adult volume, so the experiences of early childhood have lasting consequences that are only partly reversible.

The quality of the family environment directly determines how well a child uses the neurological capacity he or she is born with. Verbal and nonverbal reciprocal interactions with parents help strengthen the basic synaptic networks that support attention, memory and language. In settings where passive screen viewing replaces these interactions, these brain structures are thought to be insufficiently stimulated (Lin et al., 2015; Şahlı, 2022).

Language development is a multilayered neurocognitive process that covers the processing, storage and production of verbal input. Research indicates that long-term passive screen exposure limits the child's participation in real-time dialogue, and that this limitation adversely affects vocabulary development, phonological awareness and speech fluency (Duch et al., 2013). Television viewing has been associated with delayed language development (Chonchaiya & Pruksananonda, 2008), and the effects of infant media use have been widely reviewed (Christakis, 2009). Beyond cognitive and language outcomes, exposure above recommended limits is also accompanied by health problems related to physical inactivity (Chonchaiya & Pruksananonda, 2008; Christakis, 2009). The effects of screen dependence on language, speech and other developmental areas have also been discussed in the Turkish literature (Belgin & Şahlı, 2022).

Given the risk that untreated language and speech difficulties persist into school age and adulthood (Law et al., 2009), the strategic importance of family awareness interventions in the early period becomes even clearer. International organizations such as the World Health Organization and the American Academy of Pediatrics recommend keeping young children's screen time within age-based limits and, when these limits are exceeded, giving priority to parental guidance and awareness programs (WHO, 2019; Strasburger & Council on Communications and Media, 2011; American Academy of Pediatrics, 2016).

Against this background, the present study was designed in two stages. Its aims were (i) to describe the daily screen exposure of children aged 3-9 years as reported by their parents, (ii) to determine the level of parental awareness of the effects of screen exposure on auditory perception, language and speech, and (iii) to evaluate, through participants' feedback, a structured face-to-face educational program designed to strengthen this awareness, including parents' intention to regulate their children's screen time.

Materials and Methods

Design. The study was conducted within the scope of the TÜBİTAK 2209-A University Students Research Projects Support Program between 1 May 2025 and 11 April 2026. It had a sequential two-stage, pre-test/post-test design. In the first stage, a sociodemographic information form and a parental awareness questionnaire were administered to each participant face-to-face. In the same session, a structured educational program supported by complementary materials was then delivered. In the second stage, after the training was completed, a feedback form was applied to record participants' post-training evaluations.

Participants. The study group consisted of 100 parents (N=100) who had at least one child aged 3-9 years and agreed to participate voluntarily at Hacettepe University. The call for participation was made through building notice boards and field visits, and all applicants who met the inclusion criterion were included in the sample.

Data collection tools. Data were collected with three forms. (1) The Sociodemographic Information Form covered the parent's age, gender, educational level, occupation, perceived socioeconomic status and number of children. (2) The Parental Awareness Questionnaire asked about the child's daily screen time and the

perceived effects of screen exposure on auditory perception, language and speech development (yes / no / undecided). (3) The Parent Feedback Form assessed the usefulness and duration of the training, the topics of interest and the intention to regulate screen time.

Educational program. The structured program was delivered by the researcher in a single face-to-face session and was supported by a set of information cards, a wall poster, a double-page brochure and a podcast published on YouTube. Its content covered what screen time is, why it matters for development, what families can do, healthy alternatives to screen use, early signs of language and speech difficulties, when screen use becomes harmful, recommendations for parents and when to seek specialist support.

Data analysis. Raw data were transferred to SPSS. Arithmetic mean ($\bar{X}$), standard deviation (SD), median, minimum and maximum values were calculated for continuous variables, and frequencies and percentages for categorical variables. The Kolmogorov-Smirnov and Shapiro-Wilk tests indicated deviation from normal distribution for age (K-S=0.129, $p<0.001$; SW=0.955, $p=0.002$), number of children (K-S=0.228, $p<0.001$; SW=0.850, $p<0.001$) and screen time (K-S=0.135, $p<0.001$; SW=0.919, $p<0.001$); therefore, medians and ranges are reported together with means.

Ethical procedures. Informed consent was obtained from all participants. Before data collection, participants were informed about the purpose, scope and use of the research, and those who agreed to participate voluntarily signed a consent form. Explicit permission was also obtained before photographs were taken during the training sessions, individuals who did not wish to be photographed were not included in photo or video records, and participants were informed again about the use of the images. Participant rights, confidentiality and voluntariness were respected throughout the study.

Findings and Discussion

Characteristics of the participants

The mean age of the 100 participating parents was 41.19 ± 7.65 years (range 24-65; 5% trimmed mean 40.80; median 41.0), and the mean number of children was 2.02 ± 0.94 (Table 1). Of the participants, 58 (58.0%) were men and 42 (42.0%) were women. High school graduates formed the largest educational group (34.0%), followed by university (23.0%), secondary school (19.0%) and primary school (16.0%) graduates; 8.0% reported that they could not read or write. Housewives made up almost one third of the sample (31.0%). Self-rated socioeconomic status was fairly evenly distributed across low (37.0%), middle (34.0%) and high (29.0%) levels. Families with two children (38.0%) were the most common, followed closely by single-child families (34.0%) (Table 2). This heterogeneous profile, spanning different educational and income levels, supports the usefulness of the findings, although the sample was obtained on a voluntary basis and cannot be considered representative of the whole population.

Table 1. Descriptive statistics of continuous variables (n=100)

Variable	Mean	SD	Min	Max	Median
Parent age (years)	41.19	7.65	24	65	41.0
Number of children	2.02	0.94	1	5	2.0
Screen time (hours/day)	3.54	1.63	1	6	3.5

Table 2. Sociodemographic characteristics of the parents (n=100)

Characteristic	Category	n	%
Gender	Male	58	58.0
	Female	42	42.0
Educational level	Cannot read or write	8	8.0
	Primary school	16	16.0
	Secondary school	19	19.0
	High school	34	34.0
	University	23	23.0
Occupation	Housewife	31	31.0
	Self-employed	15	15.0
	Civil servant	14	14.0
	Private sector employee	10	10.0
	Tradesperson	9	9.0
	Worker	8	8.0
	Retired	4	4.0
	Other	9	9.0
Socioeconomic status (self-rated)	Low	37	37.0
	Middle	34	34.0
	High	29	29.0
Number of children	1	34	34.0
	2	38	38.0
	3 or more	28	28.0

Screen exposure

The mean daily screen time of the children was 3.54 ± 1.63 hours (median 3.5; range 1-6), which is about 3.5 times the one-hour upper limit set by the World Health Organization for children under five years of age (WHO, 2019). Because the present sample included children aged 3-9 years, this comparison should be

regarded as indicative. Only 14.0% of the children had the lowest observed exposure of 1 hour per day, so 86.0% were exposed for 2 hours or more. Exactly half of the sample (50.0%) spent 4 hours or more in front of a screen per day, and 32.0% were exposed for 5-6 hours (Figure 1).

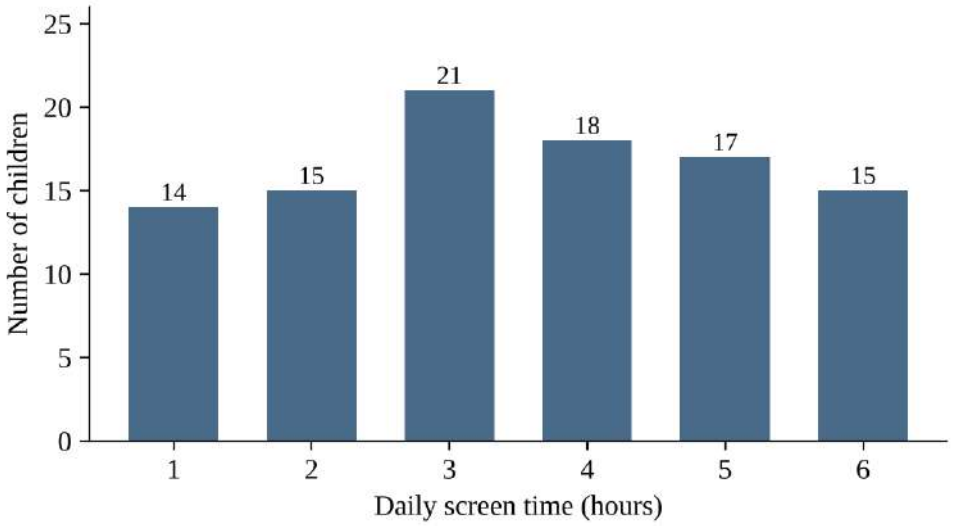


Figure 1. Distribution of children's daily screen time (n=100)

Such high exposure is a matter of concern when read against the literature. Passive viewing may take time away from play, peer interaction and parent-child communication, which are the interactions on which language-supporting brain networks depend (Lin et al., 2015; Şahlı, 2022). Time-related health risks are also not limited to language: exposure above recommended limits is accompanied by problems related to physical inactivity (Chonchaiya & Pruksananonda, 2008; Christakis, 2009).

Parental awareness and observed language development

About two thirds of the parents perceived a negative effect of screen exposure on auditory perception (64.0%), language skills (61.0%) and speech (63.0%) (Figure 2). On average across the three areas, 62.7% of parents were aware of a negative effect, 29.0% were not, and 8.3% were undecided. The proportion answering "no" was identical (29.0%) in all three areas. In other words, roughly three out of ten parents did not perceive any negative effect, and this group is a natural target for awareness-raising work.

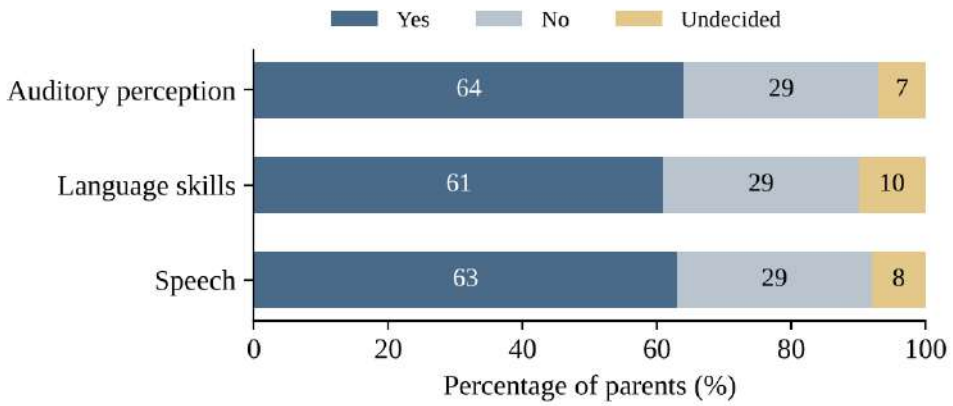


Figure 2. Parents' perceptions of the negative effects of screen exposure (%, n=100)

Sixty percent of the parents reported that they had observed a delay in their own children's language development, which is one of the most striking findings of the study. This figure is based on parental observation, not on clinical assessment, and the cross-sectional design does not allow causal inference. Nevertheless, in a sample with such high screen time, it is consistent with studies that link screen use to delayed language development (Chonchaiya & Pruksananonda, 2008; Duch et al., 2013). Because untreated language and speech difficulties may persist into school age and adulthood (Law et al., 2009), parents who observe such delays should be guided toward early evaluation. It is also noteworthy that most parents recognized possible harms while their children's average exposure remained well above recommended limits, which suggests that awareness alone does not necessarily translate into behavior and that practical guidance for families is needed.

Evaluation of the educational program

Participants evaluated the face-to-face program positively. Eighty percent rated it as useful (34.0%) or very useful (46.0%), 18.0% found it partially useful and only 2.0% found it not useful. The duration was considered appropriate by 77.0%. Most notably, all participants (100.0%) stated that they would limit their children's screen time (63.0%) or were already doing so (37.0%). These results show that a short, single-session, face-to-face program supported by simple materials is practicable and well accepted by parents with different educational and socioeconomic backgrounds. However, the findings should be interpreted with caution. Awareness was not measured again after the training, so a change in awareness cannot be quantified; the feedback form records opinions and intentions, not observed behavior; participants answered face-to-face, which may have encouraged socially desirable answers; and no follow-up was carried out. Other limitations are the voluntary, single-institution sample, the reliance on parental self-report, the absence of a control group and the wide child age range (3-9 years) compared with the WHO limit for children under five.

Conclusion and Recommendations

In this study of 100 parents of children aged 3-9 years, children's mean daily screen exposure was 3.54 hours, and 86.0% of children were exposed for more than the one-hour limit that the WHO recommends for children under five. About two thirds of the parents perceived negative effects of screen exposure on auditory perception, language and speech, and 60.0% observed delays in their children's language development. The face-to-face educational program was rated as beneficial by 80.0% of the participants, and all of them intended to limit, or had already limited, their children's screen time. The findings suggest that parent-focused awareness interventions on screen exposure are feasible and acceptable in Türkiye.

Based on these findings, the following recommendations can be made. (1) Brief, face-to-face awareness sessions and low-cost materials such as information cards, posters, brochures and podcasts can be used in

preschool education institutions, family health centers and municipal social service units. (2) Questions about children's screen time and language development could be included in routine primary healthcare and family education contacts, with referral for early evaluation when delays are suspected. (3) Families should be encouraged to replace screen time with interactive alternatives such as shared reading, drawing, play and conversation, and to review their own screen use as role models. (4) Future studies should use control groups, re-measure awareness after the training, follow participants over time, measure screen use objectively and assess children's language skills directly, so that the effects of such programs on awareness and behavior can be demonstrated.

Thanks and Information Note

This study was supported by the TÜBİTAK 2209-A University Students Research Projects Support Program. I would like to thank my advisor, Prof. Dr. Sanem Şahlı, for her valuable guidance and support throughout the study, my family for their endless support during this process, and my brother for standing by me.

References

American Academy of Pediatrics. (2016). Media and young minds. Pediatrics, 138(5), e20162591.

Belgin, E. & Şahlı, A. S. (2022). Çocuklarda ekran bağımlılığının dil-konuşma ve diğer gelişim alanlarına etkisi. Sağlık Bilimlerinde Uluslararası Araştırmalar. İzmir: Serüven Yayınevi.

Chonchaiya, W. & Pruksananonda, C. (2008). Television viewing associates with delayed language development. Acta Paediatrica, 97(7), 977-982.

Christakis, D. A. (2009). The effects of infant media usage. Acta Paediatrica, 98(1), 8-16.

Common Sense Media. (2011). Zero to eight: Children's media use in America.

Duch, H. et al. (2013). Association of screen time use and language development in Hispanic toddlers. Clinical Pediatrics, 52(9), 857-865.

Law, J. et al. (2009). Modeling developmental language difficulties from school entry into adulthood. Journal of Speech, Language, and Hearing Research, 52, 1401-1416.

Lin, L. Y. et al. (2015). Effects of television exposure on developmental skills among young children. Infant Behavior and Development, 38, 20-26.

Strasburger, V. C. & Council on Communications and Media. (2011). Pediatrics, 128(1), 201-208.

Şahlı, A. S. (2022). Çocuklarda ekran maruziyetinin dil-konuşma gelişimine etkisi. İzmir: Serüven Yayınevi.

World Health Organization. (2019). Guidelines on physical activity, sedentary behavior and sleep for children under 5 years of age.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

DISEASE BURDEN, MODIFIABLE RISK FACTORS, AND HEALTH POLICY RESPONSES IN ALBANIA: PRIORITIES FOR 2021-2030

Bledar KRAJA
Division of Physiology, Department of Biomedical and Experimental Sciences, Faculty of Medicine, University of Medicine Tirana, Albania
University Clinic of Gastro-Hepatology, University Hospital Center "Mother Teresa", Dibra Street 371, 1001, Tirana, Albania
ORCID ID: 0000-0001-7685-8394.

Abstract

Albania is undergoing an epidemiological transition characterized by a substantial burden of non-communicable diseases (NCDs) and a high prevalence of modifiable risk factors. Understanding this burden is essential for effective population-health policies.
To describe the major components of disease burden and associated risk factors in Albania and examine their relevance to the National Health Strategy 2021-2030.
Mortality, disability-adjusted life years (DALYs), attributable risk factors, and trends in major behavioral and metabolic risks were reviewed, with particular emphasis on 2019 estimates. Findings were considered in relation to national health-policy priorities.
In 2019, NCDs accounted for 82% (95% CI: 81-84%) of total DALYs in Albania. Cardiovascular diseases (CVDs) represented the largest component, accounting for 29% (95% CI: 25-33%) of the overall disease burden, followed by neoplasms (15%), chronic respiratory diseases (2.6%), and diabetes (2.1%). High blood pressure was the leading risk factor, contributing approximately 34% of overall mortality, followed by nutrition-related risks (25%) and smoking (20%). Other important contributors included overweight and obesity, high plasma glucose, and physical inactivity. In 2019, smoking was responsible for approximately 50% of chronic respiratory disease deaths, 31% of neoplasm deaths, and 17% of CVD deaths. High blood pressure contributed to more than 57% of CVD deaths, while high body mass index was attributable to approximately 43% of diabetes deaths, >19% of CVD deaths, and 5% of neoplasm deaths. Despite a modest decline in smoking among men, obesity increased by approximately 28% in both sexes over the preceding decade.
Albania's disease burden is predominantly driven by NCDs, particularly CVDs and neoplasms. Hypertension, unhealthy diet, smoking, and increasing obesity represent major modifiable determinants, underscoring the importance of prevention, health promotion, early detection, and strengthened primary healthcare within the National Health Strategy 2021-2030.

Keywords: Albania, disease burden, non-communicable diseases, prevention.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FROM DIGITAL SETUP TO CLINICAL REALITY: DETERMINANTS OF PREDICTABILITY IN CLEAR ALIGNER THERAPY

Elona Hasalla
Ilda Taka
Celjana Toti
Gerta Kacani
Etleva Dobroniku
University of Elbasan "Aleksander Xhuvani", Faculty of Medical and Technical Sciences
Department of Preclinical Studies
Department of Medical and Technical Specialties
University of Tirana, Faculty of Dental Medicine
Department of Orthopedics, Department of Therapy

Abstract

Clear aligner therapy has emerged as a widely used alternative to fixed orthodontic appliances, primarily due to its aesthetic advantages and patient comfort. Advances in digital treatment planning enable the simulation of tooth movement and the prediction of clinical outcomes. However, discrepancies between the virtual setup and actual clinical results remain a significant challenge in orthodontic practice.
To evaluate the main factors influencing the predictability of clear aligner therapy and to analyze the causes of deviation between planned and clinically achieved tooth movements.
A review of contemporary literature was conducted through searches in scientific databases such as *Web of Science* and *Google Scholar*, using keywords related to "clear aligners", "treatment predictability", "biomechanics", and "orthodontic tooth movement". A total of approximately **95 articles** were initially identified, of which **32 were selected for detailed analysis** based on relevance and methodological quality.
Articles published in English within the **last 10 years (2014–2024)** were included. Inclusion criteria comprised **systematic reviews, meta-analyses, randomized controlled trials**, and clinically relevant studies. Case reports, studies with small sample sizes, and publications with low methodological quality were excluded.
Evidence suggests that the predictability of aligner therapy is highly dependent on the type of tooth movement. Tipping movements demonstrate relatively high accuracy, whereas rotations, extrusions, and torque control remain less predictable. Additional factors, including patient compliance, attachment design and positioning, treatment planning strategies, and individual biological variability, significantly influence clinical outcomes.
Despite advancements in digital technology, clear aligner therapy does not always achieve the outcomes predicted by the virtual setup. Understanding biomechanical limitations and clinical factors is essential to improving treatment predictability.
Careful case selection, the use of overcorrection in digital planning, optimization of attachment design, and continuous clinical monitoring are recommended. Patient education and compliance remain key factors for treatment success.

Keywords: clear aligners, digital orthodontics, treatment predictability, biomechanics, attachments, patient compliance.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE ROLE OF NURSING CARE IN THE MANAGEMENT OF PATIENTS WITH BRAIN METASTASES TREATED WITH STEREOTACTIC RADIOSURGERY: A NARRATIVE REVIEW

Ilda Taka
Elona Hasalla
University of Elbasan, Albania

Abstract

Stereotactic radiosurgery (SRS) is an important method for treating brain metastases, enabling local disease control and, in selected cases, avoiding whole-brain radiotherapy. However, patients may experience complications and side effects during and after treatment. Nurses play a significant role in monitoring symptoms, identifying complications early, educating patients and their families, and coordinating multidisciplinary care.

To examine current literature on the role of nurses in the management of patients with brain metastases treated with SRS.

A narrative literature review was conducted covering studies published over the last five years (2021–2026) in the PubMed/MEDLINE, Scopus, CINAHL, and Cochrane Library databases, using the terms "brain metastases," "stereotactic radiosurgery," "nursing care," "neuro-oncology nursing," "symptom management," and "supportive care." The review included 21 articles, which were synthesized narratively according to key areas of nursing practice.

The literature identified four key areas of nursing contribution: (1) neurological and clinical assessment for the early identification of deterioration, epileptic seizures, and increased intracranial pressure; (2) symptom and medication management, including the monitoring of side effects; (3) patient and family education regarding warning signs following treatment; and (4) the coordination of multidisciplinary care. Studies emphasize the need for long-term follow-up after SRS to monitor for late complications, such as radiation necrosis. However, studies that directly evaluate the effectiveness of nursing interventions remain scarce.

Specialized nursing care constitutes an important component in the management of patients with cerebral metastases treated with SRS. Nurses play a key role in the early identification of symptoms, treatment safety, patient education, and the continuity of care. Further research is needed to develop standardized, evidence-based, and patient-centered nursing protocols.

Keywords: cerebral metastases; stereotactic radiosurgery; nursing care; neuro-oncology nursing; symptom management; multidisciplinary care.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

NOVEL MONO- AND BIS-ENAMINONE COUMARINS: CRYSTAL STRUCTURE, THEORETICAL INSIGHTS AND ANTIMICROBIAL POTENTIAL

Ameni Brahmia
Linda Bejaoui
Rached Ben Hassen
Laboratory of Materials and Environment for Sustainable Development (LR18ES10), University of Tunis El Manar, Tunisia.
Chemistry Department, College of Science, King Khalid University, Abha 61413, Saudi Arabia.

Abstract

Two novel enaminone-coumarins, namely 3-(1-(2-aminophenylamino) ethylidene) chromene-2,4-dione (1) and 3-(1-(2-(1-(2,4-dioxochromen-3-ylidene) ethylamino) phenylamino) ethylidene) chromene-2,4-dione (2), were synthesized by HCl-catalysed condensation of 3-acetyl-4-hydroxycoumarin with o-phenylenediamine in ethanol (1:1 and 2:1 ratios, respectively) and characterized by FT-IR, UV–Vis and fluorescence spectroscopies. Low-temperature single-crystal X-ray diffraction showed that (1) crystallizes in the orthorhombic space group *Iba*2 and (2) in the monoclinic space group $P2_1/c$. Hirshfeld surface and fingerprint analyses revealed H···H (46.2% and 39.6%), H···O/O···H (17.7% and 25.7%), and C···H/H···C (20.3% and 18.3%) contacts for (1) and (2), respectively, together with C–H···π interactions and parallel π···π stacking (C···C contacts of 7.8% and 8.7%). Geometries were optimized by DFT at the B3LYP/6-31+G(d,p) level, with solvent effects treated by the PCM model; the calculated structural and vibrational data agree well with experiment. Compound (1) has the higher HOMO energy and thus the stronger electron-donating ability, whereas (2) has the larger HOMO–LUMO gap (3.97 vs 3.79 eV) and chemical hardness (1.986 vs 1.894 eV) in the gas phase, indicating greater stability. NBO analysis highlighted strong π→π* and lone pair→π* delocalization responsible for intramolecular charge transfer and stabilization. Both compounds fluoresce, with the most intense emission in polar aprotic solvents (DMSO, DMF), attributed to a twisted intramolecular charge-transfer state and showing solvatochromic behaviour. In antimicrobial tests, compound (1) showed moderate activity against several bacterial strains, with a minimum inhibitory concentration of 62.5 µg/mL against *Escherichia coli*, *Vibrio alginolyticus* and *Vibrio anguillarum*, whereas (2) was markedly weaker.

Keywords: Enaminone coumarins, Hirshfeld surface analysis, DFT, fluorescence, antimicrobial activity.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

STROKE INCIDENCE IN ALBANIA COMPARED WITH BALKAN AND EUROPEAN COUNTRIES: SEX AND AGE DIFFERENCES

Amarilda Hysenshahaj
Dorina Toçi
Alban Ylli
Jolanda Hyska
Institute of Public Health, Department of Public Health Performance and Chronic Diseases, Tirana, Albania.
Institute of Public Health, Tirana, Albania.
Institute of Public Health; University of Medicine Tirana, Department of Public Health, Tirana, Albania.
Institute of Public Health; University of Medicine Tirana, Department of Public Health, Tirana, Albania.

Abstract

Stroke is a leading cause of death and long-term disability in Europe, with a particularly high burden in the Balkan countries. Age- and sex-specific incidence data are essential for planning prevention and acute care.

Data were obtained from the National Registry of Ischemic Heart Disease and Stroke of the Institute of Public Health for January–December 2024, covering newly diagnosed hospitalised cases from all hospitals. Incidence rates per 100 000 population were calculated by sex and age group. Albania was compared with other Balkan countries and Italy using sex-specific, age-standardised incidence rates for 2023 from the Global Burden of Disease (GBD) Study.

In 2024, 4990 new cases of stroke were registered (56.1% in males), an incidence of 207.7 per 100 000 population (210.3 in 2023). Incidence was 30% higher in males (235.3) than in females (180.7). Rates rose steeply with age and peaked at ≥85 years in males (1687.1) and at 80–84 years in females (1373.0); at 55–64 years, male rates were about twice those of females. According to GBD, incidence among Albanian men (143.4 per 100 000) was lower than in Serbia, Montenegro, Bosnia and Herzegovina, Bulgaria and North Macedonia (174.4–309.1) and higher only than in Greece (109.9) and Italy (84.5). Among women (143.0), Albania ranked fourth of eight countries, above Bosnia and Herzegovina, Serbia, Greece and Italy. Male rates exceeded female rates by 25–66% in all comparison countries, but by less than 1% in Albania.

Regionally, Albania ranks low for men but intermediate for women, and above Greece and Italy for both sexes. According to GBD, the sex difference in Albania is very small, unlike in neighbouring countries. Stronger control of cardiovascular risk factors is needed, particularly among middle-aged men and older adults.

Keywords: stroke; incidence; sex differences; age; Albania; Balkans.

INTRODUCTION

Stroke remains one of the main causes of death and long-term disability worldwide. In 2021, there were an estimated 11.9 million new strokes and 93.8 million people living after a stroke. Stroke caused 7.3 million deaths, making it the third leading cause of death after ischaemic heart disease and COVID-19, and it was the fourth leading cause of disability-adjusted life years (Feigin et al., 2024). Most of this burden is linked to modifiable risk factors, of which high systolic blood pressure is the most important (Feigin et al., 2024). At the population level, about one in four adults is expected to have a stroke during their lifetime (GBD 2016 Lifetime Risk of Stroke Collaborators, 2018), and four in ten stroke deaths could be prevented by keeping blood pressure under control (WHO EMRO n.d).

The burden of stroke is not evenly distributed across Europe. Incidence and mortality are higher in Central and Eastern European countries, including the Balkans, than in Western Europe (Wafa et al., 2020). Differences between men and women are also well documented: men have higher age-specific incidence in middle age, while women tend to have strokes at older ages and, because they live longer, account for a large share of cases in the oldest age groups (Bushnell et al., 2018).

In Albania, diseases of the circulatory system accounted for 52.9% of all deaths in 2024, and cerebrovascular diseases for one fifth of these, about 20 % of all deaths (INSTAT, 2025). New cases have been reported to the Institute of Public Health (IPH) through a national registry that also covers ischaemic heart disease. Registry data are published nationally, but they have rarely been compared with estimates for neighbouring countries.

The aim of this study was to describe the incidence of stroke in Albania in 2024 by sex, age group and county, and to compare Albania with other Balkan countries and Italy using sex-specific estimates from the Global Burden of Disease (GBD) Study.

MATERIALS AND METHODS

Data source

The study used data from the National Registry of Ischemic Heart Disease and Stroke, managed by the IPH. Data are collected on the basis of Decision of the Council of Ministers No. 327 of 2014, which sets the format and method of data collection from public and private health care providers (Institute of Public Health, 2025. For each new case of stroke diagnosed in a hospital, an individual report form is completed. The form contains demographic data (age, sex and place of residence) and data on the diagnosis and its ICD-10 code.

Cases are reported by the emergency and inpatient services of all public and private hospitals. Local health care units send the data to the IPH every six months, while the University Hospital Centre "Mother Teresa" in Tirana, which serves as the national reference centre and treats the largest number of cases, reports once a year. At the IPH, records are checked for repeated entries and duplicates are removed, so that each case is counted only once. Only hospitalised cases are included; strokes managed outside hospital and out-of-hospital deaths are not captured by the registry.

Incidence rates

The study period was January-December 2024, and the results were compared with 2023. Crude incidence rates were calculated as the number of new cases divided by the resident population and expressed per 100 000 population. Population denominators were taken from the 2023 Population and Housing Census (INSTAT, 2024). Rates were calculated for the total population, by sex, by five-year age group (0-4 to 85+ years) and by county. Sex differences were described with the male-to-female rate ratio, and the change between years as a percentage.

International comparison

For the regional comparison, we used Global Burden Diseases (GBD) 2023 estimates of stroke incidence obtained from the Institute for Health Metrics and Evaluation (IHME, 2025). We extracted age-standardised incidence rates per 100 000 population for both sexes and for each sex in 2023 for Albania, six other Balkan countries (Bosnia and Herzegovina, Bulgaria, Greece, Montenegro, North Macedonia and Serbia) and Italy. Rates for both sexes in Croatia were also extracted, as Croatia is included in the regional trend charts. Trends in age-standardised incidence for 1990–2023 and incidence in adults aged 55 years and over by sex were obtained from GBD Compare and are reproduced without modification. GBD estimates are modelled and age-standardised, whereas the registry rates are crude; for this reason, the two sources were not compared directly, and GBD estimates were used only to compare countries with each other.

RESULTS

National incidence

In 2024, 4990 new cases of stroke were registered in Albania: 2801 in males (56.1%) and 2189 in females (43.9%). The national incidence was 207.7 per 100 000 population, slightly lower than in 2023 (210.3 per 100 000), a decrease of 1.2%. Incidence was 235.3 per 100 000 in males and 180.7 in females (238.6 and 182.6 in 2023), giving a male-to-female rate ratio of 1.3.

Incidence by county and sex

Incidence varied widely between counties (Figure 1). The highest rates were recorded in Fier (341.5 per 100 000), Vlorë (302.7) and Lezhë (293.8), and the lowest in Durrës (73.6), Dibër (163.3) and Tiranë (164.5). Compared with 2023, the largest increases were in Fier (from 241.7) and Elbasan (from 168.5 to 231.7), while the largest decrease was in Durrës (from 238.5).

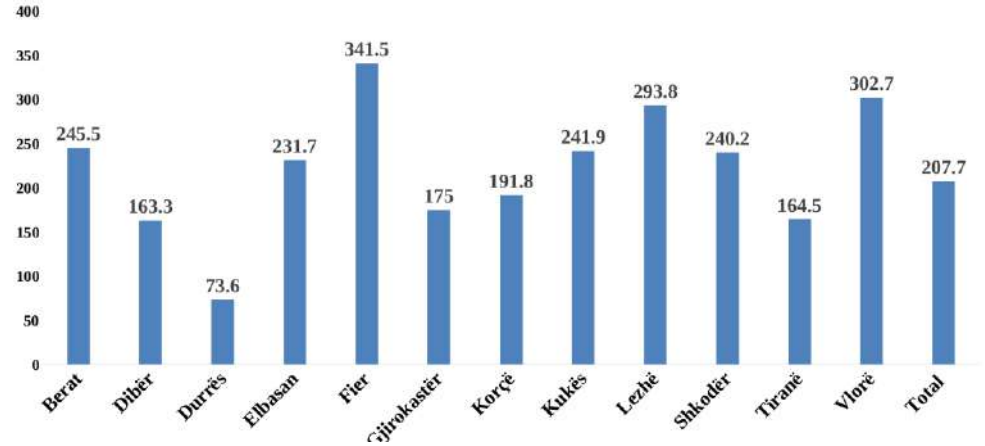


Figure 1. Stroke incidence per 100 000 population by county, Albania, 2024

Male incidence was higher than female incidence in 11 of the 12 counties (Figure 2). Korçë was the only exception (195.8 in females vs 187.9 in males), and in Durrës the rates were almost equal (74.7 vs 72.6). The highest male rates were in Vlorë (382.5) and Fier (365.1), and the highest female rates in Fier (317.7) and Lezhë (273.5). The sex gap was largest in Gjirokastër and Vlorë, where the male rate was about 1.7 times the female rate.

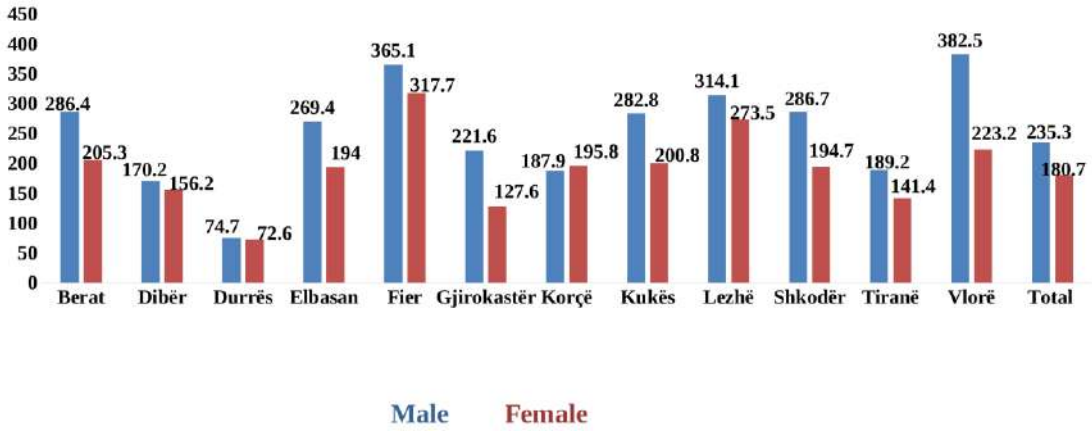


Figure 2. Stroke incidence per 100 000 population by county and sex, Albania, 2024

Incidence by age group and sex

Stroke was rare before the age of 30, with fewer than 10 cases per 100 000 in every age group in both sexes (Figure 3). Rates remained low until 39 years, although they were already higher in men (28.0 vs 10.9 per 100 000 at 35-39 years). From the age of 50, incidence rose steeply in each successive age group. The highest rate in men was at 85 years and over (1687.1 per 100 000), and in women at 80-84 years (1373.0).

The difference between sexes was largest at 55-64 years, when the male rate was about twice the female rate (243.2 vs 107.5 at 55-59 years and 385.0 vs 190.3 at 60-64 years). After 65 years the gap narrowed (rate ratio about 1.5 at 65-74 and 1.2 at 75-79 years), and at 80-84 years the rate in women was slightly higher than in men (1373.0 vs 1342.2).

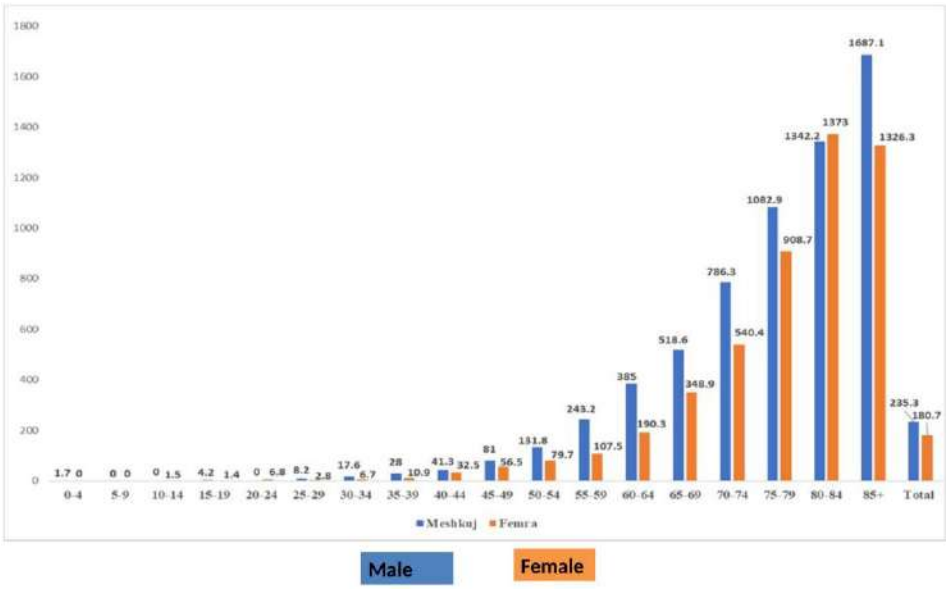


Figure 3. Stroke incidence per 100 000 population by age group and sex, Albania, 2024 (Meshkuj = males, Femra = females)

Regional comparison

According to GBD estimates, the age-standardised incidence of stroke in Albania in 2023 was 143.8 per 100 000 population for both sexes. Among the Balkan countries compared, the highest rates were in North Macedonia (242.4) and Bulgaria (209.8), followed by Montenegro (168.9) and Bosnia and Herzegovina (165.8). The rate in Albania was slightly lower than in Serbia (147.9) and higher than in Croatia (104.6) and Greece (95.4).

Incidence declined in all countries over the period 1990-2023, with the steepest fall around 2010-2015 (Figure 4). In Albania, the age-standardised rate fell from 158.1 per 100 000 in 2013 to 143.8 in 2023, a decrease of about 9% over ten years, or roughly 1% per year. Over the last few years, the rate in Albania has remained stable, while North Macedonia showed a small increase after 2020.

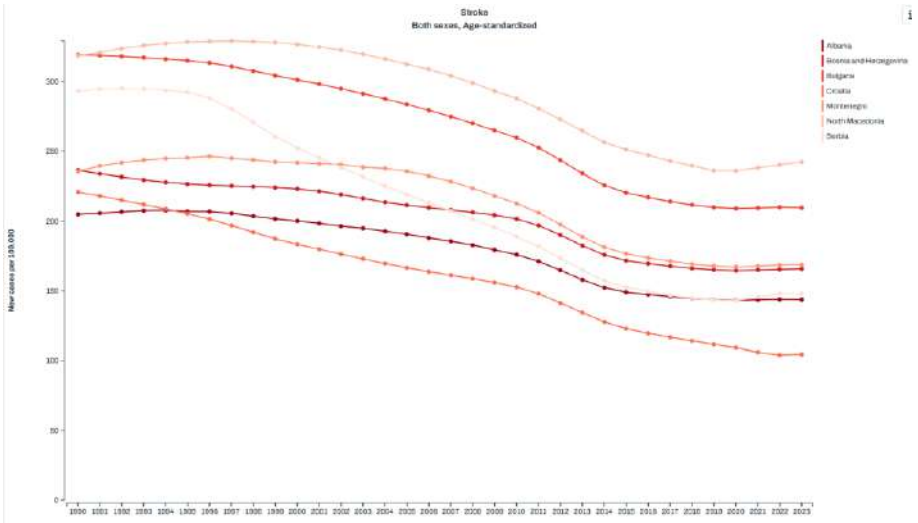


Figure 4. Trends in age-standardised stroke incidence per 100 000 population, both sexes, 1990–2023 (source: IHME, GBD Compare)

The sex-specific estimates showed a different position for Albania in men and women (Figure 5). Among men, the rate in Albania (143.4 per 100 000) was lower than in Serbia (174.4), Montenegro (188.9), Bosnia and Herzegovina (199.1), Bulgaria (252.5) and North Macedonia (309.1), and higher only than in Greece (109.9) and Italy (84.5). Among women, Albania (143.0) ranked fourth of eight countries, after North Macedonia (185.8), Bulgaria (174.3) and Montenegro (150.8), and above Bosnia and Herzegovina (138.9), Serbia (125.8), Greece (82.9) and Italy (55.9). In all comparison countries, the male rate exceeded the female rate by 25-66%, whereas in Albania the two rates were almost the same.

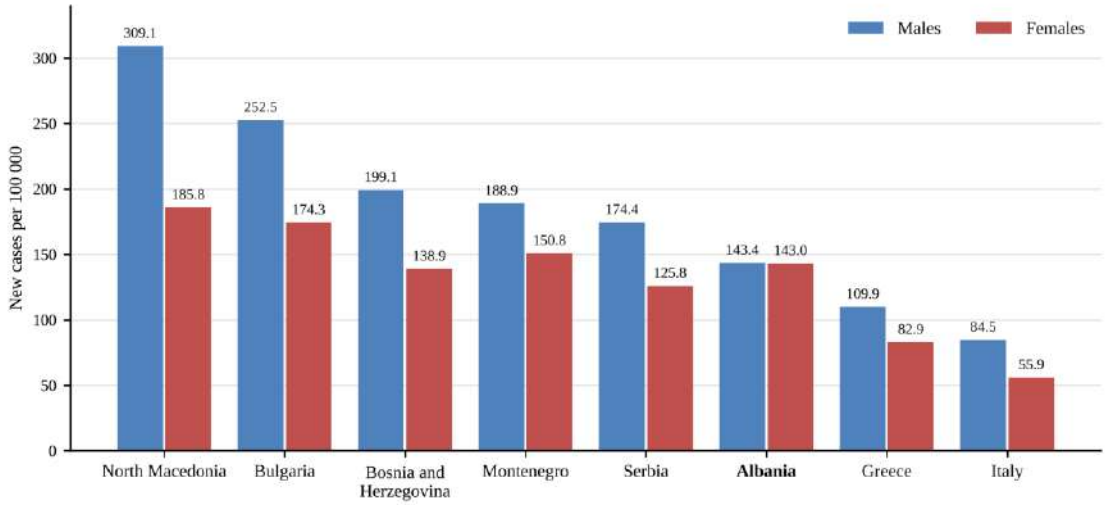


Figure 5. Age-standardised stroke incidence per 100 000 population by sex and country, 2023 (data source: IHME, GBD)

A similar pattern was seen in adults aged 55 years and over (Figure 6). Incidence declined over time in both sexes in most countries. Among men, Albania had one of the lowest rates in the region, close to Croatia and well below North Macedonia. Among women, Albania was at an intermediate level, above Croatia and below Montenegro and North Macedonia. Unlike the other countries, the GBD estimates for Albania did not show a higher incidence in men than in women in this age group.

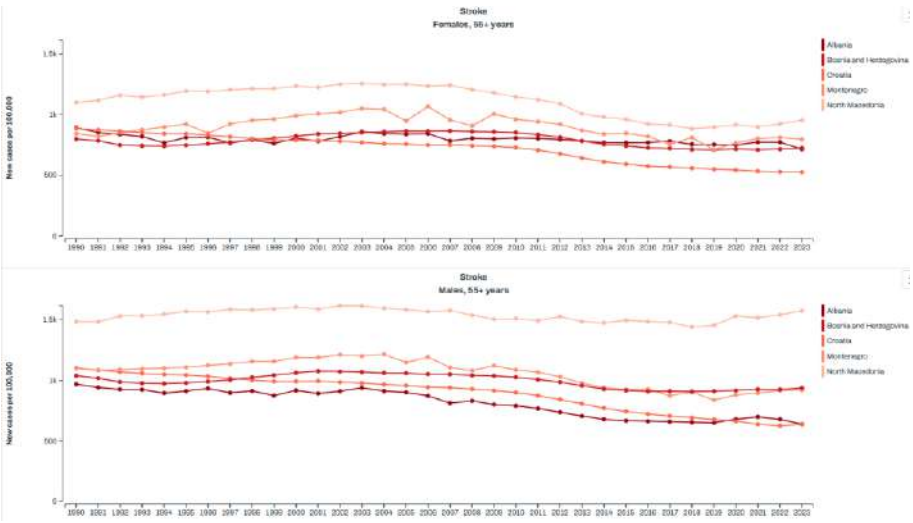


Figure 6. Stroke incidence per 100 000 population in adults aged 55 years and over, by sex, 1990-2023 (source: IHME, GBD Compare)

DISCUSSION

In 2024, the incidence of hospitalised stroke in Albania was 207.7 per 100 000 population, almost unchanged from the previous year. The registry rate is higher than the GBD age-standardised estimate for Albania (143.8 per 100 000). This difference is expected, because the registry rate is crude and depends on the age structure of the population. The Albanian population has aged in recent decades, partly because of the emigration of younger adults, which raises the crude rate compared with a rate standardised to a reference population.

The age and sex pattern in the registry is consistent with findings from other countries. Stroke was rare before 40 years, increased sharply after 50, and was more frequent in men in middle age, with women reaching similar rates only in the oldest age groups (Bushnell et al., 2018). The larger difference at 55-64 years may reflect greater exposure of men to smoking, hypertension and other cardiovascular risk factors. Even though rates in young adults were low, studies in other European populations have shown an increase in stroke among young people (Béjot et al., 2014), so this group should continue to be monitored.

The most notable finding of the comparison is the sex difference. In all neighbouring countries and in Italy, GBD estimates show a clearly higher incidence in men, while for Albania the rates for men and women are almost equal. Our registry, in contrast, shows a 30% higher rate in men. We cannot explain this difference with the available data. One possible reason is that GBD estimates for countries with limited published data rely more on statistical modelling; another is that the registry includes only hospitalised cases, and access to hospital care may differ between men and women. Using national registry data as an input to international estimates could help to clarify this question.

Albania ranks in the lower part of the Balkan region, and its incidence has declined slowly over the last decade, in line with the general trend in Europe (Wafa et al., 2020). Several factors may help explain the current figures, although our study was not designed to test them. Hypertension, diabetes, obesity, smoking and high cholesterol remain common in the Albanian population, and uncontrolled blood pressure is the main modifiable cause of stroke (WHO, 2023). Longer life expectancy and population ageing increase the number of people in the age groups at highest risk. Unhealthy diet and physical inactivity add to this risk. On the other hand, the free annual check-up programme for people aged 35-75 years offers an opportunity for early detection and treatment of hypertension, and improvements in hospital services and diagnosis have made the registration of cases more complete.

The large differences between counties should be interpreted with caution. They may reflect real differences in population structure and in the distribution of risk factors, but also differences in case detection and reporting. The fall in Durrës from 238.5 to 73.6 per 100 000 within one year is unlikely to reflect a real change in disease occurrence, and the completeness of reporting from this county needs to be reviewed.

This study has some limitations. The registry includes only hospitalised cases, so strokes managed outside hospital and sudden deaths before admission are not counted, and the true incidence is likely to be higher. Stroke subtypes were not analysed. Registry rates were not age-standardised and cannot be compared directly with GBD estimates. Finally, the GBD values are modelled estimates and may not fully reflect the situation in countries with limited primary data.

CONCLUSION

The incidence of hospitalised stroke in Albania in 2024 was 207.7 per 100 000 population, with a 30% higher rate in men than in women and a steep increase after the age of 50. Within the Balkan region, Albania has one of the lower stroke incidences, and its age-standardised rate has declined by about 9% over the last ten years. However, the burden remains considerable. Unlike neighbouring countries, GBD estimates show almost no sex difference in Albania, which does not agree with registry data and should be investigated further. Better control of hypertension and other cardiovascular risk factors, especially in middle-aged men and older adults, more complete reporting from all counties, and the inclusion of out-of-hospital cases in the registry are recommended.

REFERENCES

Béjot Y, Daubail B, Jacquin A, Durier J, Osseby GV, Rouaud O, Giroud M 2014. Trends in the incidence of ischaemic stroke in young adults between 1985 and 2011: the Dijon Stroke Registry. Journal of Neurology, Neurosurgery and Psychiatry, 85(5): 509–513.

Bushnell C, Howard VJ, Lisabeth L, et al. 2018. Sex differences in the evaluation and treatment of acute ischaemic stroke. The Lancet Neurology, 17(7): 641–650.

Feigin VL, Abate MD, Abate YH, et al. 2024. Global, regional, and national burden of stroke and its risk factors, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. The Lancet Neurology, 23(10): 973–1003.

GBD 2016 Lifetime Risk of Stroke Collaborators 2018. Global, regional, and country-specific lifetime risks of stroke, 1990 and 2016. New England Journal of Medicine, 379(25): 2429–2437.

IHME 2025. GBD Compare. Seattle, WA: Institute for Health Metrics and Evaluation, University of Washington. Available at: https://vizhub.healthdata.org/gbd-compare/ [18.10.26]

INSTAT 2024. Population and Housing Census 2023. Tirana: Institute of Statistics.

Institute of Public Health 2025. Epidemiological situation of cerebrovascular accidents in Albania, 2023–2024 [in Albanian]. Tirana: Institute of Public Health.

Wafa HA, Wolfe CDA, Emmett E, Roth GA, Johnson CO, Wang Y 2020. Burden of stroke in Europe: thirty-year projections of incidence, prevalence, deaths, and disability-adjusted life years. Stroke, 51(8): 2418–2427.

WHO 2023. Global report on hypertension: the race against a silent killer. Geneva: World Health Organization.

WHO EMRO n.d. Stroke, cerebrovascular accident. Cairo: World Health Organization, Regional Office for the Eastern Mediterranean. Available at: https://www.emro.who.int/health-topics/stroke-cerebrovascular-accident/ [09.10.26]

BREAST CANCER DORMANCY AND MINIMAL RESIDUAL DISEASE: MOLECULAR MECHANISMS AND THERAPEUTIC CHALLENGES

Maroua RIAD
Ahmad AL-SHAMI
Jamal MABROUKI
Laboratory of Spectroscopy, Molecular Modelling, Materials, Nanomaterials, Water and Environment, CERN2D, Mohammed V University in Rabat, Faculty of Science, AV Ibn Battouta, Agdal, Rabat 10106, Morocco

Abstract

Breast cancer recurrence remains a major clinical challenge, particularly because disseminated tumor cells can persist in a dormant state for prolonged periods following apparently successful treatment. Tumor dormancy represents a complex biological phenomenon in which residual cancer cells remain viable but exhibit limited proliferative activity, allowing them to evade conventional therapies and potentially reactivate years after initial treatment. Molecular mechanisms involved in breast cancer dormancy include alterations in cell-cycle regulation, stress responses, immune surveillance, angiogenic signaling, and interactions with the surrounding microenvironment. The concept of minimal residual disease has further gained attention as a potential indicator of persistent tumor cells that may contribute to future relapse. Recent advances in molecular profiling and liquid-based approaches have created new opportunities for detecting residual disease and identifying patients at increased risk of recurrence. Understanding the transition between dormancy and metastatic outgrowth may also reveal therapeutic vulnerabilities that could be exploited before clinical relapse occurs. However, accurately identifying dormant tumor cells and distinguishing clinically relevant residual disease from biologically inactive cells remain important challenges. This review summarizes current knowledge of the molecular mechanisms underlying breast cancer dormancy and minimal residual disease and discusses emerging strategies for detection, risk stratification, and therapeutic intervention aimed at preventing late recurrence.

Keywords: Breast cancer; Tumor dormancy; Minimal residual disease; Disseminated tumor cells; Cancer recurrence; Metastasis; Tumor microenvironment; Therapeutic resistance.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FIXED-TIME SYNCHRONIZATION OF HYPERCHAOTIC SYSTEMS

Israr Ahmad
Department of Mathematics and Computer Science, Coppin State University, Baltimore, Maryland, United States.

Abstract

This paper presents a continuous hyperbolic-sine-based feedback controller for the fixed-time synchronization of two identical Lorenz-type hyperchaotic systems. Unlike conventional cancellation-based designs, the proposed controller does not require explicit cancellation of the system nonlinearities and generates smooth control inputs. The analysis is conducted on a prescribed forward-invariant operating region, where a one-sided Lipschitz bound characterizes nonlinear growth along the synchronization-error direction and the linear feedback gain is chosen to dominate this bound. The hyperbolic-sine structure induces a sublinear Lyapunov power near the synchronization manifold and a superlinear power away from it, thereby ensuring exact fixed-time convergence. A Lyapunov-based theorem establishes synchronization within the stated region and provides a settling-time upper bound independent of the initial conditions. Numerical simulations further demonstrate the theoretical results, showing the error trajectories converges to zero in 0.4165 seconds well within the analytical upper bound of 5.08 seconds.

Keywords: Chaos synchronization; Fixed-time stability; Nonlinear controller; Lorenz-Stenflo hyperchaotc system.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE ILLUSION OF ORGANIZATIONAL CHANGE: WHEN INNOVATION BECOMES SYMBOLIC RATHER THAN TRANSFORMATIVE

Amal Algouti
0009-0001-9644-0881, Cadi Ayyad University, Faculty of Legal Economic and Social Sciences, Department of Management Sciences, Marrakech, Morocco.

Abstract

Organizations increasingly promote innovation initiatives to demonstrate adaptability and maintain legitimacy in rapidly changing environments. However, not all innovation efforts lead to substantive organizational transformation. In many cases, innovation remains largely symbolic, creating an appearance of change while underlying structures, routines, and organizational practices remain unchanged. Although research has extensively examined organizational change and symbolic management separately, limited attention has been given to understanding how symbolic innovation influences employees' perceptions of organizational transformation. This study proposes a conceptual framework to explore the phenomenon of the illusion of organizational change by integrating insights from institutional theory and sensemaking theory. It argues that employees actively interpret organizational signals to assess whether innovation initiatives represent genuine transformation or symbolic compliance. These interpretations are expected to influence trust in management, organizational commitment, and support for future change initiatives. To investigate this phenomenon, the study proposes a qualitative research design based on semi-structured interviews with employees from organizations undergoing innovation or digital transformation initiatives. By shifting the focus from organizational intentions to employee interpretations, this research seeks to extend the literature on organizational change while providing practical insights for managers seeking to implement authentic and credible innovation strategies.

Keywords: Organizational Change; Symbolic Innovation; Sensemaking; Institutional Theory; Organizational Legitimacy; Employee Perceptions.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

RETHINKING MACROECONOMIC NOWCASTING AND FORECASTING: INTEGRATING ECONOMETRICS AND ARTIFICIAL INTELLIGENCE

Altay Mahmudov
PhD Candidate, Azerbaijan State University of Economics (UNEC)

Abstract

The increasing complexity of modern economies, structural transformations, and the growing availability of high-frequency data have challenged traditional approaches to macroeconomic analysis and prediction. Conventional econometric models, while providing theoretically grounded and interpretable frameworks, often face limitations in capturing nonlinear relationships, structural breaks, and rapidly changing economic conditions. Against this background, the integration of artificial intelligence (AI) into macroeconometric analysis presents new opportunities for improving real-time economic assessments and short-term forecasting. This study examines the evolving relationship between traditional macroeconometric methods and AI-based techniques, focusing on their applications in macroeconomic nowcasting and forecasting. Adopting a conceptual and comparative methodological approach, the research explores three interconnected dimensions: the theoretical foundations of conventional econometric forecasting, the potential contributions of machine learning and large language models to predictive analysis, and the development of hybrid frameworks integrating econometric interpretability with AI-driven predictive capabilities.

Drawing on recent academic literature and institutional research, including previous findings by Mahmudov on the opportunities and risks of AI implementation in central banking, the study considers how alternative data sources, nonlinear modelling techniques, and advanced computational methods may enhance macroeconomic monitoring. Particular attention is devoted to methodological challenges involving data quality, model transparency, overfitting, structural instability, and the trade-off between predictive accuracy and economic interpretability.

The study argues that AI-based forecasting should be viewed not as a replacement for traditional macroeconometrics but as a complementary methodological advancement. It proposes a conceptual framework for integrating econometric reasoning with data-driven prediction, highlighting the importance of explainability, robustness, and institutional oversight. The research contributes to ongoing discussions on the methodological evolution of macroeconomic forecasting and identifies directions for future empirical investigation.

Keywords: Macroeconometrics; Artificial Intelligence; Nowcasting; Macroeconomic Forecasting; Machine Learning; Hybrid Models.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

SUSTAINABILITY DISCLOSURE AND THE COST OF DEBT: PANEL EVIDENCE FROM SAUDI NON-FINANCIAL LISTED FIRMS

Wahiba HENNICHE
Department of Accounting, College of Business, King Khalid University, KSA
ORCID: https://orcid.org/0009-0003-5226-4809

Abstract

Whether sustainability disclosure reduces borrowing costs remains an open question in Saudi Arabia. Reporting has gained attention under Vision 2030, but a single mandatory framework has not yet been established. This study examines the association between sustainability disclosure and the cost of debt among non-financial firms listed on the Saudi Exchange (Tadawul). Signalling, legitimacy, stakeholder and agency theories suggest that greater transparency may lower financing costs. Other studies argue that the expense of implementing sustainability strategies can increase them. Accordingly, this study tests whether prior-year disclosure is positively associated with current cost of debt.

The sample comprises 125 firms selected through proportional stratified and purposive sampling from 180 non-financial listed firms across 18 sectors. The initial panel covers 2021–2023 (375 firm-year observations). Annual and sustainability reports are assessed using a binary content-analysis checklist informed by IFRS S1, IFRS S2 and the Global Reporting Initiative. Each item is coded 1 if disclosed and 0 otherwise. Cost of debt is measured as interest expense divided by average interest-bearing debt. Because disclosure is lagged by one year, 2021 outcome observations are excluded. The fixed-effects regressions therefore cover 125 firms in 2022–2023 (250 firm-year observations). Controls include firm size, leverage, sales growth, firm age, earnings per share and board size; robust standard errors are used.

Lagged sustainability disclosure is positively associated with cost of debt ($p < 0.001$). Year-specific estimates show a significant association for 2023 cost of debt, paired with 2022 disclosure, but no significant association for 2022 cost of debt, paired with 2021 disclosure. One possible explanation is that lenders at this early stage may view disclosure alongside transition costs rather than as clear evidence of lower risk. The findings support developing a consistent national disclosure framework and green-financing incentives that may help firms manage borrowing costs.

Keywords: Sustainability disclosure; Cost of debt; Saudi Arabia.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

CAN WE TRUST AI PREDICTIONS OF PUBLIC PROJECT OVERRUNS? A STATISTICAL RE-EVALUATION

Olgerta Idrizi
Dr., Faculty of Informatics, Mediterranean University of Albania, Tirana, Albania

Abstract

Many studies claim that artificial intelligence (AI) can predict cost and schedule overruns in public projects with an accuracy of 85–90% or higher. This study examines the reliability of such claims. First, a review of 35 published studies found that only four quantified the uncertainty of their forecasts and only one tested whether its model was statistically superior to alternatives. Second, prediction models were re-evaluated on open World Bank data covering 9,960 closed public projects in 180 countries, using implementation delay at the effectiveness stage as the outcome. Logistic regression, random forest and gradient boosting were assessed within a Bayesian framework that combined descriptive statistics, hierarchical logistic regression, Monte Carlo simulation and uncertainty quantification. Overall, 67.6% of projects were delayed, and financing type and lending instrument were the factors most strongly associated with delay. Under temporal validation, the best models reached about 69% accuracy, only 6.4 percentage points above a naive rule that classifies every project as delayed (62.7%), and the random forest performed no better than logistic regression. Reported accuracy was inflated by about nine percentage points under random cross-validation, increased artificially when post-completion information was included, and varied between 52% and 84% when test samples were small. Albania had the highest delay rate in the Western Balkans (82.5%), and the models underestimated its delays by about 20%. We conclude that AI can support project risk assessment only when it is validated with appropriate statistical methods, and we propose simple evidence rules for public institutions.

Keywords: artificial intelligence; public projects; implementation delays; Bayesian evaluation; model validation; Western Balkans.

INTRODUCTION

Delays represent the most persistent challenges in the delivery of public investment projects. In a study of 258 transport infrastructure projects, Flyvbjerg et al. (2002) discovered that nearly nine out of ten exceeded their estimated costs, a pattern attributed not only to technical forecasting errors but also to optimism bias and strategic misrepresentation during appraisal. Investigation on World Bank operations indicates that project outcomes depend on both country-level conditions and project-level characteristics such as size, duration and supervision quality (Denizer et al., 2013; Ika et al., 2012). The consequences of overruns are particularly serious in economies with limited fiscal capacity, where delayed services and misallocated resources have a high opportunity cost.

Techniques in artificial intelligence (AI) and machine learning (ML) are increasingly proposed for the early identification of projects at risk. Following the initial use of neural networks to construction cost estimation (Ahiaga-Dagbui and Smith, 2014), studies have used decision trees, random forests, gradient boosting and deep learning, frequently reporting accuracies of 85–90% or more. These statistics have contributed to the perception that AI tools are ready to inform public investment decisions.

The validity of these claims, however, depends on how performance is evaluated. Because overruns are frequent, project datasets are imbalanced, and a trivial classifier that assigns every project to the majority class can attain high accuracy without any discriminative ability; measures that account for the base rate are therefore more informative (Saito and Rehmsmeier, 2015). Differences between algorithms may reflect sampling variability and require formal statistical comparison (Demšar, 2006). Data leakage, the use of information unavailable at the time of prediction, has been documented in hundreds of ML-based studies and

can substantially overstate performance (Kapoor and Narayanan, 2023). Finally, the uncertainty of individual predictions can be quantified with distribution-free methods such as conformal prediction (Angelopoulos and Bates, 2023), yet such methods are rarely applied to project overruns.

A review of 35 published studies focused on AI-based prediction of public project delys confirms that these concerns are of practical relevance: only four studies assessed the uncertainty of their forecasts, and only one tested whether its model performed significantly better than alternative approaches. Evidence is particularly limited in the Western Balkans, where public investment has increased in the context of European Union accession but remains constrained by weaknesses in project appraisal and implementation (IMF, 2018).

This study therefore asks to what extent the reported performance of AI models for predicting public project overruns can be considered reliable. Using open World Bank data on 9,960 closed projects, it re-examines widely used prediction methods within a Bayesian evaluation framework, with particular attention to the Western Balkans and Albania, and translates the findings into evidence rules for public institutions.

MATERIALS AND METHODS

Data and Outcome Variable

The analysis uses the World Bank Projects and Operations database (World Bank, 2026), extracted on 8 November 2026. Of 28,238 projects in the export, 18,332 were closed. Projects with missing or implausible approval and effectiveness dates (an interval below zero or above ten years), without a recorded financing type or with a project cost of zero were excluded, giving a final sample of 9,960 closed projects approved between 1981 and 2026 in 180 countries and multi-country groupings.

Because the database does not record planned completion dates or planned costs, the outcome is defined as an **effectiveness delay**: a binary variable equal to 1 when more than 90 days elapsed between Board approval and the date on which the financing agreement became effective. This measure captures the early implementation stage, in which legal, institutional and fiscal readiness are tested. Predictors were restricted to characteristics known at approval: financing type (IDA, IBRD, grants, other), lending instrument, environmental assessment category, primary sector, region, project cost (log, standardized), approval year (standardized) and a Western Balkans indicator (Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Serbia). Project duration, known only at closing, was used exclusively to test the effect of data leakage.

Prediction Models and Validation Design

Four approaches were compared: a naive rule that classifies every project as delayed, logistic regression, random forest (300 trees) and gradient boosting. The primary validation design is a **temporal split**, in which models were trained on projects approved up to 2010 (n = 6,365) and tested on projects approved from 2011 onwards (n = 3,595), reproducing the practical task of predicting future projects from past experience. The secondary design is repeated stratified 10-fold cross-validation (five repetitions), the strategy most often used in the literature. Performance was measured by accuracy, the area under the ROC curve (AUC) and the Brier score, and accuracy was always interpreted relative to the no-information rate of the test set.

Bayesian Inference

The determinants of delay were estimated with a hierarchical Bayesian logistic regression with a random intercept for each country, which accounts for unobserved country conditions and allows countries with few projects to borrow strength from the overall distribution. For project i in country c:

$$y_i \sim Bernoulli(p_i), \quad logit(p_i) = \alpha + x_i^{\top}\beta + u_{c[i]}, \quad u_c \sim N(0, \sigma_u^2) \tag{1}$$

where y_i is the delay indicator, $\mathbf{x}_i$ the vector of predictors, $\boldsymbol{\beta}$ their coefficients and u the country-specific random effect. Weakly informative priors were used: $\alpha \sim N(0, 2.5^2)$, $\beta_k \sim N(0, 1)$ and $\sigma_u \sim$ Half-Normal(1). The posterior was sampled with the No-U-Turn Sampler (Hoffman and Gelman, 2014) in PyMC (four chains of 1,500 draws after 1,500 tuning iterations). Results are reported as posterior median odds ratios (OR) with 95% credible

intervals (CrI) and the probability P(OR > 1). Delay rates of groups were estimated with a Beta–Binomial model; with *k* delayed projects out of *n* and a uniform prior, the posterior of the delay rate θ is:

$$\theta \mid k,n \sim Beta(1+k,\ 1+n-k) \quad (2)$$

For Albania, sensitivity to the prior was examined with a Jeffreys prior and informative priors centered at the overall rate with prior sample sizes of 20, 100 and 500 projects.

Bayesian Evaluation of Predictive Performance

Five procedures were applied. (i) The accuracy of each model was modelled as a Beta–Binomial posterior and compared with a region of practical equivalence (ROPE) of ±2 percentage points around the no-information rate (Kruschke, 2018). (ii) Paired differences in accuracy and Brier score were estimated with the Bayesian bootstrap (Rubin, 1981). (iii) Differences across cross-validation folds were evaluated with the Bayesian correlated t-test (Benavoli et al., 2017). (iv) Calibration was assessed by Bayesian logistic recalibration of outcomes on the logit of predicted probabilities (ideal intercept 0, slope 1). (v) For each region, observed (O) and expected (E) delays were compared through a Gamma–Poisson posterior of O/E. Two sensitivity analyses addressed data leakage, by adding project duration to the random forest, and test-sample size, through a Monte Carlo simulation drawing 2,000 random test subsamples of 25 to 1,000 projects. All analyses were carried out in Python with scikit-learn, SciPy and PyMC.

RESULTS

Descriptive Statistics and Determinants of Delay

Of the 9,960 projects, 6,731 (67.6%; 95% CrI 66.7–68.5%) experienced an effectiveness delay; the median interval between approval and effectiveness was 134 days. Delay rates were highest for IBRD-financed projects (78.9%) and lowest for grants (45.9%), and ranged from 75.8% in Latin America and the Caribbean to 57.1% in the Middle East and North Africa. The hierarchical model converged well (all $\hat{R} \leq 1.003$, no divergent transitions). Table 1 shows that financing type and lending instrument were the strongest predictors: IBRD projects had 40% higher odds of delay than IDA projects, and development policy operations had odds almost nine times lower than investment projects. Larger projects were more often delayed, and delays declined over time. Country effects showed substantial heterogeneity ($\sigma_u = 0.57$; 95% CrI 0.48–0.68), whereas the Western Balkans indicator was not credibly different from the rest of Europe and Central Asia.

Table 1. Posterior odds ratios of effectiveness delay, hierarchical Bayesian logistic regression (n = 9,960)

Predictor	OR (median)	95% CrI	P(OR > 1)
Financing: IBRD (ref. IDA)	1.40	1.17–1.68	1.00
Financing: grants (ref. IDA)	0.31	0.27–0.37	0.00
Instrument: development policy (ref. investment)	0.12	0.09–0.15	0.00
Instrument: technical assistance (ref. investment)	0.49	0.40–0.61	0.00
Sector: water and sanitation (ref. public admin.)	1.32	1.05–1.67	0.99
Project cost, log (per SD)	1.24	1.15–1.34	1.00
Approval year (per SD)	0.88	0.82–0.94	0.00
Western Balkans (ref. rest of Europe and Central Asia)	1.31	0.72–2.35	0.81

Note: The model also includes environmental category, remaining sectors, region and country random intercepts. OR = odds ratio; CrI = credible interval.

Predictive Performance against the Naive Benchmark

In the temporal test set, 62.7% of projects were delayed, so the naive rule achieved 62.7% accuracy. All models exceeded this benchmark (Table 2 and Figure 1): logistic regression and random forest reached about 69%, an improvement of 6.4 percentage points (95% CrI 4.7–8.0), and the probability of exceeding the ROPE was effectively 1. However, the random forest was not more accurate than logistic regression: the difference was below 0.1 percentage points (95% CrI −1.4 to 1.3), with a probability of 0.995 of lying within the ROPE. The random forest produced slightly better-calibrated probabilities (slope 0.99 versus 0.83 for logistic regression).

Table 2. Predictive performance on the temporal test set (projects approved 2011 onwards, n = 3,595)

Model	Accuracy (%)	95% CrI	AUC	Brier score
Naive rule (all delayed)	62.7	61.1–64.2	0.500	0.373
Logistic regression	69.1	67.5–70.6	0.747	0.197
Random forest	69.0	67.5–70.5	0.753	0.192
Gradient boosting	68.1	66.6–69.6	0.740	0.201

Note: Credible intervals from Beta–Binomial posteriors with a uniform prior.

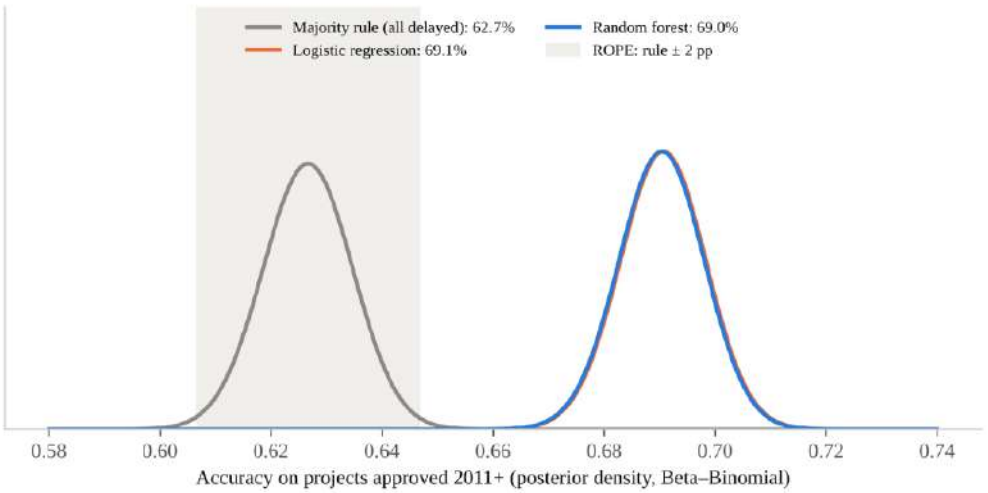


Figure 1. Posterior distributions of accuracy for the naive rule, logistic regression and random forest on the temporal test set; the shaded band is the ROPE of ±2 percentage points around the naive benchmark

Validation Design, Data Leakage and Test-Sample Size

Under random cross-validation, the random forest reached 78.0% accuracy (AUC 0.827) and logistic regression 76.1%, about nine percentage points above the temporal-split results, because random partitioning lets models learn from projects approved after those they predict. Adding project duration, which is known only at closing, raised the AUC of the random forest from 0.753 to 0.774 (difference 0.021; 95% CrI 0.014–0.029) and accuracy from 69.0% to 71.8%, an entirely artificial gain. The Monte Carlo simulation (Table 3 and Figure 2) shows that small test samples produce highly unstable results: with 25 test projects, accuracy ranged from 52% to 84%, and the model beat the naive rule in only 67% of subsamples.

Table 3. Monte Carlo simulation of random forest accuracy by test-sample size (2,000 subsamples each)

Test projects	2.5th pct. (%)	Median (%)	97.5th pct. (%)	Beats naive rule (%)
25	52.0	68.0	84.0	67.4
50	56.0	70.0	82.0	76.8
100	60.0	69.0	78.0	88.0
200	63.0	69.0	75.5	96.0
500	65.2	69.0	72.6	99.8
1,000	66.6	69.1	71.5	100.0

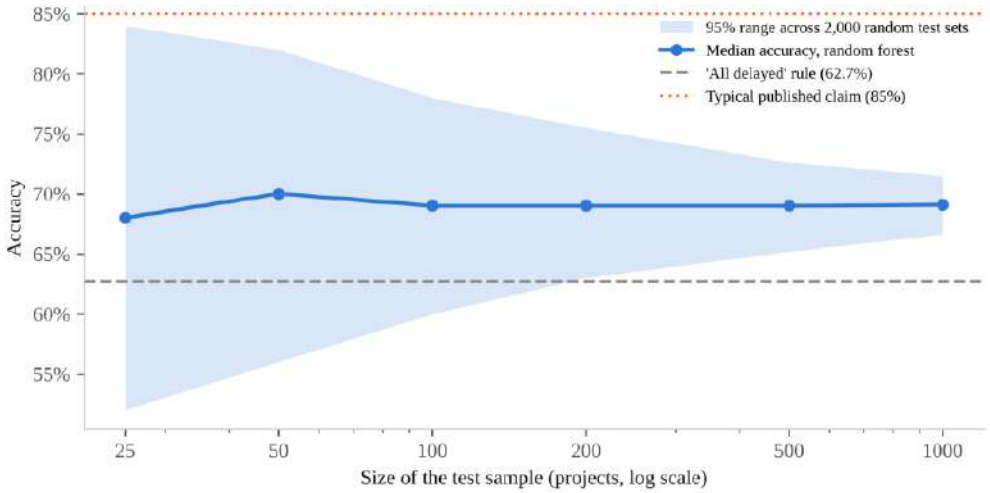


Figure 2. Random forest accuracy as a function of test-sample size compared with the naive benchmark and the accuracy commonly reported in the literature

The Western Balkans and Albania

The 375 Western Balkan projects had a delay rate of 71.5% (95% CrI 66.7–75.8%), but the pattern differed between countries (Table 4). Albania recorded the highest rate, with 85 of 103 projects delayed (82.5%), and was the only country whose credible interval lay entirely above the overall rate. After adjusting for project characteristics, Albania's country effect corresponded to about twice the odds of delay of an average country (OR = 2.01; 95% CrI 1.08–3.91; P(OR > 1) = 0.985). The result was robust to the prior: the probability that Albania's rate exceeds the overall rate remained 0.91 even under a skeptical prior equivalent to 500 projects. The random forest expected about 71 delayed Albanian projects, whereas 85 occurred (O/E = 1.20; 95% CrI 0.95–1.46; P(O/E > 1) = 0.94); no other region showed comparable underestimation (Figure 3).

Table 4. Effectiveness delay in the Western Balkans

Country	Projects	Delayed (%)	95% CrI (%)	Country OR (95% CrI)
Albania	103	82.5	74.0–88.6	2.01 (1.08–3.91)
Bosnia and Herzegovina	78	73.1	62.3–81.7	1.05 (0.55–1.94)
Serbia	62	72.6	60.3–82.1	1.47 (0.74–2.88)
Montenegro	19	68.4	45.7–84.6	0.74 (0.32–1.72)
North Macedonia	55	63.6	50.4–75.1	0.64 (0.32–1.29)
Kosovo	52	55.8	42.3–68.4	0.84 (0.42–1.66)

Note: Delay rates from Beta–Binomial posteriors; country OR = posterior odds multiplier of the country random intercept relative to an average country.

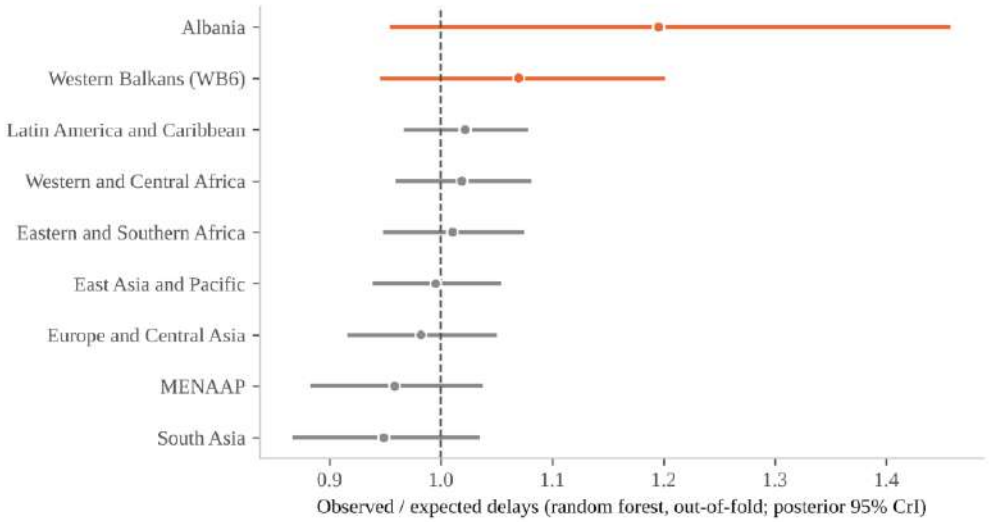


Figure 3. Ratio of observed to expected delays by region, based on out-of-fold random forest predictions (posterior medians and 95% credible intervals); values above 1 indicate that the model underestimates delays

DISCUSSION

The results give a nuanced answer to the question posed in the title. AI models predict delays better than chance and better than a naive rule, but their advantage is modest, at about six percentage points, and far below the 85–90% accuracy often reported. The gap between published claims and the present results can be explained by three evaluation practices: random rather than temporal validation, which inflated accuracy by about nine points; the inclusion of post-approval information, which raised performance artificially; and small test samples, with which the same model could appear to reach 84% accuracy by chance alone. These findings are consistent with broader concerns about leakage and reproducibility in ML-based research (Kapoor and Narayanan, 2023).

Model complexity did not translate into better classification. A transparent logistic regression performed as well as a random forest, which agrees with simulation evidence for Albanian public projects showing that simple linear models can match or outperform more complex ensembles. The strong role of financing type and lending instrument indicates that early delays are driven largely by institutional and procedural requirements, such as ratification of agreements and fulfilment of effectiveness conditions, while the large country effects confirm the importance of national conditions (Denizer et al., 2013).

For Albania, the results carry a practical message. Albanian projects were delayed more often than those of any other Western Balkan country, and a model trained on global data understated their risk by about 20%. This points to country-specific factors not captured by standard project characteristics, such as procurement procedures, land acquisition and institutional capacity, which are consistent with the causes of delay identified in recent European Commission monitoring (CNA, 2026). Internationally developed AI tools therefore cannot be assumed to perform well locally without validation on national data.

CONCLUSION

This study combined a review of 35 published studies with a Bayesian re-evaluation of prediction models on 9,960 closed World Bank projects. AI models contain useful information about the risk of delay, but under realistic validation their advantage over a naive rule is modest, a simple logistic regression performs as well as a random forest, and much of the high accuracy reported in the literature reflects evaluation practices rather than genuine predictive ability. AI predictions of public project overruns can therefore be trusted only when their performance is verified with appropriate statistical methods. The study proposes the following evidence rules for public institutions:

- Compare with a simple benchmark and adopt a model only if it exceeds the majority-class rule by a practically meaningful margin.
- Report uncertainty for every performance measure and, where possible, for individual predictions.
- Validate on future projects rather than on randomly selected projects from the same period.
- Use only information available at decision time and exclude variables recorded during or after implementation.
- Require an adequate test sample of several hundred projects before drawing conclusions.
- Validate locally and recalibrate international models on Albanian projects before use.
- Prefer transparent models when their performance is equivalent, in line with the transparency requirements of the EU AI Act.

The study has limitations. The outcome measures delay at the effectiveness stage, because the data do not record planned completion dates or costs; the extension of the conclusions to cost overruns therefore rests on shared methodological principles rather than direct estimation. Future research should apply the same framework to cost overruns and completion delays using project-level data with planned and actual costs and dates, such as a national register of Albanian public investment projects.

REFERENCES

Ahiaga-Dagbui DD, Smith SD 2014. Dealing with construction cost overruns using data mining. Construction Management and Economics, 32(7-8): 682-694.

Angelopoulos AN, Bates S 2023. Conformal prediction: A gentle introduction. Foundations and Trends in Machine Learning, 16(4): 494-591.

Benavoli A, Corani G, Demšar J, Zaffalon M 2017. Time for a change: A tutorial for comparing multiple classifiers through Bayesian analysis. Journal of Machine Learning Research, 18(77): 1-36.

CNA, 2026. EC: Procurement and land ownership problems are delaying investments in Albania. Available at: https://www.cna.al/english/aktualitet/ke-prokurimet-dhe-problemet-me-pronesine-e-tokes-po-vonojne-investime-i471856 [19.08.26]

Demšar J 2006. Statistical comparisons of classifiers over multiple data sets. Journal of Machine Learning Research, 7: 1-30.

Denizer C, Kaufmann D, Kraay A 2013. Good countries or good projects? Macro and micro correlates of World Bank project performance. Journal of Development Economics, 105: 288-302.

Flyvbjerg B, Holm MS, Buhl S 2002. Underestimating costs in public works projects: Error or lie? Journal of the American Planning Association, 68(3): 279-295.

Hoffman MD, Gelman A 2014. The No-U-Turn Sampler: Adaptively setting path lengths in Hamiltonian Monte Carlo. Journal of Machine Learning Research, 15(47): 1593-1623.

Ika LA, Diallo A, Thuillier D 2012. Critical success factors for World Bank projects: An empirical investigation. International Journal of Project Management, 30(1): 105-116.

IMF, 2018. Public infrastructure in the Western Balkans: Opportunities and challenges. IMF Departmental Paper No. 18/02. Washington, DC: International Monetary Fund, 71 pp.

Kapoor S, Narayanan A 2023. Leakage and the reproducibility crisis in machine-learning-based science. Patterns, 4(9): 100804.

Kruschke JK 2018. Rejecting or accepting parameter values in Bayesian estimation. Advances in Methods and Practices in Psychological Science, 1(2): 270-280.

Rubin DB 1981. The Bayesian bootstrap. The Annals of Statistics, 9(1): 130-134.

Saito T, Rehmsmeier M 2015. The precision-recall plot is more informative than the ROC plot when evaluating binary classifiers on imbalanced datasets. PLoS ONE, 10(3): e0118432.

World Bank, 2026. Projects & Operations: Projects list. Available at: https://projects.worldbank.org/en/projects-operations/projects-list?os=0 [08.11.26]

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE STRATEGIC ROLE OF SOCIAL MARKETING IN ENHANCING THE SOCIOECONOMIC IMPACT OF SOCIAL ENTERPRISES

Elena Denisa MATEEVICI
Ivona RĂPAN
Anca CRISTEA
Felicia MICU
ORCID https://orcid.org/0009-0002-4344-419X, Romanian Academy, School of Advanced Studies of the Romanian Academy, Doctoral School of Economic Sciences, National Institute for Economic Research "Costin C. Kirițescu", Institute of National Economy, Bucharest, Romania.
ORCID https://orcid.org/0000-0001-8436-9494, Romanian Academy, Institute of National Economy, Bucharest, Romania.
ORCID https://orcid.org/0000-0001-5499-7836, Romanian Academy, The Institute for World Economy, Bucharest, Romania.
ORCID https://orcid.org/0009-0002-9401-6582, Elina Matei Basarab Economic Technological High School, Ramnicu Sarat, Romania.

Abstract

Social enterprises occupy a distinctive position between market activity and social responsibility, seeking to address societal needs while maintaining economic viability. Balancing these objectives is rarely straightforward. Beyond financial resources and organisational capabilities, their capacity to create lasting social value depends on how effectively they understand communities, engage stakeholders, and encourage meaningful behavioural change. Within this context, social marketing offers a strategic perspective that extends well beyond conventional promotional activities.

This paper explores the relationship between social marketing and the socioeconomic contribution of social enterprises through a conceptual analysis grounded in the literature on social entrepreneurship, stakeholder theory, and sustainable development.

The discussion examines how social marketing principles can inform organisational priorities, strengthen relationships with beneficiaries and local actors, and align economic activities with broader social objectives. Particular attention is given to stakeholder engagement, community participation, and the role of trust in sustaining socially oriented initiatives.

The analysis also considers the conceptual links between social marketing practices and wider socioeconomic outcomes, including social inclusion, employment opportunities, community empowerment, and local economic resilience. Such relationships are neither automatic nor uniform. Their potential depends on organisational context, available resources, and the ability to reconcile competing expectations without compromising the underlying social mission.

Building on these considerations, the paper proposes an integrated conceptual perspective in which social marketing connects stakeholder relationships, organisational decision-making, and the creation of socioeconomic value. It further discusses the relevance of multidimensional approaches to understanding social impact, recognising that economic performance alone cannot capture the broader contribution of social enterprises.

By bringing these perspectives together, the study contributes to theoretical discussions on socially oriented management and offers a foundation for further research into the strategic role of marketing in mission-driven organisations.

Keywords: Social Marketing; Social Enterprises; Socioeconomic Impact; Social Entrepreneurship; Stakeholder Engagement; Sustainable Development.

INTRODUCTION

Social enterprises have gained increasing attention in discussions of inclusive economic development, particularly in relation to persistent social inequalities that market mechanisms and public welfare systems have not fully addressed (Defourny & Nyssens, 2010; Mair & Martí, 2006).

Their distinctive contribution lies in combining entrepreneurial activity with an explicit social mission, although maintaining this balance introduces considerable organisational tensions. As Defourny and Nyssens (2010) argue, social enterprises operate within institutional arrangements shaped by market forces, public policies, and civil society, making their economic and social objectives inherently interconnected.

The scale of the wider social economy illustrates its socioeconomic significance. According to the European Commission (2021), approximately 2.8 million social economy entities operate across Europe, employing around 13.6 million people. These figures concern the broader social economy, rather than social enterprises exclusively, but demonstrate the importance of mission-oriented economic activity.

Nevertheless, organisational growth or employment creation alone cannot fully explain their contribution. A social enterprise may generate revenue and maintain stable operations while achieving only limited improvements in the circumstances of its intended beneficiaries. Understanding socioeconomic impact therefore requires attention to both measurable economic outcomes and less tangible dimensions, including participation, empowerment, and community resilience (Ebrahim & Rangan, 2014).

Within this context, social marketing provides a potentially valuable, yet insufficiently integrated, strategic perspective. Unlike conventional commercial marketing, which primarily seeks to stimulate market demand, social marketing focuses on influencing behaviours that contribute to individual and collective well-being (Andreasen, 1994; Gordon et al., 2006; Stead, Gordon, et al., 2007; Stead, Hastings, et al., 2007).

Its relevance to social enterprises extends beyond communication campaigns or promotional activities. It concerns how organisations identify community needs, understand barriers to participation, develop appropriate value propositions, and establish relationships capable of supporting sustained social change (Andreasen, 2002; Srivetbodee et al., 2017).

Consider a work-integration social enterprise employing individuals who face barriers to entering the labour market. Providing employment represents an immediate organisational achievement (Battilana et al., 2015).

Yet its longer-term contribution may also depend on whether local employers reconsider discriminatory assumptions, customers recognize the social value embedded in their purchasing decisions, and beneficiaries develop greater confidence in their professional capabilities. These interconnected processes suggest that social marketing can function as a mechanism linking organisational activities with wider socioeconomic outcomes (Battilana et al., 2015; Srivetbodee et al., 2017).

However, such effects should not be assumed. Limited financial resources and competing stakeholder expectations may constrain the implementation of socially oriented marketing strategies (Ebrahim et al., 2014; Mitchell et al., 1997). Evaluating behavioural change presents an additional challenge.

Although social entrepreneurship and social marketing have developed substantial theoretical foundations, their strategic relationship warrants further conceptual examination. In particular, the mechanisms through which social marketing may strengthen stakeholder engagement and contribute to socioeconomic value creation require clearer articulation (Battilana & Lee, 2014; Freeman, 1984).

Accordingly, this paper aims to examine the strategic role of social marketing in enhancing the socioeconomic impact of social enterprises. Drawing on social entrepreneurship literature, stakeholder theory, and sustainable development perspectives, the study develops an integrated conceptual framework connecting social marketing practices, stakeholder relationships, and multidimensional social outcomes.

The intended contribution is twofold. Theoretically, the paper positions social marketing as an organisational capability rather than a supplementary communication instrument. From a managerial perspective, it identifies

mechanisms through which social enterprises may align economic viability with meaningful and sustainable social value creation, while acknowledging the contextual conditions that shape these relationships.

MATERIALS AND METHODS

Research Design: A Conceptual Approach

This study adopts a conceptual research design to investigate how social marketing may contribute to the socioeconomic impact of social enterprises. Rather than testing predetermined hypotheses, the analysis seeks to clarify relationships between established theoretical constructs and identify mechanisms through which marketing-oriented decisions may influence social value creation. This approach is consistent with Jaakkola (2020), who emphasizes that conceptual research requires an explicit analytical logic and a clearly articulated theoretical contribution.

The research combines theoretical synthesis with conceptual model development. Theoretical synthesis brings together perspectives from different areas of research, while conceptual model development helps identify potential relationships between organisational practices, stakeholder responses, and socioeconomic outcomes.

The study does not involve primary data collection or statistical hypothesis testing. Consequently, the proposed relationships are interpreted as theoretically grounded propositions rather than empirically established causal effects.

Theoretical Foundations and Literature Selection

The analytical foundation brings together three complementary research streams: social entrepreneurship, social marketing, and stakeholder-oriented management. Social entrepreneurship literature provides the organisational context, particularly the tensions between economic sustainability and social mission (Battilana & Dorado, 2010; Battilana & Lee, 2014). Social marketing contributes a behavioural and relational perspective (Andreasen, 2002), while stakeholder theory helps explain how interactions among beneficiaries, employees, customers, and community actors may influence organisational outcomes (Freeman, 1984; Mitchell et al., 1997).

The literature was selected using a purposive, concept-driven approach, prioritizing peer-reviewed contributions that clarify theoretical constructs, explain organisational mechanisms, or provide relevant empirical evidence. Institutional publications were included where they offered contextual indicators concerning the social economy and socioeconomic development. This approach is informed by Snyder (2019), who highlights the importance of methodological transparency when synthesizing fragmented interdisciplinary research.

Particular attention is given to distinguishing conceptual arguments from empirical findings. Evidence concerning employment, inclusion, or community development is therefore interpreted within its original institutional and geographical context, avoiding the assumption that findings from one category of social enterprise necessarily apply to others.

Analytical Framework

The analysis is organized around three interconnected dimensions. The first concerns social marketing practices, including stakeholder needs assessment, value proposition development, participatory communication, and behavioural change orientation (Andreasen, 1994; Andreasen, 2002). The second examines relational mechanisms, particularly stakeholder engagement, community participation, and trust (Freeman, 1984; Mitchell et al., 1997). The third addresses socioeconomic value creation through employment opportunities, social inclusion, empowerment, and local economic resilience (Ebrahim & Rangan, 2014).

These dimensions are examined through a comparative interpretation of theoretical arguments and documented empirical findings. The analytical process seeks to identify conceptual complementarities, possible tensions, and contextual conditions that may strengthen or weaken the proposed relationships. Following MacInnis

(2011), the objective is not simply to reproduce existing concepts but to organize them into a framework capable of generating further theoretical understanding.

The resulting framework treats social marketing as a potential strategic mechanism connecting organisational decision-making with socioeconomic outcomes. Its explanatory relevance remains conditional on institutional settings, organisational capabilities, and stakeholder characteristics. These boundaries are retained throughout the analysis to avoid attributing universal effects to practices whose effectiveness may vary substantially across social enterprise contexts.

RESULTS

Social Marketing as a Strategic Mechanism in Social Enterprises

The conceptual analysis identifies social marketing as a potential strategic mechanism through which social enterprises can connect their economic activities with broader societal objectives. Its contribution is not restricted to increasing organisational visibility. More fundamentally, it concerns the identification of social needs, the reduction of barriers to desirable behaviours, and the development of value propositions that respond to the expectations of different stakeholder groups (Andreasen, 2002; Srivetbodee et al., 2017).

This distinction is particularly relevant in work-integration social enterprises, where commercial transactions and social objectives coexist (Battilana et al., 2015). Selling a product may generate the revenue required to sustain operations, but the underlying social mission depends on additional processes, including access to employment, skills development, and social participation. Social marketing can help connect these dimensions by encouraging stakeholder involvement and communicating the value of socially oriented choices (Srivetbodee et al., 2017).

The institutional significance of this relationship becomes clearer when examining the European social economy. The European Commission's 2024 benchmarking study documents a substantial organisational ecosystem, although its aggregate indicators do not establish the effectiveness of social marketing interventions.

Table 1. Selected socioeconomic indicators of the social economy and social enterprises in the European Union

Indicator	Reported value
Social economy entities	Over 4.3 million
Social enterprises	Over 246,000
Ex Lege social enterprises	Almost 43,000
De facto social enterprises	Over 203,000
Employment in the social economy	At least 11.5 million
Employment in social enterprises	At least 3.9 million
Social economy share of total EU employment	6.3%

Source: European Commission (2024), Benchmarking the socio-economic performance of the EU social economy. Figures refer to the EU-27 and reflect the study's statistical coverage and definitions.

Table 1 demonstrates the scale of mission-oriented economic activity, but it also highlights the need to distinguish organisational presence from demonstrated social impact. Employment figures, for example, reveal labour-market participation without necessarily capturing job quality, long-term integration, or changes in beneficiaries' well-being.

Stakeholder Engagement, Community Participation and Trust

The second analytical finding concerns the relational character of social marketing. Stakeholder engagement emerges as a plausible intermediary mechanism between organisational practices and socioeconomic outcomes. Social enterprises depend on relationships with beneficiaries, employees, customers, public

institutions, and local communities (Freeman, 1984; Mitchell et al., 1997). These actors do not necessarily share identical expectations, and their participation cannot be secured through promotional communication alone (Ebrahim et al., 2014).

Community involvement may improve the identification of unmet needs and increase the relevance of organisational interventions (Srivetbodee et al., 2017). Trust, meanwhile, can support continued participation, especially where beneficiaries have experienced exclusion or institutional instability. Yet engagement is not automatically beneficial. Consultation that does not influence organisational decisions may create expectations that remain unfulfilled (Ebrahim et al., 2014).

These observations suggest that the strategic value of social marketing depends partly on whether stakeholder participation becomes embedded in organisational decision-making rather than remaining a symbolic communication exercise (Ebrahim et al., 2014).

Social Marketing and Socioeconomic Value Creation

The third finding concerns the distinction between organisational outputs and sustained socioeconomic outcomes. Ebrahim and Rangan (2014) demonstrate that evaluating social performance requires attention to the scale and scope of organisational activities, rather than assuming that immediate outputs represent long-term impact.

Empirical evidence from social marketing research supports the relevance of behavioural mechanisms, although its transferability to social enterprises remains uncertain. Firestone et al. (2017), in a systematic review of 125 studies concerning social marketing in global health, identified 97 studies reporting behavioural outcomes and 42 reporting health outcomes. The review also associated positive findings with stronger audience insights and attention to the perceived costs and benefits of behavioural change.

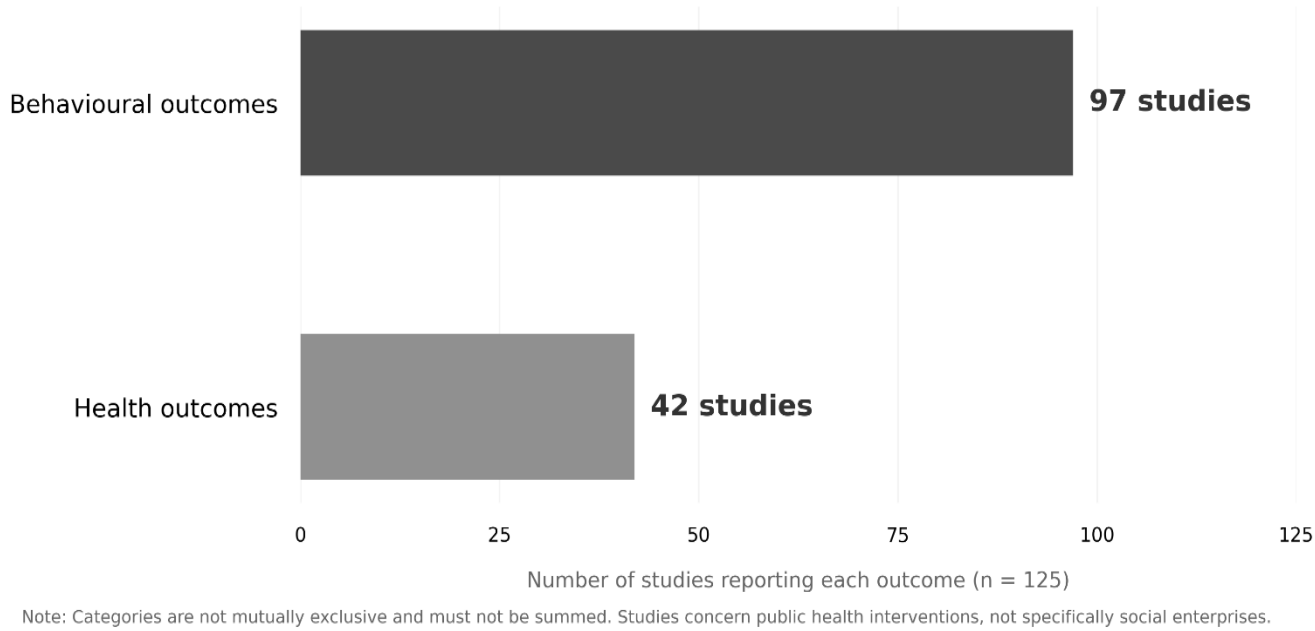


Figure 1. Outcome measures reported in 125 social marketing studies

Source: Firestone et al. (2017). Categories are not mutually exclusive and should not be summed.

The distribution illustrates a methodological challenge in the studies reviewed by Firestone et al. (2017): behavioural outcomes were reported more frequently than health outcomes. For social enterprises, this finding

highlights the importance of distinguishing participation, behavioural change, and longer-term socioeconomic outcomes.

In the context of social enterprises, these distinctions are particularly important because observable organisational achievements do not necessarily reflect the full extent of social value creation. Employment opportunities, service accessibility, and stakeholder participation may represent meaningful initial results, but their longer-term significance depends on changes in beneficiaries' circumstances and community well-being. From this perspective, social marketing practices can be examined in relation to the mechanisms through which they may contribute to broader socioeconomic outcomes, while recognising that these relationships require empirical validation.

Table 2. Conceptual relationships between social marketing practices and socioeconomic outcomes

Social marketing dimension	Proposed mechanism	Potential socioeconomic outcome
Stakeholder needs assessment	Identification of participation barriers	Improved accessibility and inclusion
Audience segmentation	Adaptation of interventions to specific groups	More equitable service provision
Participatory communication	Dialogue and shared decision-making	Community empowerment
Behavioural value proposition	Reduction of perceived costs of participation	Greater engagement and behavioural adoption
Trust-based relationships	Continued stakeholder involvement	Organisational legitimacy and resilience
Impact-oriented evaluation	Feedback and organisational learning	Improved accountability and mission alignment

Source: Authors' conceptual synthesis, informed by Andreasen (1994), Firestone et al. (2017), and Ebrahim and Rangan (2014). The relationships are proposed mechanisms, not statistically tested effects.

An Integrated Conceptual Framework

Integrating these findings, the study proposes a three-stage conceptual framework in which social marketing practices influence socioeconomic value creation through stakeholder-related mechanisms.

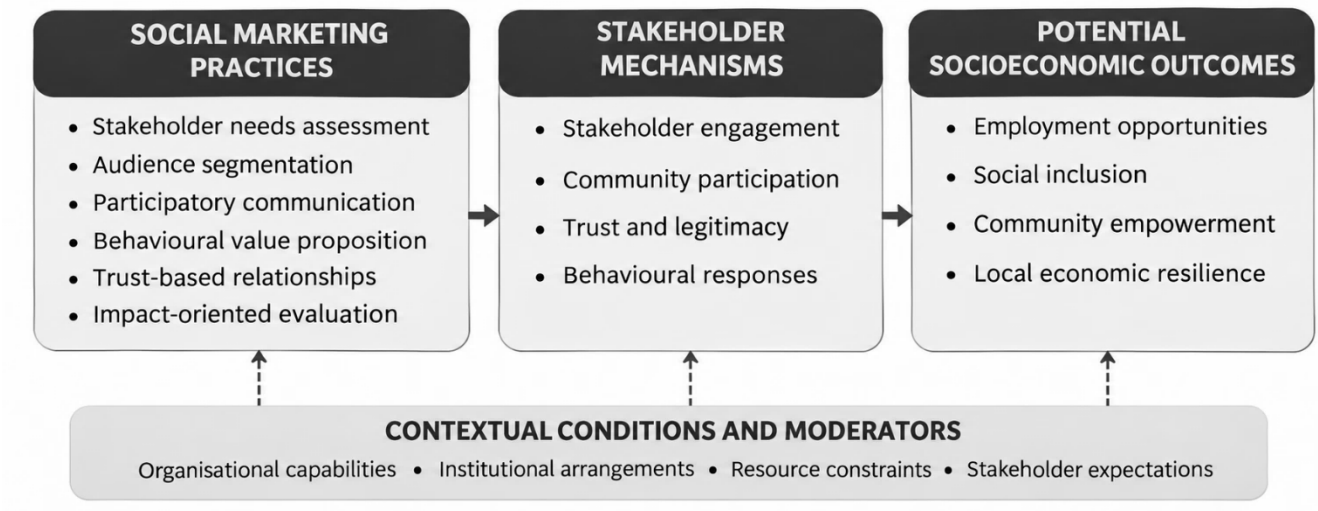


Figure 2. Proposed integrated conceptual framework.

Source: Authors' conceptual development.

The proposed framework highlights the intermediary role of stakeholder-related mechanisms in connecting social marketing practices with socioeconomic value creation. Rather than producing direct and uniform effects, social marketing may contribute to social enterprise performance by improving the identification of community needs, encouraging meaningful participation, and strengthening relationships based on trust and shared objectives (Andreasen, 2002; Srivetbodee et al., 2017). These mechanisms may facilitate behavioural responses that extend beyond immediate organisational activities and support broader processes of social inclusion, empowerment, and local economic resilience.

An important implication of the framework is that economic viability and social value creation should not be regarded as independent organisational objectives (Battilana & Lee, 2014). Financial sustainability provides the resources necessary to maintain socially oriented activities, while stakeholder engagement and responsiveness to community needs may reinforce organisational legitimacy and long-term relevance (Ebrahim et al., 2014). Social marketing can therefore be understood as a strategic capability that helps social enterprises navigate the relationship between market requirements and their underlying social mission.

Nevertheless, the proposed relationships remain conditional rather than universally applicable. Organisational resources, institutional arrangements, stakeholder characteristics, and competing expectations may influence the extent to which social marketing practices translate into meaningful socioeconomic outcomes. Furthermore, increased participation or short-term behavioural change should not automatically be interpreted as evidence of sustained social impact (Ebrahim & Rangan, 2014). Such distinctions underline the importance of multidimensional evaluation approaches that consider both organisational outputs and longer-term changes in beneficiaries' circumstances and community well-being.

Overall, the integrated framework provides a theoretically grounded explanation of how social marketing may support socioeconomic value creation in social enterprises. Its principal contribution lies in identifying plausible relational and behavioural pathways that can inform future empirical research, rather than establishing causal relationships. This perspective also provides a basis for examining the theoretical, managerial, and contextual implications discussed in the following section.

DISCUSSION

The findings of this study contribute to the understanding of social marketing as a strategic organisational capability within social enterprises, extending its relevance beyond communication and promotional activities. While Andreasen (1994) conceptualizes social marketing primarily through its orientation towards socially beneficial behavioural change, the present analysis suggests that its principles may also inform organisational decision-making, stakeholder relationships, and the alignment of economic activities with social objectives. This interpretation is particularly relevant to social enterprises, whose hybrid nature requires the continuous reconciliation of market demands and social commitments (Defourny & Nyssens, 2010).

The proposed conceptual framework further suggests that the relationship between social marketing and socioeconomic value creation is mediated by relational and behavioural mechanisms rather than determined solely by organisational activities. Stakeholder engagement, community participation, and trust may influence how social initiatives are perceived, adopted, and sustained. However, their effectiveness depends on whether stakeholder involvement translates into meaningful participation in organisational decisions. This perspective is consistent with the broader understanding of social performance advanced by Ebrahim and Rangan (2014), who emphasize the importance of distinguishing immediate organisational outputs from longer-term outcomes and societal impact. From a managerial perspective, these findings indicate that social enterprises may benefit from integrating social marketing principles into strategic planning rather than treating them as supplementary communication instruments. Systematic assessment of stakeholder needs, audience segmentation, participatory communication, and attention to perceived barriers to behavioural change may improve the relevance and accessibility of socially oriented interventions. Evidence from the systematic review conducted by Firestone et al. (2017) supports the importance of audience insights and behavioural mechanisms in social

marketing interventions. Nevertheless, because that review focuses on global health, its findings cannot be directly generalized to social enterprises without further empirical investigation.

The socioeconomic implications extend beyond organisational sustainability to the conditions under which economic activity may generate broader social benefits. Employment opportunities, social inclusion, and community empowerment represent interconnected but analytically distinct dimensions of value creation. Accordingly, evaluating the contribution of social enterprises requires multidimensional approaches capable of capturing both economic performance and changes in beneficiaries' circumstances. The scale of the European social economy documented by the European Commission (2024) reinforces the relevance of such evaluation, although aggregate employment and organisational indicators cannot independently demonstrate the effectiveness of particular social marketing practices.

Several limitations must be acknowledged. The study is conceptual and does not provide empirical validation of the proposed relationships. Moreover, differences in organisational resources, institutional environments, stakeholder expectations, and social missions may influence the applicability of the framework across different types of social enterprises. The purposive selection of literature also limits the comprehensiveness of the theoretical synthesis. These considerations suggest that the framework should be interpreted as an analytical foundation rather than a universally applicable explanatory model.

Future research could examine the proposed mechanisms through comparative case studies, longitudinal investigations, and mixed-methods approaches. Particular attention should be given to the conditions under which stakeholder engagement and behavioural change contribute to sustained socioeconomic outcomes. Empirical studies could also investigate how organisational capabilities and institutional support influence the effectiveness of social marketing strategies across different social enterprise models. Such research would help clarify the explanatory value of the proposed framework and strengthen the evidence base for socially oriented management practices.

CONCLUSION

This study examined the strategic role of social marketing in enhancing the socioeconomic contribution of social enterprises, with particular attention to the relationships between organisational practices, stakeholder engagement, and social value creation. By integrating perspectives from social marketing, social entrepreneurship, and stakeholder theory, the analysis provides a conceptual understanding of how marketing-oriented decisions may support the pursuit of economic sustainability alongside social objectives.

The principal contribution of the study lies in the proposed integrated framework, which positions stakeholder engagement, community participation, trust, and behavioural responses as potential mechanisms connecting social marketing practices with broader socioeconomic outcomes. This perspective highlights that the contribution of social enterprises cannot be adequately assessed through financial performance or immediate organisational outputs alone, but requires consideration of social inclusion, empowerment, employment opportunities, and community resilience.

The findings also suggest that the strategic relevance of social marketing depends on its integration into organisational decision-making and its responsiveness to stakeholder needs. However, the proposed relationships remain context-dependent and should not be interpreted as empirically validated causal effects. Organisational capabilities, institutional conditions, and competing stakeholder expectations may shape their practical relevance.

Further empirical research is therefore necessary to examine these relationships across different social enterprise models and institutional environments. By identifying plausible mechanisms and their contextual boundaries, the study offers a theoretical foundation for investigating how social marketing may contribute to more inclusive and sustainable socioeconomic development.

REFERENCES

Andreasen, A. R. (1994). Social marketing: Its definition and domain. *Journal of Public Policy & Marketing, 13*(1), 108–114. https://doi.org/10.1177/074391569401300109

Andreasen, A. R. (2002). Marketing social marketing in the social change marketplace. *Journal of Public Policy & Marketing, 21*(1), 3–13. https://doi.org/10.1509/jppm.21.1.3.17602

Battilana, J., & Dorado, S. (2010). Building sustainable hybrid organizations: The case of commercial microfinance organizations. *Academy of Management Journal, 53*(6), 1419–1440. https://doi.org/10.5465/amj.2010.57318391

Battilana, J., & Lee, M. (2014). Advancing research on hybrid organizing: Insights from the study of social enterprises. *Academy of Management Annals, 8*(1), 397–441. https://doi.org/10.5465/19416520.2014.893615

Battilana, J., Sengul, M., Pache, A.-C., & Model, J. (2015). Harnessing productive tensions in hybrid organizations: The case of work integration social enterprises. *Academy of Management Journal, 58*(6), 1658–1685. https://doi.org/10.5465/amj.2013.0903

Defourny, J., & Nyssens, M. (2010). Conceptions of social enterprise and social entrepreneurship in Europe and the United States: Convergences and divergences. *Journal of Social Entrepreneurship, 1*(1), 32–53. https://doi.org/10.1080/19420670903442053

Ebrahim, A., Battilana, J., & Mair, J. (2014). The governance of social enterprises: Mission drift and accountability challenges in hybrid organizations. *Research in Organizational Behavior, 34*, 81–100. https://doi.org/10.1016/j.riob.2014.09.001

Ebrahim, A., & Rangan, V. K. (2014). What impact? A framework for measuring the scale and scope of social performance. *California Management Review, 56*(3), 118–141. https://doi.org/10.1525/cmr.2014.56.3.118

European Commission. (2021). *Building an economy that works for people: An action plan for the social economy* (COM(2021) 778 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0778

European Commission. (2024). *Benchmarking the socio-economic performance of the EU social economy: Improving the socio-economic knowledge of the proximity and social economy ecosystem*. Publications Office of the European Union.

Firestone, R., Rowe, C. J., Modi, S. N., & Sievers, D. (2017). The effectiveness of social marketing in global health: A systematic review. *Health Policy and Planning, 32*(1), 110–124. https://doi.org/10.1093/heapol/czw088

Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Pitman.

Gordon, R., McDermott, L., Stead, M., & Angus, K. (2006). The effectiveness of social marketing interventions for health improvement: What's the evidence? *Public Health, 120*(12), 1133–1139. https://doi.org/10.1016/j.puhe.2006.10.008

Jaakkola, E. (2020). Designing conceptual articles: Four approaches. *AMS Review, 10*, 18–26. https://doi.org/10.1007/s13162-020-00161-0

MacInnis, D. J. (2011). A framework for conceptual contributions in marketing. *Journal of Marketing, 75*(4), 136–154. https://doi.org/10.1509/jmkg.75.4.136

Mair, J., & Martí, I. (2006). Social entrepreneurship research: A source of explanation, prediction, and delight. *Journal of World Business, 41*(1), 36–44. https://doi.org/10.1016/j.jwb.2005.09.002

Mitchell, R. K., Agle, B. R., & Wood, D. J. (1997). Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of Management Review*, *22*(4), 853–886. https://doi.org/10.5465/amr.1997.9711022105

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Srivetbodee, S., Igel, B., & Kraisornsuthasinee, S. (2017). Creating social value through social enterprise marketing: Case studies from Thailand's food-focused social entrepreneurs. *Journal of Social Entrepreneurship, 8*(2), 201–224. https://doi.org/10.1080/19420676.2017.1371630

Stead, M., Gordon, R., Angus, K., & McDermott, L. (2007). A systematic review of social marketing effectiveness. *Health Education, 107*(2), 126–191. https://doi.org/10.1108/09654280710731548

Stead, M., Hastings, G., & McDermott, L. (2007). The meaning, effectiveness and future of social marketing. *Obesity Reviews, 8*(S1), 189–193. https://doi.org/10.1111/j.1467-789X.2007.00340.x

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE GRAVITY MODEL IN THE ANALYSIS OF INTERNATIONAL MIGRATION: A LITERATURE REVIEW WITH A FOCUS ON THE WESTERN BALKAN COUNTRIES

Isak Kafexholli
Alma Braimllari
0009-0001-0766-0701, Phd.C-University of Tirana, Faculty of Economy, Statistics and Applied Informatics , Tiranë, Albania.
0000-0003-3162-8987, University of Tirana, Faculty of Economy, Statistics and Applied Informatics, Tiranë, Albania.

Abstract

International migration is a complex phenomenon shaped by economic, demographic, institutional, and geographical factors. In this context, the gravity model represents an important approach to analysing migration relationships between countries of origin and destination. The aim of this paper is to examine the application of the gravity model in the analysis of international migration, with particular emphasis on the Western Balkan countries. The paper is based on a comparative review of nine scientific studies published between 2017 and 2025, which examine the determinants of migration across different European contexts. By analysing the study periods, countries of origin and destination, key variables, and econometric methods, the paper identifies the approaches adopted and the common findings emerging from the literature.

The results indicate that economic and labour market factors, particularly GDP per capita, wages, unemployment, and poverty, play an important role in explaining migration movements. Furthermore, corruption and the quality of governance are identified as institutional factors associated with migration decisions. Population size and geographical distance remain important components of traditional gravity model specifications. An additional dimension is provided by the mobility of healthcare professionals, highlighting the importance of examining specific categories of the labour force. The comparative analysis reveals differences in the periods examined, geographical coverage, and estimation methods, which to some extent limit the direct comparability of the findings.

The paper concludes that the gravity model provides a suitable framework for studying migration from the Western Balkans. Future research should focus on harmonising bilateral migration data, incorporating institutional and social factors, and applying more advanced econometric methods.

Keywords: international migration, Western Balkans, migration determinants, econometric analysis.

INTRODUCTION

International migration is one of the most significant demographic, economic, and social processes of recent decades. Population movements from countries of origin to destination countries are influenced by a complex set of economic, demographic, institutional, political, and social factors. Differences in GDP per capita, employment opportunities, living standards, institutional quality, and the presence of diaspora networks are among the factors associated with the intensity and direction of migration flows.

The Western Balkan countries have a long history of migration, with considerable movements towards European Union member states and other economically more developed destinations. Differences between the WB6 countries and destination countries in terms of economic development, unemployment, wages, professional opportunities, and institutional conditions have contributed to shaping these migration patterns. In addition to affecting demographic structures and labour markets, emigration also has implications for human capital, economic development, and relations between countries of origin and host countries. The analysis of

migration flows requires theoretical and methodological approaches that enable the identification of factors influencing population movements between countries. One widely used approach in this field is the gravity model, which was initially developed to explain international trade flows and was subsequently adapted to the analysis of migration. The basic principle of this model is based on the assumption that the intensity of flows between two countries is positively associated with their economic and demographic size, while being negatively affected by the geographical distance between them. In contemporary studies, the basic gravity model has been extended through the inclusion of economic, institutional, educational, cultural, and political variables.The importance of the gravity model in migration studies lies in its ability to analyse bilateral relationships between countries of origin and destination while simultaneously considering the characteristics of both countries and the factors influencing the relationships between them. This approach is particularly relevant to the experience of the Western Balkan countries. Through the use of panel data and advanced econometric methods, such as Fixed Effects and Poisson Pseudo-Maximum Likelihood (PPML), the model enables a more comprehensive analysis of migration flows and the factors associated with them.

The main objective of this paper is to review and critically analyse the scientific literature on the development and application of the gravity model in the study of international migration, with particular emphasis on the Western Balkan countries. To achieve this objective, three research objectives are established: to examine the theoretical foundations and methodological development of the gravity model, identifying how it has been adapted to analyse international migration flows; to analyse and compare empirical studies applying the gravity model to migration from the Western Balkan countries and in the broader European context, identifying the countries of origin and destination, study periods, variables, and econometric methods employed; and to identify similarities, differences, methodological limitations, and existing gaps in the literature, with a view to highlighting opportunities for further empirical research in the Western Balkan region. This paper may serve as a reference for researchers interested in analysing migration relationships between countries in the region and European destination countries. Furthermore, it provides a methodological basis for developing an extended gravity model incorporating economic, demographic, and institutional factors. Although several studies have applied the gravity model to the analysis of emigration from the Western Balkans, the available literature remains relatively limited and varies in terms of the periods examined, countries covered, variables included, and estimation methods employed. Some studies focus on overall emigration, while others examine specific labour force groups, such as healthcare professionals.

Furthermore, there is a need for a more structured comparison of the econometric specifications and estimation methods used in studies addressing migration flows from the WB6 countries to European destinations. In this context, the paper seeks to contribute to addressing this gap through a comparative review of the literature and the identification of potential directions for future research.

MATERIALS AND METHODS

The gravity model is an econometric approach used to analyse migration flows between countries, based on the size of the countries of origin and destination, as well as the distance separating them. In its basic form, the model assumes that migration flows increase with the demographic and economic size of countries, while decreasing as distance increases, with distance serving as a proxy for migration costs. As the literature has developed, the model has been extended to incorporate economic, demographic, institutional, and social factors, such as income per capita, unemployment, educational attainment, institutional quality, family ties, and diaspora networks.

Beine, Bertoli, and Fernández-Huertas Moraga (2016), in their study, examine the theoretical foundations of the model and approaches to using bilateral migration data. They emphasise that analysing relationships between countries of origin and destination makes it possible to identify the factors influencing migration decisions and flows. The authors highlight several methodological challenges, including the distinction between migrant stocks and flows, the treatment of multilateral resistance to migration, the endogeneity of

explanatory variables, and the selection of an appropriate estimation method. According to the authors, model specification should be based on a clear theoretical foundation and the characteristics of the available data to ensure the reliability of the estimates. An important empirical contribution is also provided by Caballero Reina et al. (2024), whose study develops and evaluates gravity models for bilateral migration flows between countries at the global level. The authors incorporate demographic, economic, and geographical factors into their analysis, including the populations of origin and destination countries, geographical distance, GDP per capita, unemployment, population structure, education, and the presence of diaspora networks. To evaluate the model specifications, they employ log-linearised models, as well as specifications with origin- and destination-country fixed effects. They also examine Poisson and negative binomial models, comparing their results with alternative predictive approaches. The findings highlight the importance of country size and geographical distance in explaining migration flows, while the predictive analysis demonstrates that model specification and variable selection influence model performance. Overall, these two studies demonstrate that estimating gravity models requires not only the selection of appropriate variables but also careful consideration of the characteristics of bilateral data. The main methodological challenges include missing data for certain country pairs, zero migration flows, heteroskedasticity, endogeneity, and the control of country-specific and country-pair-specific effects. For this reason, contemporary literature employs various estimation methods, including OLS, Poisson Pseudo-Maximum Likelihood (PPML), and fixed-effects models, depending on the data structure and the research objectives.

RESULTS AND DISCUSSION

The literature review indicates that the application of the gravity model to the analysis of migration from the Western Balkan countries has developed gradually, beginning with the inclusion of traditional economic and demographic factors and subsequently extending to institutional and social variables, as well as factors specific to particular labour force groups. The selected studies differ in terms of the periods examined, countries of origin and destination, variables employed, and econometric methods applied. Table 1 presents the main characteristics of the nine empirical publications included in the analysis.

Table 1. Comparative overview of studies applying the gravity model to the analysis of migration

Authors (Year)	Period	Countries of Origin and Destination	Methodology	Main Variables	Key Findings
Malaj & de Rubertis (2017)	2009–2014	Western Balkan countries towards major European destinations	Extended gravity model; panel data regression	Migrant stock, GDP per capita, population, distance, unemployment, CPI, and HDI	Differences in economic development, unemployment, and corruption are associated with migration. The model explains a considerable proportion of the variation in migrant stocks.
Malaj & Teka (2023)	2009–2021	Western Balkan countries towards foreign destinations	Various gravity model specifications	Tertiary education, HDI, and GDP per capita	The results indicate satisfactory explanatory power of the estimated equations.

Malaj (2023)	2012–2021	Western Balkan countries towards several major European destinations	Gravity model	Migrant stock, poverty, unemployment, and corruption	Unfavourable economic and social conditions in countries of origin are associated with emigration towards more developed countries.
Malaj & Firza (2023)	2012–2020	Western Balkan countries towards 31 European destinations	Gravity-based equation	Migrant stock, corruption, and governance	Corruption and weak governance in countries of origin are associated with emigration towards wealthier and less corrupt destinations.
Mara (2023)	2001–2019 (for the empirical assessment of bilateral mobility)	Western Balkan countries and other European countries, with a focus on European destinations	Gravity model; Pooled OLS/WLS and PPML in selected specifications	Physician stock, healthcare-sector wages, GDP per capita, physician density, healthcare graduates, distance, and migration policies	Income differentials act as an attracting factor; Germany particularly benefits from the mobility of healthcare professionals.
Malaj, E. & Malaj, V. (2024)	2007–2016	Central and Eastern European countries towards foreign destinations	Extended gravity model	Poverty, unemployment, and corruption	Economic and social conditions in countries of origin are associated with the intensity of emigration.
Bernini et al. (2024)	2008–2018	EU and EFTA countries	Gravity model with time fixed effects and additional controls	Bilateral migration flows, corruption, GDP per capita, inflation, unemployment, distance, and cultural factors	Corruption in the country of origin acts as a push factor, whereas corruption in the destination country reduces its attractiveness to migrants.
Çali & Malaj (2025)	2012–2023	Western Balkan countries towards European destinations	Gravity model; Pooled OLS	Wages, unemployment, GDP per capita, population, and distance	Wage differentials and unemployment in countries of origin are associated with labour mobility.
Malaj & Çali (2025)	2014–2023	Western Balkan countries towards major European destinations	Gravity model; Pooled OLS	GDP per capita, population, distance, and labour market conditions	The economic and demographic size of destination countries emerges as an attracting factor, while unfavourable conditions in countries of origin act as push factors.

Source: Authors' own elaboration based on the publications reviewed on the gravity model.

One of the early contributions to the application of the gravity model to migration from the Western Balkans is the study by Malaj and de Rubertis (2017), which examines the determinants of emigration through an extended gravity model. The authors include three variables associated with the characteristic challenges of the countries in the region: standard of living, unemployment, and corruption. An important aspect of this study is its use of migrant stocks from the countries of origin in major European destination countries over the period 2009–2014. Migration data were obtained primarily from Eurostat and the OECD, while economic and demographic indicators were sourced from the World Bank. The results indicate that economic and institutional factors play an important role in explaining differences in the number of migrants across countries. In their study, Malaj and Teka (2023) analyse the social and economic factors associated with emigration from the Western Balkan countries. The authors formulate and estimate different gravity equations, incorporating the share of the population with tertiary education, the Human Development Index (HDI), and GDP per capita. Their results indicate that the estimated models have satisfactory explanatory power. This study extends the analysis by incorporating indicators of human capital and human development, going beyond traditional economic factors. Another contribution is the study by Malaj (2023), which examines migrant stocks from the Balkan countries in several major European destination countries over the period 2012–2021. The model includes poverty, unemployment, and corruption as variables reflecting the economic and social challenges of the countries of origin. The author emphasises that public policies should focus on reducing corruption, poverty, and inequality in order to ease the pressures associated with emigration.

Corruption and the quality of governance have been addressed as important factors in several studies on migration from the Western Balkans. Malaj and Firza (2023) analyse the impact of corruption on migrant stocks over the period 2012–2020, using an equation based on the gravity model. The study covers 31 European destination countries and highlights the importance of institutional differences between countries of origin and destination. According to the authors, individuals tend to move from countries characterised by corruption and weak governance towards countries with higher levels of economic development and lower levels of corruption.

A complementary perspective is provided by Bernini et al. (2024), who examine the relationship between corruption and bilateral migration flows in EU and EFTA countries over the period 2008–2018. Unlike some studies focusing on the Western Balkans that use migrant stocks, this study employs annual migration flows. The authors examine corruption as a push factor in the country of origin and as a pull factor in the destination country. The results indicate that an increase in corruption in the country of origin is associated with higher emigration, whereas an increase in corruption in the destination country is associated with lower immigration. This study is particularly relevant for interpreting the role of institutional factors on both sides of the migration relationship.

A specific area of research concerns the migration of healthcare professionals from the Western Balkans to Europe. Mara (2023) applies the gravity model to analyse the mobility of physicians over the period 2001–2019. The study uses bilateral data on the stocks of foreign-trained physicians, obtained from the OECD Health Workforce Database. In addition to geographical distance and linguistic ties, the model incorporates wages in the healthcare sector, GDP per capita, physician density, the number of graduates in health-related fields, and changes in migration policies.

The methodological significance of this study lies in its use of Pooled OLS/WLS and PPML across different model specifications. PPML is employed to address the problem of zero values and the limitations arising from the logarithmic transformation of the dependent variable. The results highlight the importance of migration networks and income differences, while Germany is identified as one of the destination countries that has benefited considerably from the mobility of healthcare professionals from the region.

In two papers presented at the XXIII IBANESS Congress, Çali and Malaj (2025) extend the analysis to wage differentials, unemployment, and economic conditions between countries of origin and destination. These papers examine labour mobility over the period 2012–2023 and the determinants of emigration over the period 2014–2023. Both studies apply the gravity model and use the Pooled OLS estimation method. Their findings emphasise the importance of wage differentials and labour market conditions in explaining emigration from the Western Balkan countries. In addition to studies focusing directly on the Western Balkans, the literature also includes broader regional analyses. Malaj, E., and Malaj, V. (2024) examine the relationship between migration and factors such as poverty, unemployment, and corruption. Although this study is not limited exclusively to the WB6 countries, it is relevant for comparing the experiences of Central and Eastern European countries with those of the Western Balkans. The authors emphasise that job creation and the reduction of inequality may contribute to easing migration pressures. From a broader methodological perspective, Bernini et al. (2024) provide evidence that institutional factors in countries of origin and destination may affect migration flows in different ways.

A comparison of the selected studies reveals several important similarities. First, most of the studies that directly examine the Western Balkans approach migration as the result of interactions between push factors in countries of origin and pull factors in destination countries. Second, economic factors, particularly GDP per capita, unemployment, and wages, repeatedly emerge as important determinants of migration. Third, several studies extend the traditional gravity model by incorporating corruption, human development, education, and institutional quality. Nevertheless, differences across the studies are evident in several dimensions. One important distinction concerns the dependent variable. Malaj and de Rubertis (2017), Malaj (2023), Malaj and Firza (2023), and Mara (2023) use migrant stocks, whereas Bernini et al. (2024) analyse annual migration flows. This distinction affects the interpretation of the results, since migrant stocks reflect the number of migrants residing in a destination country, whereas migration flows measure movements over a given period. Differences are also evident in the econometric methodologies employed. Earlier studies use extended gravity model specifications and traditional regression methods, whereas more recent contributions incorporate methods such as Pooled OLS, WLS, and PPML. The use of PPML in Mara (2023) represents an important methodological development, particularly given the presence of zero values in migration data. Furthermore, the periods analysed and the groups of destination countries included vary across studies, limiting the direct comparability of the estimated coefficients.

Overall, the literature indicates that the gravity model provides a suitable framework for analysing bilateral migration relationships. However, the results depend on data quality, the definition and measurement of migration, variable selection, and the estimation method employed. Therefore, the findings of individual studies should be interpreted in light of their specific contexts and econometric specifications.

CONCLUSIONS

The literature review indicates that the gravity model represents an important theoretical and empirical approach to analysing international migration, as it enables the assessment of migration relationships between countries of origin and destination. The studies examined highlight that the demographic and economic size of countries, geographical distance, income differentials, employment opportunities, institutional quality, and diaspora networks are among the factors associated with the intensity and direction of migration. In the case of the Western Balkans, the literature emphasises the importance of economic and institutional factors, while also highlighting the need for more comparable analyses across the six countries of the region and their main destination countries.

Nevertheless, the reviewed literature has several limitations. The studies differ in terms of the periods examined, countries covered, variable selection, and econometric methods employed. Furthermore, differences in statistical data sources and in the measurement of migration, particularly between migration flows and migrant stocks, make direct comparisons of the findings more difficult. Other challenges include the lack of

bilateral data, zero-valued observations, heteroskedasticity, and the possibility of endogeneity in the estimation models.

Future research should focus on developing more harmonised panel databases for the Western Balkan countries, covering longer periods and a broader range of destination countries. Furthermore, the use of extended gravity model specifications and appropriate econometric methods, such as Poisson Pseudo-Maximum Likelihood (PPML) and fixed-effects models, is recommended, together with robustness checks using alternative specifications. The inclusion of institutional, educational, and labour market factors may contribute to a more comprehensive understanding of migration dynamics. In this way, future studies could provide more robust evidence on the determinants of migration and contribute to the formulation of policies addressing the demographic and economic challenges facing the region.

REFERENCES

Bernini, A., Bossavie, L., Garrote-Sánchez, D., et al. (2024). Corruption as a push and pull factor of migration flows: evidence from European countries. *Empirica, 51*, 263–281. Available at: https://doi.org/10.1007/s10663-023-09600-0

Beyer, R. M., Schewe, J., & Lotze-Campen, H. (2022). Gravity models do not explain, and cannot predict, international migration dynamics. *Humanities and Social Sciences Communications, 9*, 56. Available at: https://doi.org/10.1057/s41599-022-01067-x

Beine, M., Bertoli, S., & Fernández-Huertas Moraga, J. (2016). A practitioners' guide to gravity models of international migration. *The World Economy, 39*(4), 496–512.

Caballero Reina, J., Crespo Cuaresma, J., Fenz, K., Zellmann, J., Yankov, T., & Taha, A. (2024). Gravity models for global migration flows: A predictive evaluation. *Population Research and Policy Review, 43*, Article 29. https://doi.org/10.1007/s11113-024-09867-6

Leitão, N. C. (2024). Gravity Model and International Trade: A Survey of the Literature. *Administrative Sciences, 14*(9), 219. Available at: https://doi.org/10.3390/admsci14090219

Malaj, E. (2023). Social and Economic Factors of Emigration: Evidence from the Western Balkans. *Review of Economics and Finance, 21*, 2646–2648. Available at: https://doi.org/10.55365/1923.x2023.21.284

Malaj, E., & Malaj, V. (2020). Poverty and Migration in Western Balkan Countries. *European Journal of Interdisciplinary Studies, 5*(1), 8–17. Available at: https://doi.org/10.26417/ejms.v4i2.p51-56

Malaj, E., & Malaj, V. (2024). Migrimi dhe varfëria në vendet e Evropës Qendrore dhe Lindore: Një zbatim i modelit të gravitetit (2007–2016). *Optime*, 139–147. Available at: https://doi.org/10.55312/op.vi1.4621

Malaj, V., & de Rubertis, S. (2017). Determinants of migration and the gravity model of migration – application on Western Balkan emigration flows. *Migration Letters, 14(2),* 204–220. Available at: https://doi.org/10.59670/ml.v14i2.327

Malaj, V., & Firza, N. (2023). The Impact of Corruption on Migration: Evidence from the Western Balkans. *Migration Letters, 20*(8), 896–907. Available at: https://doi.org/10.59670/ml.v20i8.5627

Malaj, V., & Teka, S. J. (2023). Emigration and Gravity Theory: Application on the Western Balkans. *European Journal of Interdisciplinary Studies*, *8*(3), 50–59.

Mara, I. (2023). Health Professionals Wanted: The Case of Health Professionals from Western Balkan Countries to Europe. *Central and Eastern European Migration Review, 12*(2), 33–52. Available at: https://doi.org/10.54667/ceemr.2023.24

Çali, E., & Malaj, E. (2025). Migration, Wages, and Unemployment: A Gravity Model Analysis of Workforce Mobility in the Western Balkans. *XXIII IBANESS Congress Series on Economics, Business and Management*, Plovdiv, Bulgaria.

Malaj, E., & Çali, E. (2025). Drivers of Emigration in the Western Balkans: A Gravity Model Perspective (2014–2023*). XXIII IBANESS Congress Series on Economics, Business and Management*, Plovdiv, Bulgaria.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FROM LEGAL PRINCIPLE TO TECHNICAL REQUIREMENT: THE INTERDISCIPLINARY ARCHITECTURE OF ADMINISTRATIVE INSTRUMENTS CONCRETISING SUSTAINABILITY IN CIRCULAR ECONOMY REGULATION

Anita Boros
ORCID: 0000-0001-5330-9050, Institute: Department of Administrative and International Policy, Ludovika University of Public Service, Budapest, Hungary

Abstract

Sustainability is increasingly invoked as a legal principle in circular economy (CE) regulation, yet its normative content remains largely indeterminate until it is translated into measurable product- and process-level requirements. This paper argues that the decisive site of this translation is not the legislative norm itself but the architecture of administrative instruments (permitting, conformity assessment, market surveillance and reporting), which function as interfaces between law, the technical knowledge of engineering, materials science and life-cycle assessment, and the compliance practices of firms. A statutory requirement that a building material be sustainable has no operative meaning until standards and verification procedures specify what it entails for a brick or a cement product. Combining doctrinal and norm-structure analysis, a functional analysis of administrative instruments and a comparative study of the European Union, the United States and China, supported by a PRISMA-guided systematic review and bibliometric mapping, the paper examines how these regulatory models allocate the task of concretising sustainability among legislators, administrative authorities, standardisation bodies and companies. The EU's normative-integrative model delegates substantive content to secondary legislation, harmonised technical standards and digital product information tools; the market- and incentive-based US model relies largely on state-level instruments such as extended producer responsibility and right-to-repair legislation; China's state-led model embeds CE objectives in economic planning and in the performance evaluation of administrative bodies. Preliminary findings suggest that the enforceability of sustainability depends less on its formal rank in the hierarchy of norms than on the administrative capacity to verify technical compliance, and that the incorporation of voluntary standards into binding requirements is a key, under-theorised mechanism of legal concretisation, directly shaping the regulatory certainty firms face. Effective CE regulation thus requires interdisciplinary regulatory design in which law engages directly with the technical and economic disciplines that define what sustainability means in practice.

Keywords: circular economy; sustainability as a legal principle; administrative law; conformity assessment; technical standards; comparative regulation.

INTRODUCTION

Over the past decade the circular economy (CE) has moved from a heuristic of industrial ecology and corporate strategy to a pillar of public regulation. In the European Union, the 2020 Circular Economy Action Plan (European Commission, 2020) initiated a sequence of instruments, among them the Ecodesign for Sustainable Products Regulation (ESPR), the recast Construction Products Regulation (CPR), the Batteries Regulation and the Packaging and Packaging Waste Regulation, which convert resource-efficiency objectives into conditions of market access. In the United States, a growing body of state legislation on extended producer responsibility (EPR) and the right to repair pursues comparable aims by different means, while in China the circular economy, codified since 2008 in the Circular Economy Promotion Law, has been integrated into the Ecological and Environmental Code adopted in March 2026. Across these settings sustainability serves as the normative justification of regulation and frequently as an express legal principle (Voigt, 2009; Bosselmann, 2016). The conceptual literature shows, however, that neither the circular economy nor sustainability possesses a stable meaning: Kirchherr et al. (2017) identified 114 definitions of the CE and their later revisitation 221 (Kirchherr

et al., 2023), while Geissdoerfer et al. (2017) showed that the relationship between circularity and sustainability is itself contested.

For legal scholarship this indeterminacy poses a familiar problem in sharpened form. Sustainability displays the structure that Dworkin (1977) and Alexy (2002) attribute to principles rather than rules: it is an optimisation requirement to be realised to the greatest extent possible relative to competing interests, and its operative content depends on legal and factual possibilities. In the economic analysis of law, such open-textured norms are standards whose content is fixed ex post, at the point of application, as opposed to rules whose content is fixed ex ante (Kaplow, 1992). CE regulation cannot, however, rely on ex post adjudication, because a manufacturer placing a product on the market must know before production whether its design complies. The content of sustainability must therefore be determined in advance, and the decisive questions are by whom, through which instruments and on the basis of what kind of technical knowledge this determination is made.

This paper argues that the decisive site of this translation is not the legislative norm itself but the architecture of administrative instruments, namely permitting, conformity assessment, market surveillance and reporting, which function as interfaces between law, the technical knowledge of engineering, materials science and life-cycle assessment (LCA), and the compliance practices of firms. The construction sector illustrates the point. Basic Requirement 7 of Regulation (EU) No 305/2011 required construction works to be designed, built and demolished in such a way that the use of natural resources is sustainable, with reference to recyclability, durability and the use of environmentally compatible materials; in the absence of harmonised assessment methods, however, the requirement remained largely inoperative, while environmental product declarations based on the voluntary standard EN 15804 developed on a parallel, private track (CEN, 2019). Only the recast CPR, Regulation (EU) 2024/3110, applicable since January 2026, sets out to turn this aspiration into declarable environmental performance characteristics, beginning with global warming potential, through harmonised technical specifications and delegated acts, and the Commission's first CPR working plan places cement among the first product families to be addressed. A statutory requirement that a building material be sustainable thus acquires operative meaning only once standards and verification procedures specify what it entails for a brick or a cement product.

The regulatory literature has examined CE policy mixes (Milios, 2018; Domenech and Bahn-Walkowiak, 2019; Hartley et al., 2020) and, separately, the legitimacy of standardisation as a regulatory technique (Schepel, 2005; Eliantonio and Cauffman, 2020), but the two strands rarely meet: CE policy analyses treat standards as neutral technical inputs, while the standardisation literature seldom addresses the principle that standards concretise. The paper addresses this gap through two research questions. RQ1 asks how the regulatory models of the EU, the United States and China allocate the task of concretising sustainability among legislators, administrative authorities, standardisation bodies and firms; RQ2 asks which institutional features determine whether a sustainability requirement becomes enforceable in practice.

MATERIALS AND METHODS

The study combines three legal-analytical methods with a systematic evidence base, the choice of method following from the type of question asked (Van Hoecke, 2011).

Doctrinal and norm-structure analysis

The first layer reconstructs, for each jurisdiction, the normative chain linking the highest-ranking sustainability norm to the lowest-level technical specification. For the EU, the chain begins with Article 3(3) TEU, Article 11 TFEU and Article 37 of the Charter of Fundamental Rights and runs through framework regulations, delegated and implementing acts and standardisation requests under Regulation (EU) No 1025/2012 to the harmonised standards whose references are published in the Official Journal. Each link was coded according to its norm structure (principle, objective, rule or technical parameter), its addressee (public body or firm) and its legal force (binding, presumption-generating or voluntary). Equivalent chains were reconstructed for the US and China.

Functional analysis of administrative instruments

The second layer analyses four families of administrative instruments according to the function they perform in concretisation rather than their formal label: permitting as ex ante individual authorisation, conformity assessment as ex ante verification of product characteristics (from self-declaration to third-party certification),

market surveillance as ex post verification and sanction, and reporting and disclosure as information-based steering. For each instrument the analysis asks who defines the measurable criterion, who verifies it, by which technical method and with what legal consequence. The approach builds on a decentred understanding of regulation (Black, 2001).

Comparative design and evidence base

The comparison follows the functional method (Zweigert and Kötz, 1998; Michaels, 2006), treating the concretisation of sustainability as the shared problem and the three models as alternative solutions; the EU, the United States and China were selected as the three largest economies with distinct CE governance logics (McDowall et al., 2017). The legal analysis is supported by a systematic literature search reported in accordance with the PRISMA 2020 statement (Page et al., 2021). The Web of Science Core Collection and Scopus were searched on 2 November 2026 with a topic search combining CE terms (circular economy, circularity, extended producer responsibility, ecodesign, right to repair) with regulatory terms (regulation, law, standard*, conformity assessment, market surveillance, administrative), which returned 9,848 and 7,216 records, respectively. After the removal of 5,167 duplicates identified by normalised title, records published outside 2010–2025 (n = 2,735), retracted publications (n = 11), document types other than articles and reviews (n = 767) and non-English publications (n = 136) were removed from the Web of Science set before screening, while the Scopus search was limited at source to 2010–2025. The remaining 8,248 records were screened on title and abstract against a predefined term protocol requiring at least one CE term and at least one legal-regulatory term, which excluded 3,690 records and yielded an analytical corpus of 4,558 publications (3,559 from Web of Science and 999 unique to Scopus). A stratified random sample of 200 records (100 included, 100 excluded) was manually checked against the substantive criterion, namely that a record analyses the CE together with law, regulation, policy instruments or standards. The check showed that the protocol favours recall over precision (precision 0.35; 16% of excluded records relevant; estimated recall 0.73). The corpus is therefore interpreted as the CE literature engaging with regulatory vocabulary, and the main results were re-estimated on a high-precision subset of 1,023 records with a regulatory term in the title (sample precision 0.80).The corpus was mapped through a co-occurrence analysis of 66 concepts identified in titles and abstracts by means of a controlled thesaurus that merged spelling variants and synonyms; co-occurrence counts were normalised by association strength (van Eck and Waltman, 2009) and clustered with the Louvain modularity algorithm (Blondel et al., 2008). The share of publications combining legal, technical-assessment and standardisation vocabulary served as an indicator of interdisciplinary connectedness.

RESULTS

The concretisation chain

In all three jurisdictions the doctrinal reconstruction reveals the same basic architecture: an abstract principle at the top, a measurable technical parameter at the bottom, and a sequence of intermediate norms and instruments through which meaning is progressively specified (Figure 1). What differs between the models is not the existence of the chain but the identity of the actor controlling each link and the legal status of the technical knowledge incorporated into it. The legislative norm typically contributes the objective, the product scope and the empowerment to act, whereas the content of the requirement itself, be it a minimum recycled-content share, a repairability score or a carbon-footprint class, is determined further down the chain, where legal and engineering expertise meet.

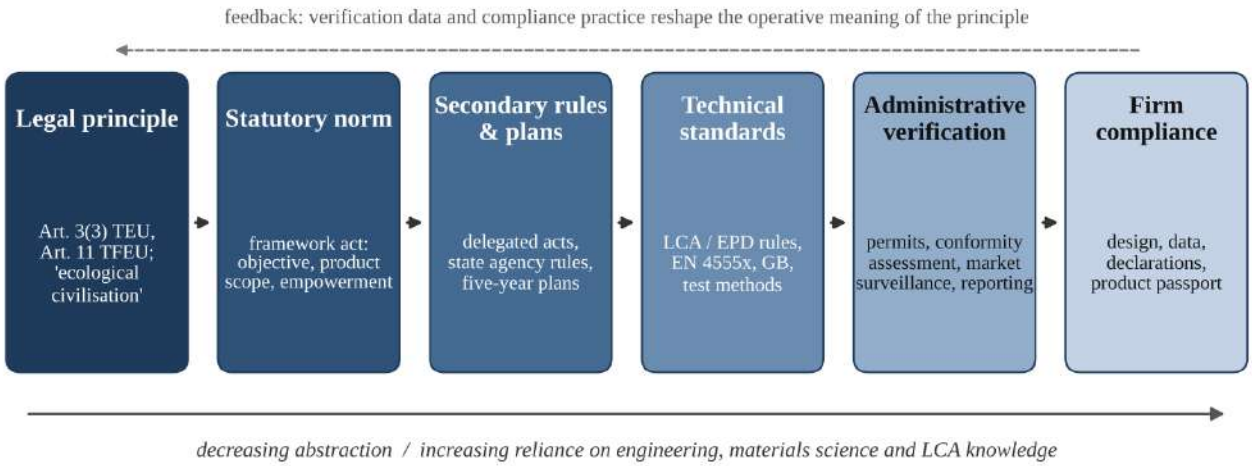


Figure 1. The concretisation chain of sustainability from legal principle to firm compliance

The normative-integrative model of the European Union

The EU model anchors sustainability at the constitutional level but leaves the substantive content of its framework regulations deliberately open, delegating it to secondary legislation and standardisation. The ESPR, Regulation (EU) 2024/1781, is emblematic: Article 5 and Annex I enumerate the product aspects that ecodesign requirements may address, including durability, reparability, recycled content, recyclability and carbon and environmental footprint, while product-specific performance and information requirements are left to delegated acts adopted product group by product group, the first working plan prioritising intermediate products such as steel and aluminium together with textiles, furniture, tyres and mattresses (European Commission, 2025). Measurement methods are supplied by harmonised standards, building on the CEN-CENELEC material-efficiency series such as EN 45554 on the ability to repair, reuse and upgrade (CEN, 2020), whose application confers a presumption of conformity, and the digital product passport adds an informational layer that makes compliance data machine-readable for authorities and value-chain actors (Adisorn et al., 2021; Walden et al., 2021). The same architecture structures the Batteries Regulation (EU) 2023/1542, the Packaging and Packaging Waste Regulation (EU) 2025/40, with recyclability grades deferred to delegated acts, and the recast CPR. On the disclosure side, ESRS E5 translates the same principle into resource-use metrics, although Directive (EU) 2025/794 has postponed its application for many undertakings. Concretisation in the EU is therefore distributed among the Commission as delegated legislator, the European standardisation organisations as technical co-legislators, notified bodies and manufacturers in conformity assessment, and national authorities enforcing under the Market Surveillance Regulation (EU) 2019/1020. Evaluations note that this architecture yields high formal coherence but uneven implementation and a persistent gap between objectives and operative requirements (Dalhammar, 2016; Friant et al., 2021).

The market- and incentive-based model of the United States

The United States has no federal CE statute; the Resource Conservation and Recovery Act remains oriented towards waste management, and federal action consists largely of non-binding strategies such as the National Recycling Strategy (EPA, 2021). Concretisation has therefore migrated to the states. Seven states, Maine and Oregon (2021), Colorado and California (2022), Minnesota (2024), and Maryland and Washington (2025), have enacted packaging EPR laws that oblige producers, mostly through producer responsibility organisations, to finance and organise collection and recycling, while state agencies define what counts as recyclable and approve programme plans. California's truth-in-labelling statute (SB 343, 2021) shows the administrative technique in its purest form: whether a product may bear the recycling symbol depends on criteria derived from a material characterisation study conducted by CalRecycle, so that a consumer-protection norm acquires its content from an empirical administrative assessment. Right-to-repair laws in New York (2022), Minnesota and California (2023) and Oregon (2024) turn reparability into duties to supply parts, tools and documentation, enforced through consumer-protection mechanisms rather than pre-market verification (Svensson-Hoglund et al., 2021; Perzanowski, 2022). Federal law nonetheless plays a structural role through incorporation by reference: the National Technology Transfer and Advancement Act of 1995 and OMB Circular A-119 direct

agencies to use voluntary consensus standards, and 1 CFR Part 51 permits their incorporation into binding regulations provided they are reasonably available. The tension between private copyright in standards and public access to binding law (Bremer, 2013; Mendelson, 2014) was eased, not resolved, in *ASTM v. Public.Resource.Org* (2023), which held non-commercial reproduction of incorporated standards to be fair use.

The state-led model of China

The Circular Economy Promotion Law of 2008, amended in 2018, framed the circular economy as a national development strategy and linked it to a target-responsibility system under which the fulfilment of CE indicators enters the performance evaluation of local governments and their leading officials (Mathews and Tan, 2011; Su et al., 2013). Concretisation therefore runs primarily through planning, most recently the 14th Five-Year Plan for Circular Economy Development (NDRC, 2021), rather than through conditions of market access. The Ecological and Environmental Code, adopted on 12 March 2026 and in force since 15 August 2026, incorporates much of the CE regime, while the Circular Economy Promotion Law remains a separate statute, and it introduces take-back obligations for products and packaging on a mandatory recycling list. Technical concretisation relies on the dual structure of the Standardization Law, which distinguishes mandatory national standards (GB) from recommended ones (GB/T), so that a technical specification becomes binding by designation rather than by incorporation into a legislative act. Target-based steering, however, rewards formal compliance rather than verifiable performance, a pattern Kostka (2016) called command without control, producing implementation gaps wherever local data cannot be independently checked (Ran, 2013).

Table 1 summarises how the three models allocate the concretising function.

Table 1. Allocation of the concretisation of sustainability in the three regulatory models

Dimension	European Union (normative-integrative)	United States (market- and incentive-based)	China (state-led)
Normative anchor	Treaty and Charter principle; framework regulations (ESPR, CPR, PPWR)	No federal CE statute; state EPR and right-to-repair laws	CE Promotion Law (2008/2018); Ecological and Environmental Code (2026)
Main concretising actor	Commission (delegated acts); CEN-CENELEC (harmonised standards)	State agencies; producer responsibility organisations; standards developers	NDRC and ministries (plans, targets); standardisation administration
Technical instruments	Ecodesign requirements, EPD/LCA rules, digital product passport	Recyclability criteria, programme plans, repair-information duties	Indicator systems, mandatory GB standards, recycling lists
Verification	Conformity assessment; market surveillance (Reg. 2019/1020)	Agency approval and audit; consumer-protection enforcement	Hierarchical target evaluation of local governments
Legal status of standards	Part of EU law; presumption of conformity	Incorporation by reference; private copyright	Binding by designation (GB vs GB/T)
Main source of uncertainty for firms	Gap between framework and delegated/technical specification	Fragmented state requirements and definitions	Shifting plans and local implementation

The co-occurrence network of the 4,558 publications resolved into seven clusters (modularity Q = 0.48), and its structure separates precisely the elements that the concretisation chain connects: standardisation co-occurs with construction and cement, carbon footprint, durability and LCA, that is, with the technical-assessment literature; law and legislation cluster with repair, the right to repair and consumer behaviour, next to a distinct EU cluster of directives and ecodesign; and administrative authorities and enforcement appear together with municipal waste management, EPR and hazardous substances. The separation is robust: in 200 runs of the algorithm across five resolution values, standardisation never shared a cluster with law or administrative authorities, but did so with LCA in 94% of the runs. Legal vocabulary occurs in 37.8% and technical-assessment vocabulary in 27.0% of the corpus, yet only 8.5% of the publications combine the two and only 1.5% combine them with standardisation or verification terms; of the 131 Web of Science publications in

journals classified under Law, 10 refer to technical-assessment methods and 5 to standards. Conformity assessment and market surveillance appear in four titles or abstracts each, and the presumption of conformity, notified bodies and incorporation by reference in none. Between 2010–2015 and 2024–2025 the share of legal vocabulary fell from 55.0% to 29.7% and that of technical vocabulary rose from 20.3% to 30.7%, while their overlap declined from 10.4% to 7.3%. The pattern persists in the high-precision subset, where legal and technical vocabulary co-occur in 10.8% and all three vocabularies in 1.9% of records, and standardisation again never clusters with law or administrative authorities but always with LCA, here within an EU cluster of ecodesign and directives.

DISCUSSION

The comparison suggests, first, that the enforceability of sustainability depends less on its formal rank in the hierarchy of norms than on the administrative capacity to verify technical compliance. The EU anchors sustainability at the highest constitutional level, yet the experience with Basic Requirement 7 of the 2011 CPR shows that a requirement without an assessment method and a verifying authority remains declaratory; conversely, the Californian recyclability criteria, positioned low in the hierarchy of norms, are operative because an agency is empowered to generate and apply the empirical data on which they rest, and China's statutory commitments coexist with the verification deficit described by Kostka (2016). Verification capacity has an epistemic dimension, the availability of validated measurement methods such as LCA-based footprint rules, durability tests or repairability scoring systems, and an institutional dimension, the existence of laboratories, notified bodies, market-surveillance authorities and data infrastructures able to apply them. The digital product passport and EU market surveillance attempt to build both dimensions at once; US reliance on producer responsibility organisations delegates verification to industry itself, with risks of capture that have prompted proposals for pre-market producer responsibility (Maitre-Ekern, 2021); and the Chinese target system concentrates verification within the hierarchy whose performance it evaluates.

Second, the incorporation of voluntary standards into binding requirements emerges as a key and under-theorised mechanism of legal concretisation. The Court of Justice held in *James Elliott Construction* (C-613/14) that a harmonised standard forms part of EU law, and in *Public.Resource.Org and Right to Know* (C-588/21 P) that there is an overriding public interest in access to harmonised standards; read together, the two judgments reclassify technical knowledge produced by private bodies as a component of the legal order (Volpato, 2017). The United States reaches a functionally similar result through incorporation by reference but continues to treat the incorporated text as private property to which access must be negotiated, while China resolves the question by designation, turning a standard into law through its mandatory status. In each system the moment of incorporation is where sustainability acquires operative content, yet it is precisely this moment that legal doctrine examines least, as the near-absence of verification instruments from the mapped literature confirms, because the classical hierarchy of norms offers no ready category for a norm drafted by an expert committee, endorsed by an administrative act and enforced by a market-surveillance authority. The legitimacy questions raised by such hybrid norms, concerning participation, transparency and judicial review, are well rehearsed in the standardisation literature (Schepel, 2005; Eliantonio and Cauffman, 2020), but they have not been examined in relation to sustainability, whose contested content turns the choice of metric into a normative rather than a merely technical decision. Selecting global warming potential as the first declarable characteristic of construction products privileges climate impact over resource depletion or toxicity, a weighing of interests in Alexy's (2002) sense carried out within a technical committee rather than by the legislator.

Third, these architectures translate into different profiles of regulatory certainty for firms. The EU offers high ex ante certainty once a delegated act and the corresponding harmonised standards are in place, but considerable uncertainty during the often lengthy interval between the adoption of a framework and its technical specification, as the decade-long transition from the 2011 to the 2024 CPR illustrates. The US model generates a patchwork of state definitions that multiplies compliance costs, while disputes over access to standards add legal uncertainty. In China, certainty depends on administrative plans and local implementation, which may shift quickly with policy priorities. The findings are preliminary: the comparison covers three systems at a time of rapid legislative change, US state law is heterogeneous and Chinese sources were partly analysed in translation.

CONCLUSION

Sustainability becomes a legal requirement for products and processes not when it is proclaimed as a principle but when an identifiable actor, using an identifiable method, can verify whether a brick, a battery or a package conforms to it. The three regulatory models examined here allocate this concretising function differently, the EU to delegated legislation and harmonised standards, the United States to state agencies, producer organisations and incorporated private standards, and China to planning, target responsibility and mandatory national standards, yet in all three the operative content of sustainability is produced at the interface between administrative instruments and technical knowledge. Two implications follow for regulatory design. Legislators should treat verification capacity as a constitutive element of any sustainability requirement and provide for it when the requirement is adopted rather than after it, and the incorporation of standards into law should be made subject to procedural guarantees commensurate with the normative choices it embodies. Effective CE regulation thus requires interdisciplinary regulatory design in which law engages directly with the engineering, materials-science, LCA and economic disciplines that define what sustainability means in practice.

ACKNOWLEDGEMENTS

This paper was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

REFERENCES

Adisorn T, Tholen L, Götz T 2021. Towards a digital product passport fit for contributing to a circular economy. Energies, 14(8): 2289. https://doi.org/10.3390/en14082289

Alexy R 2002. A Theory of Constitutional Rights. Oxford: Oxford University Press, 462 pp.

Black J 2001. Decentring regulation: Understanding the role of regulation and self-regulation in a 'post-regulatory' world. Current Legal Problems, 54(1): 103-146. https://doi.org/10.1093/clp/54.1.103

Blondel VD, Guillaume JL, Lambiotte R, Lefebvre E 2008. Fast unfolding of communities in large networks. Journal of Statistical Mechanics: Theory and Experiment, 2008(10): P10008. https://doi.org/10.1088/1742-5468/2008/10/p10008

Bosselmann K 2016. The Principle of Sustainability: Transforming Law and Governance, 2nd ed. London: Routledge.

Bremer ES 2013. Incorporation by reference in an open-government age. Harvard Journal of Law & Public Policy, 36(1): 131-210. https://ssrn.com/abstract=2127288

CEN 2019. EN 15804:2012+A2:2019 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products. Brussels: European Committee for Standardization.

CEN 2020. EN 45554:2020 General methods for the assessment of the ability to repair, reuse and upgrade energy-related products. Brussels: CEN-CENELEC.

Dalhammar C 2016. Industry attitudes towards ecodesign standards for improved resource efficiency. Journal of Cleaner Production, 123: 155-166. https://doi.org/10.1016/j.jclepro.2015.12.035

Domenech T, Bahn-Walkowiak B 2019. Transition towards a resource efficient circular economy in Europe: Policy lessons from the EU and the member states. Ecological Economics, 155: 7-19. https://doi.org/10.1016/j.ecolecon.2017.11.001

Dworkin R 1977. Taking Rights Seriously. Cambridge, MA: Harvard University Press.

Eliantonio M, Cauffman C (eds) 2020. The Legitimacy of Standardisation as a Regulatory Technique: A Cross-disciplinary and Multi-level Analysis. Cheltenham: Edward Elgar.

EPA 2021. National Recycling Strategy: Part One of a Series on Building a Circular Economy for All. Washington, DC: U.S. Environmental Protection Agency.

European Commission 2020. A new Circular Economy Action Plan for a cleaner and more competitive Europe. COM(2020) 98 final, Brussels.

European Commission 2025. Ecodesign for Sustainable Products and Energy Labelling Working Plan 2025–2030. Brussels, 16 April 2025.

Friant MC, Vermeulen WJV, Salomone R 2021. Analysing European Union circular economy policies: Words versus actions. Sustainable Production and Consumption, 27: 337-353. https://doi.org/10.1016/j.spc.2020.11.001
Geissdoerfer M, Savaget P, Bocken NMP, Hultink EJ 2017. The circular economy – A new sustainability paradigm? Journal of Cleaner Production, 143: 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048
Hartley K, van Santen R, Kirchherr J 2020. Policies for transitioning towards a circular economy: Expectations from the European Union (EU). Resources, Conservation and Recycling, 155: 104634. https://doi.org/10.1016/j.resconrec.2019.104634
Kaplow L 1992. Rules versus standards: An economic analysis. Duke Law Journal, 42(3): 557-629. https://doi.org/10.2307/1372840
Kirchherr J, Reike D, Hekkert M 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127: 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005
Kirchherr J, Yang NHN, Schulze-Spüntrup F, Heerink MJ, Hartley K 2023. Conceptualizing the circular economy (revisited): An analysis of 221 definitions. Resources, Conservation and Recycling, 194: 107001. https://doi.org/10.1016/j.resconrec.2023.107001
Kostka G 2016. Command without control: The case of China's environmental target system. Regulation & Governance, 10(1): 58-74. https://doi.org/10.1111/rego.12082
Maitre-Ekern E 2021. Re-thinking producer responsibility for a sustainable circular economy from extended producer responsibility to pre-market producer responsibility. Journal of Cleaner Production, 286: 125454. https://doi.org/10.1016/j.jclepro.2020.125454
Mathews JA, Tan H 2011. Progress toward a circular economy in China: The drivers (and inhibitors) of eco-industrial initiative. Journal of Industrial Ecology, 15(3): 435-457. https://doi.org/10.1111/j.1530-9290.2011.00332.x
McDowall W, Geng Y, Huang B, Barteková E, Bleischwitz R, Türkeli S, Kemp R, Doménech T 2017. Circular economy policies in China and Europe. Journal of Industrial Ecology, 21(3): 651-661. https://doi.org/10.1111/jiec.12597
Mendelson NA 2014. Private control over access to the law: The perplexing federal regulatory use of private standards. Michigan Law Review, 112(5): 737-807. https://doi.org/10.36644/mlr.112.5.private
Michaels R 2006. The functional method of comparative law. In: Reimann M, Zimmermann R (eds), The Oxford Handbook of Comparative Law. Oxford: Oxford University Press, pp. 339-382.
Milios L 2018. Advancing to a circular economy: Three essential ingredients for a comprehensive policy mix. Sustainability Science, 13(3): 861-878. https://doi.org/10.1007/s11625-017-0502-9
NDRC 2021. 14th Five-Year Plan for Circular Economy Development. Beijing: National Development and Reform Commission.
Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. 2021. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372: n71. https://doi.org/10.31222/osf.io/v7gm2_v1
Perzanowski A 2022. The Right to Repair: Reclaiming the Things We Own. Cambridge: Cambridge University Press.
Ran R 2013. Perverse incentive structure and policy implementation gap in China's local environmental politics. Journal of Environmental Policy & Planning, 15(1): 17-39. https://doi.org/10.1080/1523908x.2012.752186
Schepel H 2005. The Constitution of Private Governance: Product Standards in the Regulation of Integrating Markets. Oxford: Hart Publishing.
Su B, Heshmati A, Geng Y, Yu X 2013. A review of the circular economy in China: Moving from rhetoric to implementation. Journal of Cleaner Production, 42: 215-227. https://doi.org/10.1016/j.jclepro.2012.11.020
Svensson-Hoglund S, Richter JL, Maitre-Ekern E, Russell JD, Pihlajarinne T, Dalhammar C 2021. Barriers, enablers and market governance: A review of the policy landscape for repair of consumer electronics in the EU and the U.S. Journal of Cleaner Production, 288: 125488. https://doi.org/10.1016/j.jclepro.2020.125488

van Eck NJ, Waltman L 2009. How to normalize cooccurrence data? An analysis of some well-known similarity measures. Journal of the American Society for Information Science and Technology, 60(8): 1635-1651. https://doi.org/10.1002/asi.21075
Van Hoecke M (ed) 2011. Methodologies of Legal Research: Which Kind of Method for What Kind of Discipline? Oxford: Hart Publishing.
Voigt C 2009. Sustainable Development as a Principle of International Law. Leiden: Martinus Nijhoff.
Volpato A 2017. The harmonized standards before the ECJ: James Elliott Construction. Common Market Law Review, 54(2): 591-603. https://doi.org/10.54648/cola2017036
Walden J, Steinbrecher A, Marinkovic M 2021. Digital product passports as enabler of the circular economy. Chemie Ingenieur Technik, 93(11): 1717-1727. https://doi.org/10.1002/cite.202100121
Zweigert K, Kötz H 1998. An Introduction to Comparative Law, 3rd ed. Oxford: Clarendon Press.

Legislation and case law

Court of Justice of the EU, Case C-613/14 James Elliott Construction, ECLI:EU:C:2016:821.
Court of Justice of the EU, Case C-588/21 P Public.Resource.Org and Right to Know v Commission, ECLI:EU:C:2024:201.
European Union: Regulations (EU) No 305/2011 and 2024/3110 (construction products), No 1025/2012 (standardisation), 2019/1020 (market surveillance), 2023/1542 (batteries), 2024/1781 (ESPR), 2025/40 (packaging); Directive (EU) 2022/2464 (CSRD); Delegated Regulation (EU) 2023/2772 (ESRS); Directive (EU) 2025/794.
United States: National Technology Transfer and Advancement Act of 1995, Pub. L. 104-113; OMB Circular A-119 (2016); 1 CFR Part 51; California SB 343 (2021) and SB 54 (2022); ASTM v. Public.Resource.Org, Inc., 82 F.4th 1262 (D.C. Cir. 2023).
People's Republic of China: Circular Economy Promotion Law (2008, amended 2018); Standardization Law (2017 revision); Ecological and Environmental Code (adopted 12 March 2026).

EXAMINING THE RELATIONSHIP BETWEEN NATURE RELATEDNESS AND SELF-COMPASSION AMONG PRE-SERVICE PRESCHOOL TEACHERS

Emine Betül KARABIYIK
Nilüfer DARICA
Res. Asst., ORCID: 0009-0008-9573-6155, Hasan Kalyoncu University, Faculty of Education, Department of Basic Education, Division of Preschool Education, Gaziantep, Türkiye.
Prof. Dr., ORCID: 0000-0002-5369-9690, Hasan Kalyoncu University, Faculty of Education, Department of Basic Education, Division of Preschool Education, Gaziantep, Türkiye.

Abstract

Early childhood is a formative period in which children develop relationships with the natural environment and begin to shape their attitudes toward nature. Preschool teachers are among the key adults who structure children's encounters with nature and their outdoor experiences, while the foundations of these pedagogical approaches begin to develop during teacher education. From this perspective, it is important to consider not only pre-service teachers' orientations toward nature but also the way they relate to themselves. Self-compassion, which refers to responding to personal difficulties with understanding and support, may be associated with the cognitive, emotional, and experiential connection individuals establish with nature. However, the relationship between these two constructs has received limited attention in the context of preschool teacher education. This study therefore aimed to examine the relationship between self-compassion and nature relatedness among pre-service preschool teachers.

The study employed a cross-sectional correlational design. The sample comprised 275 pre-service preschool teachers (M age = 21.18, SD = 3.01; 92% women); the primary correlation analysis included 214 participants with complete scores on both scales. Data were collected using the Nature Relatedness Scale and the Self-Compassion Scale. The association between the two variables was examined using Pearson's product-moment correlation coefficient.

The findings indicated a positive, moderate, and statistically significant relationship between self-compassion and nature relatedness, $r = .353$, 95% CI [.230, .465], $p < .001$. In other words, pre-service preschool teachers who reported higher levels of self-compassion also tended to report a stronger sense of connection with nature. These findings suggest that pre-service teachers' personal development and their relationship with the natural world may be meaningfully interconnected rather than independent domains. Considering these dimensions together in preschool teacher education may therefore provide a more integrated understanding of how future teachers develop both personally and in relation to the environments in which early childhood education takes place.

Keywords: early childhood education, pre-service preschool teachers, nature relatedness, self-compassion, teacher education.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

A COMPARATIVE ANALYSIS OF FORBIDDEN LOVE, TRAGIC ENDINGS, AND THE PSYCHOLOGY OF INFIDELITY IN EFFI BRIEST AND AŞK-I MEMNU

Zeynep İrem Tuncer
Fatma Karaman
0009-0003-3499-535X, Fırat University, Graduate School of Social Sciences. Faculty of Humanities and Social Sciences, Department of Western Languages and Literatures / Division of German Language and Literature, Elazığ, Türkiye
0000-0002-0461-5593, Fırat University, Graduate School of Social Sciences. Faculty of Humanities and Social Sciences, Department of Western Languages and Literatures / Division of German Language and Literature, Elazığ, Türkiye

Abstract

Theodor Fontane, one of the most prominent representatives of poetic realism in 19th-century German literature, and Halit Ziya Uşaklıgil, a pioneer of the Servet-i Fünun period and the founder of the modern Turkish novel in Turkish literature, stand out as authors who profoundly explore social reality and individual psychology within their respective literary traditions. In this study, Theodor Fontane's Effi Briest and Halit Ziya Uşaklıgil's Aşk-ı Memnu will be analyzed within the framework of comparative literature and a text-oriented methodology. The works will be comparatively analyzed in terms of their similarities, differences, and common ground through the themes of forbidden love, the psychology of infidelity, and tragic endings, supported by textual citations. In both novels, the female protagonists at the center of the narrative engage in extramarital affairs as a result of the emotional void they experience within their marriages. The study will examine how Effi and Bihter are drawn into the process of infidelity and the internal conflicts the characters experience within their inner worlds. Furthermore, the underlying causes of the forbidden love affairs and the consequences of these relationships will be compared. The aim of the study is to analyze the psychological and social conflicts experienced by female characters in these two novels written in different sociological, societal, and cultural geographies in terms of their similarities and differences, through the themes of forbidden love, the psychology of infidelity, and tragic endings. Both novels conclude with a tragic downfall for the female characters. Driven by despair and the devastation wrought by her forbidden love, Bihter ends her own life, whereas Effi, alienated by society and her family following the exposure of her affair, passes away as a result of an illness brought on by deep solitude. The fundamental common ground between Fontane and Uşaklıgil writing in distinct sociocultural geographies within the context of literatüre lies in their realistic approach to novelizing late 19th-century elite life, the moral framework of this class, and the individual's entrapment within it through the psychological depth of their characters.

Keywords: Theodor Fontane, Halit Ziya Uşaklıgil, Effi Briest, Aşk-ı Memnu, Comparative Literature.

EFFI BRIEST VE AŞK-I MEMNU'DA YASAK AŞK, TRAJİK SON VE ALDATMA PSİKOLOJİSİ ÜZERİNE KARŞILAŞTIRMALI BİR İNCELEME

Özet

19. yüzyıl Alman Edebiyatında şiirsel gerçekliğin en önemli temsilcilerinden biri olan Theodor Fontane ile Türk Edebiyatında Servet-i Fünun döneminin ve modern Türk romanının kurucularından Halit Ziya Uşaklıgil, kendi edebiyat gelenekleri içerisinde toplumsal gerçekliği ve bireysel psikolojiyi derinlemesine işleyen yazarlar olarak öne çıkmaktadır. Bu çalışmada Theodor Fontane'nin Effi Briest ve Halit Ziya Uşaklıgil'in Aşk-ı Memnu adlı eserleri, karşılaştırmalı edebiyat bağlamında ve metin odaklı yöntem çerçevesinde incelenecektir. Eserler yasak aşk, aldatma psikolojisi ve trajik son izlekleri üzerinden, metinlerden alıntı

yapılarak benzerlik, farklılık ve ortak noktaları bağlamında karşılaştırmalı olarak analiz edilecektir. Her iki romanda da merkezde yer alan kadın karakterler, evlilik içinde yaşadıkları duygusal boşluk sonucunda yasak ilişkilere yönelmektedir. Çalışmada, Effi ve Bihter'in aldatma sürecine nasıl sürüklendikleri ve karakterlerin iç dünyalarında yaşadıkları çatışmalar ele alınacaktır. Ayrıca yasak aşkın ortaya çıkış nedenleri ile bu ilişkilerin sonuçları karşılaştırılacaktır. Çalışmanın amacı, farklı, sosyolojik, toplumsal ve kültürel coğrafyalarda yazılmış bu iki romanda, kadın karakterlerin yaşadığı psikolojik ve toplumsal çatışmaları yasak aşk, aldatma psikolojisi ve trajik son izlekleri üzerinden, benzerlikleri ve farklılıkları noktalarında analiz etmektir. İki romanda da kadın karakterler açısından trajik bir yıkımla sonlanmaktadır. Bihter, çaresizlik ve yaşadığı yasak aşkın yarattığı yıkım sonucunda kendi hayatına son vermiş, Effi ise yasak aşkın ortaya çıkmasıyla toplum ve ailesi tarafından dışlanarak, yaşadığı derin yalnızlığın getirdiği hastalık sonucunda hayata veda etmiştir. Farklı sosyokültürel coğrafyalarda eserlerini yazan Fontane ve Uşaklıgil'in edebiyat bağlamındaki temel ortak noktası; 19. yüzyıl sonu seçkin sınıf yaşantısını, bu sınıfın ahlak anlayışını ve bu anlayış içinde bireyin sıkışmışlığını realist bir yaklaşımla ve karakterlerin psikolojisi üzerinden romanlaştırmış olmalarıdır.

Anahtar sözcükler: Theodor Fontane, Halit Ziya Uşaklıgil, Effi Briest, Aşkı-ı Memnu, Karşılaştırmalı Edebiyat.

Giriş

Karşılaştırmalı edebiyat, iki ya da daha fazla ulusun edebiyatını dilsel, kültürel ve toplumsal açılardan inceleyen bir alandır (Akay, 2017). Remak'ın yaklaşımında bu inceleme, edebiyatın ulusal sınırların ötesinde ele alınmasının yanı sıra edebiyatın sanat, felsefe, din ve toplumsal bilimler gibi diğer alanlarla ilişkisini de kapsar (Remak, 1961). 19. yüzyıl romanında evlilik, bireysel arzular ile toplumsal beklentilerin çatıştığı en önemli alanlardan biri olarak karşımıza çıkar. Tanner (1979), 18. ve 19. yüzyıl burjuva romanlarında evlilik sözleşmesinin ihlalinin özel bir anlam kazandığını ve bu anlatıların kadının konumu, aile yapısı ve toplumsal normlarla iç içe okunabileceğini ileri sürer. Evliliğinde aradığını bulamayan kadının yasak bir ilişkiye yönelmesi ve bunun toplumsal bedeli de farklı edebiyatlarda sıkça işlenen bir konudur. Bu iki eser farklı kültürlerde yazılmış, benzer temaları işleyen iki önemli eserdir. Her iki eserde de merkezde yer alan kadın karakterlerin, evliliklerinde yaşadıkları duygusal eksikliklerin etkisiyle yasak ilişkilere yöneldikleri görülmektedir. Bu çalışmada Fontane ile Uşaklıgil arasında bir etki ilişkisi aranmamaktadır ve benzer bir temanın iki farklı edebi gelenekte nasıl işlendiğini karşılaştırmaktadır. Bu iki romanın aldatan kadın teması üzerinden birlikte ele alındığı çalışmalar bulunmaktadır (Eğilmez, 2007). Ancak yasak aşkın ortaya çıkış nedenleri, karakterlerin aldatma sürecindeki psikolojileri ve trajik sonun biçimi doğrudan metinlerden alıntılarla yan yana okunduğu çalışmaların sınırlı olduğu görülmektedir. Bu çalışma, söz konusu boşluğa katkı sunmayı amaçlamaktadır. Çalışmada Effi ve Bihter'in yasak ilişkiye nasıl sürüklendiği, bu sürecin karakterlerin iç dünyasında yarattığı çatışma ve iki kadının farklı biçimlerde de olsa neden trajik bir sona vardığı karşılaştırmalı olarak incelenmiştir.

Edebi eserlerdeki karakterlerin davranışlarını doğru yorumlamak için önce aldatma kavramının ne anlama geldiğine bakmak gerekir. Türk Dil Kurumu sözlüğüne göre "aldatmak", birine verilen sözü tutmamak, yalan söylemek ve karşısındakini yanıltmak (TDK) gibi anlamlara gelir. Evlilik ve ilişkiler bağlamında ise eşlerden birinin diğerine sadakatsizlik etmesi olarak tanımlanır. Bu tanımlardan yola çıkılarak aldatmanın sadece fiziksel bir eylem olmadığını aynı zamanda dürüstlüğün kaybedilmesini, verilen sözlerin çiğnenmesini ve kişiler arasındaki güven bağının kopmasını ifade eden çok yönlü bir durum olduğunu görmekteyiz. Türk Dil Kurumu sözlüğüne göre "yasak aşk", hukuk, din ve töre bakımından uygun görülmeyen, toplum tarafından reddedilen ilişki biçimidir (TDK). Bu tanımdan yola çıkıldığında yasak aşkın sadece bireysel bir duygu olmadığı, aynı zamanda toplumsal normlarla, kültürel değerlerle ve yasal sınırlarla çatışan sosyolojik bir olgu olduğu düşünülebilir. Edebi metinlerde, tiyatro oyunlarında veya sinemada; baştan beri düzenli giden bir sürecin, kahramanın kendi hatası, karakter kusuru veya engellenemeyen kaderi neticesinde kaçınılmaz bir yıkımla, ölümle veya geri dönülemez bir kaosla noktalanması durumudur. Aristoteles'ten günümüze trajik son, izleyicide korku ve acıma duygusu uyandırarak duygusal bir arınma (katarsis) yaşatmayı amaçlayan edebi bir sonuçtur (Bude, 2020).

Yöntem

Bu araştırmada, Fransız Karşılaştırmalı Edebiyat Okulu'nun metinler arası ve tematik odaklı karşılaştırma anlayışından (Pichois & Rousseau, 1994) ve Amerikan Okulu'nun metin merkezli inceleme ilkelerinden (Remak, 1961) yola çıkılarak Metin Odaklı Karşılaştırmalı Analiz Yöntemi benimsenmiştir. İnceleme, Theodor Fontane'nin Effi Briest ve Halit Ziya Uşaklıgil'in Aşk-ı Memnu eserlerinin birincil metinleri üzerinden gerçekleştirilmiştir. Analiz sürecinde; kadın karakterlerin evlilik içindeki ruhsal durumları, aldatma eylemine sürüklenişlerindeki motivasyonlar ve bu sürecin beraberinde getirdiği trajik yıkım, doğrudan metinlerden yapılan alıntılarla ve derinlemesine yakın okuma tekniğiyle çözümlenmiştir. Eserler; Gürsel Aytaç'ın (2003) karşılaştırmalı edebiyat modeli doğrultusunda yasak aşk, aldatma psikolojisi ve trajik son izlekleri etrafında, benzerlikler ve farklılıklar yöntemiyle yatay ve dikey düzlemde karşılaştırılmıştır.

Bulgular ve Tartışma

Effi Briest İncelemesi

Theodor Fontane, Alman edebiyatının ve realizm akımının önde gelen temsilcilerinden biri olarak, eserlerinde 19. yüzyıl Almanya'sının toplumsal yapısını yansıtmaktadır ve dönemin kadınlarının yaşamları hakkında bilgi vermektedir (İlkılıç, 2024, s. 14).

Effi, annesinin eski hayranı olan ve kendisinden iki kat büyük, devlet görevlisi olan Geert von Innstetten ile evlendirilir. Bu evlilikle birlikte Effi Kessin'e taşınır. Innstetten'in kariyer odaklı, katı, disiplini ve duygusal mesafesi, Effi'yi derin bir yalnızlığa ve can sıkıntısına sürükler. Yapılan çalışmalar kadınların gözünden evlilik dışı ilişkilere yönelmenin arkasındaki en temel nedenlerin eşten görülen ilgi yetersizliği ve erkeğin kadın üzerinde baskıcı bir otorite kurma çabası olduğunu göstermektedir (Üstün ve Öztürk Özer, 2021, s. 3317-3318). Bu duygusal boşluk ve yabancılaşma sürecinde kasabaya gelen Binbaşı Crampas, Effi için bir kaçış kapısı olur. Effi, Crampas'a karşı büyük bir aşk duymaktan ziyade, içine düştüğü monotonluktan kaçma arzusuyla kendini yasak bir ilişkinin içinde bulur. Bir süre sonra bu ilişki sona erer ve Effi, kocasının Berlin'e tayin olmasıyla birlikte yeni, huzurlu bir hayata başladığını düşünür. Ancak yıllar sonra Innstetten, Effi'nin eski aşk mektuplarını tesadüfen bulur. Innstetten, Effi'yi hâlâ sevmesine rağmen Crampas'ı düelloda öldürür ve Effi'den boşanır. Ailesi ve toplum tarafından tamamen dışlanan Effi, çocuğu da elinden alınarak bir sosyal ölüme mahkûm edilir. Bu ağır psikolojik yükü kaldıramayan Effi, genç yaşta hastalanarak hayata veda eder. Effi'nin yasak ilişkiye zemin hazırlayan psikolojik kırılması, evliliğin ilk dönemlerinde hissetmeye başladığı tatminsizlik ve yabancılaşma duygusuyla başlar. Innstetten'in ona bir çocuk gibi şefkat göstermesi veya kariyerinin getirdiği saygınlık, Effi gibi genç bir kadının arzularını doyurmaya yetmez. Fontane, Effi'nin bu içsel aydınlanmasını şu cümlelerle aktarır: "…ama bu iyi niyetli latifeler Effi'yi eğlendirmekten başka bir sonuca varıyor, hatta bazen içinde bir acı uyandırıyordu, çünkü böylece evliliğinde asıl neyin noksan olduğunun muğlak olsa da farkına varıyordu: Sevgi gösterileri, özendirmeler, küçük hoşluklar. Innstetten iyiydi, hoştu ama bir aşık değildi" (Fontane, 2026, s. 125). Buradan Effi'nin evlilikteki eksikliği ilk başta tam olarak adlandıramadığını ancak ruhsal olarak huzursuz hissettiğini görmekteyiz. Innstetten, Effi için bir sevgiliden ziyade bir eğitmen, bir baba figürüdür. Onun gösterdiği sevgi, kurallara bağlı ve mesafeli bir özenden ibarettir. Oysa Effi'nin aradığı şey rasyonel bir evlilik değil, romantik bir tutkudur. Alıntıda belirtilen "içinde bir acı uyanması" durumu, karakterin yaşadığı çaresizliğin ilk sinyalleridir. Bu duygusal boşluk ve aşık bir partnerin yokluğu, kasabaya Binbaşı Crampas'ın gelişiyle birlikte Effi'yi bir aldatma sürecine sürükler. Effi'nin kocasından uzaklaşması sadece romantik bir beklentinin boşa çıkmasıyla sınırlı kalmaz, bu durum zamanla derin bir yabancılaşmaya ve bir korkuya dönüşür. Karakteri evlilik ilişkisindeki bu aşılmaz mesafe ve kocasının varlığı karşısında korku hissetmektedir. "… yabancı bir tarafı vardı. Sevgi gösterdiğinde de yabancı kalıyordu. Hatta en çok o vakit; Öyle zamanlar oldu ki o halinden korkuyordum" (Fontane, 2026, s. 259). Bu ifadeler, Effi'nin iç dünyasındaki yalnızlığın boyutlarını göstermektedir. Innstetten'in sevgisi Effi'de bir yakınlık hissi uyandırmak yerine, aralarındaki aşılmaz duvarları daha net görmesini sağlar. En şefkatli anlarda bile kocası ona yabancı bir figür olarak kalır. Sevginin onları yakınlaştırması gerekirken, Effi için tam tersi olur ve bu sevgi onda bir korku yaratır. Çünkü Effi, kendi çocuksu ve özgür doğasının, kocasının temsil ettiği bu katı toplumsal disiplin içinde yok olacağından korkmaktadır. Evlilik bir sığınak olmaktan çıkıp yabancı ve

ürkütücü bir mekâna dönüşür, Effi için bu ortamdan kaçmak ve yabancı olmayan, kendisi gibi yaşayan Crampas'a yönelmek bir zorunluluk haline gelir. Effi, yaşadığı bu gizli ilişkinin fiziksel detaylarından uzak dursa da aldatmanın yarattığı ahlaki yükü ruhunun en derinlerinde taşımaya devam eder. İlişki bittikten ve kocasıyla Berlin'e taşındıktan sonra bile, geçmişin gölgesi onun peşini bırakmaz.

Ancak Effi için asıl büyük trajedi, bu içsel azabın mektupların bulunmasıyla birlikte somut bir toplumsal cezalandırmaya dönüşmesidir. Innstetten'in toplum kuralları gereği ondan boşanması ve çocuğunu elinden almasının ardından, Effi asıl darbeyi sığınmayı umduğu kendi ailesinden alır. Toplumsal ayıplanma korkusu endişesi, anne ve babasının kapılarını Effi'ye kapatmasına neden olur. "Yalnız kalacaksın ve eğer bunu istemezsen herhalde kendi muhitinden aşağı inmen gerekecek. İçinde yaşamış olduğun dünya sana kapalı kalacak. Ve bizim için en üzücü olan şey, ki senin için de böyledir, ana baba evi de sana kapalı kalacak" (Fontane, 2026, s. 308). "Kendi muhitinden aşağı inmek", Effi gibi elit bir çevrede büyümüş bir kadın için sınıfsal ve sosyal bir yok oluştur. Ailesinin bile içinde yaşanılan dünyayı ve toplumsal kuralları evlat sevgisinden üstün tutması, Effi'yi bir sosyal ölüme sürükler. Sığınacak hiçbir yeri, dönecek bir baba evi kalmayan Effi, toplumdan soyutlanır. Hissettiği suçluluk duygusu, bu dışlanmışlıkla birleştiğinde, karakterin fiziksel direnci de azalır. Effi bu ağır psikolojik yük altında hastalanarak genç yaşta hayata veda eder.

Aşkı- Memnu İncelemesi

Halit Ziya Uşaklıgil, Servet-i Fünun edebiyatının başlıca temsilcilerinden biri olarak modern Türk romanının gelişiminde öncü bir rol üstlenmiştir (Eğilmez, 2007, s. 20). Halit Ziya Uşaklıgil'in Aşk-ı Memnu adlı eseri, bireysel arzular ile toplumsal kimlik arasında sıkışan bir kadının psikolojik çöküşünü merkezine alır. Edebiyat eleştirisinde bu eser, lüks bir yaşam vaadi ve statü hırsıyla kendisinden yaşça büyük, dul ve çocuklu bir erkekle evlenen genç bir kadının, evlilik kurumunun sınırları içinde aradığı duygusal tatmini bulamayarak ihanete sürüklenişinin ve bu ihanetin ifşasıyla gelen trajik intiharının analizi olarak değerlendirilir (Eğilmez, 2007, s. 21).

Romanın başkarakteri Bihter, çocukluğundan itibaren annesi Firdevs Hanım'a karşı derin bir öfke beslemiş ve onun temsil ettiği kadın imajından uzak durmayı temel amaç edinmiştir. Sırf bu toplumsal lekelenmeden kaçmak ve saygınlık kazanmak amacıyla, kendisinden yaşça büyük, iki çocuklu ve dul bir erkek olan Adnan Bey ile evlenmeyi kabul etmiştir. Bu evlilik, Bihter için hem annesine karşı bir zafer hem de toplumsal statü anlamına gelmektedir. Ancak bu mantık evliliği, kısa sürede Bihter için duygusal bir yabancılaşma sürecini başlatır. Adnan Bey'in sunduğu durağan, korumacı ve babacan sevgi, Bihter'in gençlik enerjisini ve bastırılmış duygusal ihtiyaçlarını karşılamakta yetersiz kalır. Yalı hayatının izole ve monoton atmosferinde derin bir can sıkıntısı ve yalnızlık yaşayan Bihter, bu psikolojik boşluk evresinde Adnan Bey'in yeğeni Behlül ile yakınlaşır. Bihter, başlangıçta bu ahlaki eşiği aşmamak için dirense de evlilik içi duygusal tatminsizlik galip gelir ve karakter kendini bir yasak ilişkinin içinde bulur. Bu aldatma süreci, Bihter'e aradığı huzuru getirmek yerine, onu ağır bir iç çatışmaya sürükler. Karakter, bir yandan toplumsal normların ağırlığı altında vicdan azabı yaşarken, diğer yandan en büyük korkusuyla yüzleşir. Adım adım annesi Firdevs Hanım'a benzemektedir. Nitekim psikoloji çalışmaları da çocukken şahit olunan ebeveyn hatalarının ve olumsuz aile geçmişinin, bireylerin yetişkinlikteki ilişkilerinde benzer krizlere yol açabildiğini göstermektedir (Deniz ve Baltacı, 2023, s. 1314).

Behlül'ün ilişkiyi sahiplenecek olgunluğa sahip olmaması ve nihayetinde Adnan Bey'in kızı Nihal ile evlenmeye karar vermesi, Bihter'in tüm dünyasını alt üst eder. Hem toplumsal itibarını kaybetme hem de annesinin karşısında yenilgiye uğrama ihtimaliyle karşılaşan Bihter, bu çıkmazdan intihar ile sıyrılmak ister. Kalbine sıktığı tek kurşunla intihar eder. Bihter'i yasak aşka ve aldatma psikolojisine sürükleyen en temel etken, mantık üzerine kurduğu evliliğinde aradığı ruhsal ve bedensel tatmini bulamamış olmasıdır. Annesine inat saygın bir eş olma isteğiyle evlenen Bihter, zaman geçtikçe paranın ve konforun, içindeki derin boşluğu doldurmaya yetmediğini fark eder. "Hayatında yalnız bu eksikti, fakat her şey bundan ibaretti: Sevmek, evet, bütün saadet yalnız bununla elde edilebilirdi" (Uşaklıgil, 2025, s. 148). Bu cümleler, Bihter'in o ana kadar bastırdığı, lüks ve itibar uğruna feda ettiği duygusal ihtiyaçlarının bir göstergesi sayılabilir. Onun için sevmek ve sevilmek, hayattaki tüm maddi kazanımların ötesinde, saadete ulaşmanın tek yoludur. Adnan Bey'in

sunduğu korumacı ve sakin evlilik Bihter'in içindeki bu fırtınayı dindiremeye yetmez. Bihter sıradan, tekdüze bir sevgiyle yetinmeyecek bir yapıya sahiptir. "...öyle bir aşk istiyordu ki, onun ruhunda sarhoş eden baygınlıklar bıraksın" (Uşaklıgil, 2025, s. 151). Buradaki "sarhoş eden baygınlıklar" ifadesinden, Bihter'in aşk algısının sakin ve huzurlu bir düzlemde olmadığı, aksine yıkıcı, tutkulu ve kendini yok edecek kadar yoğun bir aşk arayışında olduğu düşünülebilir. Bihter, sınırları zorlayan ve onu yalı hayatının monoton gerçekliğinden koparacak bir aşkın peşindedir. Bu noktada Behlül, ideal bir aday olarak Bihter'in karşısına çıkar. Bihter'in aldatma psikolojisi, sadece ahlaki bir sapma değil, tutku arayışının ve gençliğini yaşama arzusunun bir getirisidir. Bihter'in iç dünyasındaki tutku arayışı, zamanla mevcut evliliğini tamamen yıkmak yerine, bu evliliğin hemen yanı başında gizli bir duygusal dünya kurma arzusuna dönüşür ve bu aldatma eylemini meşrulaştırmaya başlar. "O zaman bu evlilikte boş kalan gönül boşluğunu, o aşksızlıktan doğan boşluğu doldurmak için evliliğin yanında bir büyük aşk hayatı icat etmek lazım gelmişti" (Uşaklıgil, 2025, s. 351).

Bihter için Behlül'e yönelmek, yalnızca anlık bir irade kaybı veya kontrolsüz bir dürtü değildir. Bu eylem, evliliğindeki aşksızlık gerçeğine karşı geliştirilmiş bir savunma mekanizmasıdır. Karakter, Adnan Bey'in sunduğu toplumsal ve maddi konforu tamamen terk etmek istemez, ancak ruhundaki o boşluğu da feda etmek istemez. Bu noktada evliliğin yanında var ettiği o gizli aşk hayatı, Bihter'in sığınağı olarak görülebilir. Bu sığınak, onun hem saygın bir burjuva kadını olarak kalmasını hem de bastırılmış tutkularını yaşamasını sağlar. Bihter'in evlilikteki aşksızlığı telafi etmek adına icat ettiği bu paralel aşk hayatı, beklentilerinin aksine ona aradığı kurtuluşu getirmez. Behlül ile yaşanan ilişkinin büyüsü bozuldukça, Bihter kendini büyük bir ahlaki boşluğun ve ağır bir kirlenmişlik duygusunun içinde bulur. "Artık talihsiz, talihsizliğini acınacak bir kadın değil, bir daha silinmeyecek bir leke ile kirlenmiş alçak, pis bir mahluktu" (Uşaklıgil, 2025, s. 183). Bihter, o ana kadar kendisini Adnan Bey'in ve yalı hayatının monotonluğuna kurban edilmiş talihsiz ve acınacak bir kadın olarak görerek aldatma eylemlerini meşrulaştırmaya çalışmıştır. Ancak ahlaki eşik aşıldıktan sonra kendisini bir insan olarak değil, alçak, pis bir mahluk olarak tanımlaması, iç dünyasındaki kırılmanın ve ahlaki çöküşün boyutlarını göstermektedir. Bihter aldatma eylemini özgürleşmeyi umarak gerçekleştirmiştir ancak nihayetinde bu durum onu kendi gözünde alçaltmış, saflığını ve saygınlığını tamamen yok etmiştir. Bihter için Behlül'ün ihaneti ve kaçışı, sadece bir aşkın bitişi değil, inşa ettiği paralel dünyanın ve sığındığı hayatının da çöküşüdür. İhanetin ortaya çıkması an meselesiyken, Bihter'in önünde iki seçenek kalmıştır. Ya ahlaki olarak tamamen iflas etmiş bir kadın olarak hayata devam edecek ya da bu durumu kendisi sonlandıracaktır. Bihter'i ölüme sürükleyen şeyin sadece Behlül'ü kaybetmenin getirdiği üzüntü olmadığı düşünülebilir. Asıl problem, ihaneti öğrendikten sonra çevresindeki insanların ona yönelteceği o suçlayıcı ve aşağılayıcı bakışlardır. Bihter, gururunun toplum tarafından çiğnenmesine izin vermektense, o bakışların altında ezilmektense ölümü bir kaçış olarak seçer. "Lakin mademki ortada öldürülecek bir suçlanan var -bunu düşünürken vahşi bir tebessümle gülümsüyordu-, bu görevi o kendisi yerine getirecekti" (Uşaklıgil, 2025, s. 373). Metindeki "vahşi tebessüm" ifadesi, Bihter'in son anındaki meydan okumasının sembolü olarak görülebilir. Bihter, suçluluğunu kabul eder ancak kendisini yargılama ve cezalandırma yetkisini hiç kimseye bırakmamaktadır. Toplumun ya da aldatılan kocanın onu mahkûm etmesine fırsat tanımadan kendi infazını gerçekleştirir.

Eserlerin Karşılaştırılması

Theodor Fontane'nin Effi Briest ve Halit Ziya Uşaklıgil'in Aşk-ı Memnu adlı eserleri, farklı coğrafyalarda ve edebi geleneklerde yazılmışlardır, ancak her iki eserde de 19. yüzyıl realizminin izleri vardır ve evliliklerinin içinde sıkışan kadınları merkezine almışlardır. Her iki romanda da yaş farkının ve duygusal mesafenin belirgin olduğu evlilik ilişkiler konu edinilmiştir.

Yasak Aşk

Benzerlikler

Her iki evliliğin başlangıçları farklılık gösterse de yarattığı psikolojik sonuçlar benzerdir. Innstetten'in soğukluğu, Adnan Bey'in durağan ve babacan sevgisi, kadınların duygusal ve bedensel beklentileri karşılamakta yetersiz kalmıştır. Bu duygusal boşluk ve tatminsizlik, karakterleri yalnızlaşmaya, can sıkıntısına ve nihayetinde yasak aşka itmiştir. Bu durum, evliliğinde aradığı mutluluğu ve doyumu bulamayan kişilerin

dışarıdaki ilişkilere çok daha kolay yönelebildiğini kanıtlayan bilimsel verilerle uyum içindedir (Deniz ve Baltacı, 2023, s. 1323).

Farklılıklar

Effi Briest, kendisinden yaşça oldukça büyük, kariyer odaklı bir devlet görevlisi olan Geert von Innstetten ile evlendirilirken, Bihter de annesine duyduğu öfkenin ve saygınlık arayışının bir sonucu olarak, iki çocuklu ve dul Adnan Bey ile evlenmeyi kabul etmiştir.

Aldatma Psikolojisi

Benzerlikler

Bu iki kadının ortaklaştığı en ağır psikolojik zemin ise aldatma eyleminin ardından ruhlarında hissettikleri ahlaki yük ve kirlenmişlik duygusudur. Effi, ilişkisi bittikten ve Berlin'e taşındıktan sonra bile bu içsel azaptan kaçamadığını gösterir. Bihter ise ahlaki eşik aşıldıktan sonra kendisini kirlenmiş hissederek çok daha sert bir içsel kırılma ve ahlaki çöküş yaşar. Her iki karakter de başlangıçta birer sığınak veya özgürleşme alanı olarak gördükleri yasak ilişkilerin sonucunda, kendi iç dünyalarında birer suçluya dönüşürler.

Farklılıklar

Karakterlerin aldatma psikolojilerine yönelme biçimleri incelendiğinde, aldatma eyleminin kökenindeki motivasyonlar ve karakterlerin bu sürece dahil olma şekilleri arasında farklılıklar göze çarpar.

Effi, yaşadığı monoton taşra hayatından ve kocasının soğukluğundan kaçmak için Binbaşı Crampas ile bir ilişkiye sürüklenir. Effi'nin aldatma psikolojisi, bilinçli bir aldatmadan ziyade çocuksu ve özgür doğasının, kocasının boğuculuğu tarafından yutulması endişesinden kaçma çabasıdır. Innstetten'in en şefkatli anlarda bile sergilediği o yabancı ve mesafeli hali, Effi'de yakınlık yerine korku tetiklediği için, Crampas onun için bir kaçış yolu olur. Bihter ise cüretkâr ve yıkıcı bir tutku arayışı içindedir. Bu doğrultuda Bihter'in aldatma psikolojisi, mevcut evlilik yapısını tamamen yıkmak değil, bu evliliğin yanında gizli ve paralel bir duygusal dünya inşa etme arzusudur. Bihter, Adnan Bey'in sunduğu maddi ve sınıfsal konforu kaybetmek istemez, ancak evliliğindeki boşluğu Behlül ile bu paralel dünyada doldurmaya çalışarak eylemini meşrulaştırır.

Trajik Son

Benzerlikler

Ana karakterler yasak ilişkilerinin sonucunda, kendi iç dünyalarında birer suçluya dönüşürler. Her iki karakterin de sonu trajik bir yok oluşla neticelenir.

Farklılıklar

Effi için trajedi, yıllar sonra mektupların bulunmasıyla sosyal dışlanmaya dönüşür. Innstetten, toplumsal kurallarına uyarak Crampas'ı düelloda öldürür ve Effi'yi sosyal bir ölüme mahkûm eder. Effi'nin uğradığı asıl büyük yıkım, toplumsal ayıplanma korkusuyla anne ve babasının ona kapılarını kapatmasıdır. Ailesi ve toplumu tarafından tamamen soyutlanan Effi, bu ağır psikolojik ve sosyal yok oluşun altında hastalanarak genç yaşta hayata veda eder. Bihter'in sonu ise çok daha ani, dramatik ve bir meydan okuma şeklinde gerçekleşir. İnşa ettiği paralel dünyanın çöktüğünü, gerçeklerin açığa çıktığını gören Bihter, çevresindeki insanların suçlayıcı ve aşağılayıcı bakışları altında ezilerek yaşamaktansa ölümü seçer. Bihter, Effi gibi toplumun kendisini yavaş yavaş cezalandırmasına izin vermez, kendi infazını kendisi gerçekleştirir.

Sonuç ve Öneriler

Sonuç olarak hem Effi Briest hem de Aşk-ı Memnu, bireysel arzuları ile toplumsal kurallar arasına sıkışan kadınların trajedisini anlatmaktadır. Farklı coğrafyalarda yaşasalar da Effi ve Bihter, evliliklerindeki duygusal boşluğu doldurmak için yasak ilişkilere yönelmiş ve nihayetinde ağır suçluluk duygularıyla baş başa kalmışlardır. Aralarındaki en temel fark ise bu baskıcı düzene karşı verdikleri tepkidir. Effi, kocasının katı

dünyasından korkarak yasak aşka yönelmiş ve toplum tarafından yavaş yavaş sosyal bir ölüme sürüklenmiştir. Bihter ise düzenini terk etmeden paralel bir aşk inşa edecek kadar cüretkâr davranmıştır. Bu durum açığa çıktığında ise cezasını toplumun kesmesine izin vermemiştir. Edebi metinlerin toplumun aynası olduğu gerçeğinden hareketle, gelecek çalışmalarda yalnızca kadın karakterlerin aldatma psikolojisi değil; onları bu sürece iten eşlerin otoriter tutumları ile yasak aşk yaşanan erkeklerin sorumluluktan kaçış psikolojileri de feminist eleştiri, psikanaliz ve erkeklik çalışmaları bağlamında disiplinler arası bir yaklaşımla karşılaştırmalı olarak çözümlenebilir.

Teşekkür ve Bilgilendirme Notu

Bu çalışmanın ortaya çıkmasındaki değerli akademik katkıları ve yardımları için danışman hocam Doç. Dr. Fatma Karaman'a teşekkürlerimi sunarım. Hayatım boyunca sundukları sonsuz destek ve sevgi için ailem Hicran Tuncer, Yılmaz Tuncer ve Zehra Gül Tuncer'e minnetlerimi sunarım. Bu süreçte katkıları ve manevi desteği ile her zaman yanımda olan Burak Ercan'a en içten teşekkürlerimi sunarım.

Kaynakça

Akay, R. (2017). Karşılaştırmalı edebiyat. *Kesit Akademi Dergisi*, *3*(10), 12–29. https://dergipark.org.tr/en/pub/kesitakademi/article/864575

Aytaç, G. (2003). *Karşılaştırmalı Edebiyat Bilimi*. Ankara. Doğu Batı Yayınları.

Bude, T. (2020, 17 Kasım). What is tragedy? Oregon State Guide to English Literary Terms. Oregon State University. https://liberalarts.oregonstate.edu/wlf/what-tragedy

Deniz, T. C. & Baltacı, S. (2023). Romantik ilişkilerde aldatmaya yönelik tutumu belirleyen faktörler: Ebeveyn aldatması yaşantısı, bağlanma biçimi ve ilişki doyumunun rolü. *Humanistic Perspective*, 5 (3), 1311-1331. https://doi.org/10.47793/hp.1353574

Eğilmez, S. (2007). *Theodor Fontane "Effi Briest", Lev Nikolai Tolstoy "Anna Kareninna", Halit Ziya Uşaklıgil "Aşk-ı Memnu" örneklerinde "farklı kültürlerde aldatan kadının toplumdaki yeri. [Yüksek lisans tezi, Uludağ Üniversitesi]* Yök Tez Merkezi. (Tez No. 206889) https://acikerisim.uludag.edu.tr/entities/publication/5573cc96-9e1e-4c14-b1d6-f2df8fb52eca

Fontane, T. (2026). *Effi Briest.* (T. Turan, Çev.). İstanbul. Can Yayınları. (Orijinal eserin yayın yılı 1895)

İlkılıç, S. (2024). Effi Briest ve L'adultera'da Kadın, *Korpusgermanistik,* 3(1), 14-17. http://dx.doi.org/10.62425/korpus.1491874

Pichois, C. & Rousseau, A.M. (1994). *Karşılaştırmalı edebiyat* (M. Yazıcı, Çev.). Dün Bugün Yarın Yayınları. (Orijinal eserin yayın yılı 1967)

Remak, H. H. H. (1961). Comparative literature: Its definition and function. N. P. Stallknecht ve H. Frenz (Ed.), *Comparative literature: Method and perspective* içinde (s. 1-57). Southern Illinois University Press.

Tanner, T. (1979). *Adultery in the novel: Contract and transgression*. Johns Hopkins University Press.

Türk Dil Kurumu. (2026). *Güncel Türkçe Sözlük*. Erişim adresi: https://sozluk.gov.tr/ (Erişim tarihi: 22.10.2026).

Uşaklıgil, H. Z. (2025). *Aşk-ı Memnu* (13. Basım). İstanbul. Türkiye İş Bankası Yayınları. (Orijinal eserin yayın yılı 1900)

Üstün, A. & Öztürk Özer, D. (2021). "Bireylerin Evlilikte Aldatma Problemi Hakkındaki Görüşleri ve Çözüm Önerileri", *International Social Mentality and Researcher Thinkers Journal,* 7(53): 3312-3319. http://dx.doi.org/10.31576/smryj.1231

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

A COMPARISON OF THE THEMES OF GUILT, AUTHORITY, AND ALIENATION IN FRANZ KAFKA'S 'THE TRIAL' AND SABAHATTİN ALİ'S 'İÇİMİZDEKİ ŞEYTAN'

Latife Martlı
Fatma Karaman
0009-0005-1647-1645, Fırat University, Graduate School of Social Sciences, Faculty of Humanities and Social Sciences, Department of Western Languages and Literatures / Division of German Language and Literature, Elazığ, Türkiye.
0000-0002-0461-5593
Assoc. Prof. Dr., Fırat University, Graduate School of Social Sciences, Faculty of Humanities and Social Sciences, Department of Western Languages and Literatures / Division of German Language and Literature, Elazığ, Türkiye.

Abstract

Literary works produced in different periods and cultural contexts address the human inner world in different ways. In this context, comparative literature helps identify the similarities and differences among works from different literary traditions. The individual's relationship with society, authority, and their own inner world has been explored in various ways across different periods and cultures. This study examines how similar themes are addressed differently through two works belonging to distinct literary traditions. The aim of this study is to comparatively analyze two significant works of modern literature, *The Trial* by Franz Kafka, from German literature, and *The Devil Inside Us* (*İçimizdeki Şeytan*) by Sabahattin Ali, from Turkish literature, focusing on the themes of guilt, authority, and alienation. A text-oriented approach is employed within the framework of comparative literature. Although the two works were written in different cultural and historical contexts, they share certain characteristics. The ways in which the entrapment and helplessness experienced by the modern individual are portrayed in both works are examined in terms of their similarities and differences. The findings reveal that the theme of guilt in Kafka's work stems from an external, absurd, and unknown system, whereas in Sabahattin Ali's work, it takes the form of an internal reckoning arising from the individual's lack of will and moral shortcomings. While authority in *The Trial* appears as an inaccessible, hierarchical, and bureaucratic structure, in *The Devil Within Us*, it manifests its influence on the individual through conscience, social norms, and moral pressures. The theme of alienation constitutes a common element in both works, symbolizing the individual's estrangement from their own self and society. In Kafka's work, this alienation points to a systematic existential crisis, whereas in Sabahattin Ali's work, it indicates social maladjustment and an inner disintegration. In conclusion, both authors approach the themes of guilt, authority, and alienation from different perspectives, and these themes are shown to be associated with the inner conflicts of the modern individual.

Keywords: Franz Kafka, Sabahattin Ali, Guilt, Authority, Alienation.

FRANZ KAFKA'NIN *"DAVA" VE* SABAHATTİN ALİ'NİN *"İÇİMİZDEKİ ŞEYTAN"* ESERLERİNDE SUÇLULUK, OTORİTE VE YABANCILAŞMA İZLEKLERİNİN KARŞILAŞTIRILMASI

Özet

Farklı dönemlerde ve farklı kültürlerde ortaya çıkan edebi eserler, insanın iç dünyasını farklı şekillerde ele almaktadır. Bu bağlamda karşılaştırmalı edebiyat, farklı edebi geleneklerden gelen eserlerin ortak ve farklı yönlerini ortaya koymaya yardımcı olmaktadır. Bireyin özellikle toplum, otorite ve kendi iç dünyası ile ilişkisi, farklı dönemler ve kültürler arasında çeşitli biçimlerde ele alınmıştır. Bu çalışma, farklı edebi geleneklere ait iki eser aracılığıyla benzer konuların farklı şekillerde nasıl ele alındığını incelemektedir. Çalışmanın amacı, modern edebiyatın iki önemli romanı olan Alman edebiyatından Franz Kafka'nın *Dava* ve Türk edebiyatından

Sabahattin Ali'nin *İçimizdeki Şeytan* romanlarını suçluluk, otorite ve yabancılaşma izlekleri üzerinden karşılaştırmalı olarak incelemektir. Karşılaştırmalı edebiyat bağlamında incelenen bu çalışmada metin odaklı yöntem kullanılmıştır. Her iki eser, farklı kültürel ve tarihsel zeminlerde yazılmış olmalarına rağmen benzer özellikler taşımaktadır. Her iki eserde de modern bireyin yaşadığı sıkışmışlık ve çaresizliğin nasıl işlendiği, benzerlikler ve farklılıklar üzerinden belirlenmiştir. Araştırmanın sonucunda, Kafka'daki suçluluk izleğinin dışsal, absürt ve bilinmeyen bir sistemden kaynaklandığı, Sabahattin Ali'de ise bireyin kendi iradesizliği ve ahlaki yetersizliklerinden kaynaklanan içsel bir hesaplaşma niteliği taşıdığı belirlenmiştir. *Dava'da* otorite erişilemez, hiyerarşik ve bürokratik bir yapı olarak görünürken *İçimizdeki Şeytan'da* birey üzerindeki etkisini vicdan, toplumsal normlar ve ahlaki baskılar aracılığıyla göstermektedir. Yabancılaşma izleği ise her iki eserde ortak bir nokta oluşturarak bireyin kendisinden ve toplumdan kopuşunu simgelemektedir. Söz konusu yabancılaşma izleği Kafka'da sistematik bir varoluşsal krize, Sabahattin Ali'de ise toplumsal uyumsuzluk ve içsel bir çözülmeye işaret etmektedir. Sonuç olarak, her iki yazarın da suçluluk, otorite ve yabancılaşma gibi konuları farklı açılardan ele aldığı ve bu konuların modern bireyin içsel çatışmalarıyla ilişkili olduğu görülmüştür.

Anahtar Kelimeler: Franz Kafka, Sabahattin Ali, Suçluluk, Otorite, Yabancılaşma.

Giriş

Edebiyat, insanın hem kendisiyle hem de yaşadığı toplumla kurduğu karmaşık ilişkileri okura yansıtan en geniş ifade alanlarından biri olarak kabul edilebilir. İnsan ruhunun derinliklerinde gizlenen korkular, arayışlar ve çatışmalar, edebi eserler aracılığıyla görünür hale getirilebilir. Nitekim Aşkaroğlu, edebiyatın insanın duygu ve düşünce dünyasını estetik ve düşünsel etkiyle şekillendiren önemli bir işleve sahip olduğunu belirtmektedir (Aşkaroğlu, 2020: 198). Bu bağlamda edebiyat, farklı dönemlerde, farklı coğrafyalarda ve farklı dillerde kaleme alınsa dahi insanın değişmeyen evrensel meselelerini ortak bir noktada buluşturma işlevine sahiptir. Tekin ve Bozkurt'un vurguladığı üzere, edebi metinlerde yer alan mekan unsuru, kahramanın kendini gerçekleştirme ve varoluşsal arayış sürecinde ruhsal bir sığınak niteliği kazanarak insanla birlikte anlam oluşturmaktadır (Tekin & Bozkurt, 2023: 239). Bu doğrultuda, yazarların yaşadığı çevre ve kültür değişse de ele aldıkları kişisel çatışmalar ve toplumsal baskılar çoğu zaman benzer kurgular üzerinden işlenerek ortak temalarda birleşirler. Bu ortak noktalardan hareketle, Franz Kafka'nın *Dava* (1925) adlı romanı ile Sabahattin Ali'nin *İçimizdeki Şeytan* (1940) adlı romanı, bireyin *suçluluk, otorite* ve *yabancılaşma* karşısındaki çaresizliğini benzer temalar etrafında ele alan iki önemli eser olarak değerlendirilebilir. Kefeli'nin değerlendirmesi doğrultusunda karşılaştırmalı edebiyat, farklı kültürler arasındaki ilişkilerin edebi metinlerdeki yansımalarını incelemenin yanı sıra bu metinlerin tarihsel ve toplumsal arka planını da anlamaya yönelik bir inceleme alanı olarak ele alınabilir (Kefeli, 2006: 332).

Bu çalışmanın temel amacı, Franz Kafka'nın *Dava* ve Sabahattin Ali'nin *İçimizdeki Şeytan* adlı romanlarını suçluluk, otorite ve yabancılaşma izlekleri bakımından karşılaştırmalı olarak incelemektir. Çalışmada, söz konusu izleklerin karakterler ve olaylar aracılığıyla nasıl yansıtıldığı, bireyin otoriteyle ve toplumla kurduğu ilişkinin bu izlekleri nasıl şekillendirdiği üzerinde durulmaktadır. Bu doğrultuda Josef K. ile Ömer'in yaşadığı çatışmalar ele alınarak suçluluk duygusunun, otorite karşısındaki çaresizliğin ve yabancılaşmanın iki eserdeki farklı görünümleri değerlendirilmektedir.

Çalışmanın önemi ise, farklı edebi geleneklere ait bu iki romanı ortak temalar üzerinden incelemek ve söz konusu temaların nasıl farklı biçimlerde işlendiğini ortaya koymaktır. *Dava* romanında bireyin karşı karşıya kaldığı belirsiz ve erişilemez otorite ile *İçimizdeki Şeytan* romanında bireyin kendi davranışları, toplumsal çevresi ve ahlaki çatışmalarıyla olan ilişkisi karşılaştırılarak iki eserin benzer ve farklı yönleri belirlenmektedir. Böylece suçluluk, otorite ve yabancılaşma izleklerinin, eserlerin kendi bağlamları içinde nasıl anlam kazandığı gösterilmektedir.

Bu amaç ve önem doğrultusunda çalışmada; Dava ve İçimizdeki Şeytan adlı romanlarda suçluluk izleğinin nasıl ele alındığı, her iki romanda otoritenin hangi biçimlerde ortaya çıktığını ve karakterler üzerinde nasıl bir etki gösterdiğini ve yabancılaşma izleğinin Josef K. ile Ömer'in kendileriyle ve toplumla kurdukları ilişkiler

üzerinden nasıl yansıtıldığı sorularına yanıt aranmaktadır. Ayrıca söz konusu suçluluk, otorite ve yabancılaşma izleklerinin işlenişi bakımından iki roman arasında ne tür temel benzerlikler ve farklılıklar bulunduğu da araştırmanın yanıt aradığı başlıca konular arasındadır.

Franz Kafka ve Dava Üzerine

Modern edebiyatın en özgün kalemlerinden biri olan Prag doğumlu Franz Kafka (1883-1924), eserlerinde bireyin modern dünya ve bürokratik otorite karşısındaki çaresizliğini karanlık bir atmosfer içinde ele almaktadır. Kafka'nın hukuk eğitimi almış olması, hukuk birikimini edebi eserlerine konu edinmesinde ve Dava gibi romanlarında adaletin erişilemezliğini ve hukukun karmaşık yapısını betimlemesinde belirleyici bir rol üstlenmiştir (Şahin, 2024: 516). Çataloluk'a göre ise Kafka'nın hukuk eğitimi, eserlerinde bürokrasinin labirentvari yapısının ve adaletin mekanik soğukluğunu betimlemesinde temel bir zemin oluşturmaktadır (Çataloluk, 2011: 236). Ayrıca Kafka'nın metinlerinde ortaya çıkan *kafkaesk (Kafkaesque)*[1] atmosferin temelinde, bireyin ulaşılamaz bir otorite karşısındaki mutlak çaresizliği ve bu otoritenin yarattığı belirsizliğin yattığını ifade etmektedir (Çataloluk, 2011: 235).

Franz Kafka'nın ölümünden sonra, 1925 yılında yayımlanan Dava, modern edebiyatın en çok tartışılan romanlarından biri kabul edilmektedir. Roman, banka memuru *Josef K.*'nın, otuzuncu yaş gününün sabahında, nedenini bilmediği bir suçtan dolayı tutuklandığını öğrenmesiyle başlar. Ancak bu tutukluluk hali, alışılmış hukuk kurallarından uzaktır. Josef K. hapse atılmaz ve günlük yaşamına devam etmesine izin verilir fakat gizemli ve erişilemez bir otoritenin sürekli denetimi altındadır. Şahin'in belirttiği üzere, Kafka'nın hukuk alanındaki eğitiminin eserlerinde işlediği adalet ve hukuk meselelerinin arka planını anlamak açısından dikkate alınabilecek bir unsur olduğunu ortaya koymaktadır. Bu bağlamda Dava'daki hukuki düzenin karmaşık ve erişilmesi güç yapısı da söz konusu çerçevede değerlendirilebilir (Şahin, 2024: 516).

Eser boyunca Josef K., suçunun ne olduğunu öğrenmeye çalışırken hiyerarşik, absürt ve labirenti andıran bir bürokrasinin içinde kaybolmaktadır. Karşılaştığı her yargıç, avukat veya memur, onu bu karmaşık sistemin içine daha fazla çeker. Çiçek'e göre Kafka'nın kahramanları, modern dünyanın rasyonel görünen ama özünde absürt olan işleyişi içinde kendi varlıklarına ve topluma yabancılaşmış bireyler olduğunu vurgulamaktadır (Çiçek, 2015). Josef K. başlangıçta bu durumu mantığına oturtmaya ve masumiyetini kanıtlamaya çalışsa da, zamanla otorite karşısında yabancılaşmakta ve işlemediği bir suçun ağırlığı altında ezilmektedir (Çiçek, 2015: 142). Roman, sistemin mantıksızlığına boyun eğen Josef K.'nın, bir yıl sonraki doğum gününden bir gün önce, yine nedenini tam olarak bilmediği bir infazla *bir köpek gibi* öldürülmesiyle sona ermektedir.

Sabahattin Ali ve İçimizdeki Şeytan Üzerine

Türk edebiyatının toplumcu gerçekçi çerçevesinde önemli bir yere sahip olan Sabahattin Ali (1907-1948), eserlerinde bireyin iç dünyasındaki karmaşaları toplumsal eleştiriyle bütünleştirir. Korat'ın değerlendirmesine göre Sabahattin Ali, toplumsal yaşamın farklı kesimlerinde karşılaşılan sorunları eserlerinin merkezine alan bir yazardır. Toplumsal eşitsizlikler, kamu görevlilerinin sorumlulukları, bireyler arasındaki güç ilişkileri ve kişisel yaşantılar, yazarın ele aldığı konular arasında yer almaktadır (Korat, 2021). Öznur Güzel'in de belirttiği üzere, Sabahattin Ali roman kahramanlarının üzerine yaptığı derin psikolojik tahlilleriyle Türk edebiyatında önemli bir yere sahip olan ve adından çokça söz ettiren bir sanatkardır (Güzel, 2018). Öğretmenlik ve gazetecilik yıllarında dönemin siyasi ve sosyal baskılarını bizzat deneyimleyen Ali, eserlerine aydın eleştirisi, ahlaki yozlaşma ve güç karşısında ezilen birey temaları olarak yansıtmıştır. Yazar İçimizdeki Şeytan'da ise toplumsal gerçekçiliğin ötesine geçerek insan ruhunun bastırılmış yönlerini ve irade meselesini kapsamlı bir biçimde irdeler.

Sabahattin Ali'nin 1940 yılında yayımlanan İçimizdeki Şeytan adlı romanı, II. Dünya Savaşı öncesi İstanbul'undaki entelektüel çevrelerin içine düştüğü ahlaki çöküşü ve bireyin iç dünyasındaki çatışmaları ele

[1] **Kafkaesk (*Kafkaesque*):** Franz Kafka'nın eserlerinden türetilen bu kavram; bireyin, labirenti andıran karmaşık bürokratik mekanizmalar, ulaşılamaz otorite odakları ve mantık dışı kurallar silsilesi karşısında kapıldığı çaresizlik, yabancılaşma ve absürtlük hissini tanımlamak için kullanılır (bkz. Deleuze ve Guattari, 2020) .

alan realist bir eserdir. Uluşahin, Sabahattin Ali'nin 1940 yılında basılan İçimizdeki Şeytan adlı romanının II. Dünya Savaşı öncesi İstanbul'unun entelektüel çevrelerini ve bu çevrelerdeki ahlaki çöküşü yansıttığına dikkat çeker (Uluşahin, 2020: 29). Romanın merkezinde, zayıf iradeli ve sürekli bir iç sesin -*içimizdeki şeytanın*- yönlendirmesiyle hareket eden Ömer ile onun tam zıttı olan, saf ve dürüst Macide yer alır. Güzel, eserde öncelikli olarak bu iki başat karakterler olan Ömer ve Macide'nin iç dünyaları, çatışmaları ve toplumsal çevreyle olan ilişkilerinin irdelendiğini vurgular (Güzel, 2018). Ömer, bir vapur yolculuğunda görüp aşık olduğu Macide ile evlenmesine rağmen, bu birlikteliği sürdürebilecek maddi ve manevi iradeye sahip değildir. Canpolat (2019), Ömer'in bu iradesizliği ve zayıflığı nedeniyle sürekli bir iç sesin, yani içindeki şeytanın esiri olarak hareket ettiğini ve bu durumun onu hem kendine hem de topluma yabancılaştırdığını vurgular. Öte yandan Ömer'in çevresindeki sözde aydınların kurduğu baskı, onu ahlaksızlığa ve hilekarlığa sürükler. Canpolat, Macide'nin, Ömer'in zıttı olarak dürüstlüğü ve saflığı temsil ederken, Ömer'in çevresindeki aydın görünümlü kişilerin yarattığı yozlaşmış atmosferin, bireyin içsel çöküşünü nasıl hızlandırdığına dikkat çeker (Canpolat, 2019: 10-15). Ömer, yaptığı yanlış davranışlarından sonra ağır bir suçluluk hissetmesine rağmen, davranışlarını düzeltmek yerine sorumluluğu sürekli içindeki şeytana yükler. Bu kaçış onu kendisine ve topluma yabancılaşmasını tetiklemektedir. Roman, Ömer'in kendi zayıflıklarıyla yüzleşmesi ve Macide ile olan ilişkisinin kopma noktasına gelmesiyle, bireyin içsel bunalımdan çıkış arayışını etkileyici bir biçimde yansıtmaktadır.

Yöntem ve Sınırlılıklar

Bu çalışmada, Franz Kafka'nın Dava ve Sabahattin Ali'nin İçimizdeki Şeytan adlı eserleri karşılaştırmalı edebiyat çerçevesinde metin odaklı yöntem ile ele alınmıştır. Aktaş'ın yaklaşımı doğrultusunda metin odaklı inceleme, edebi eserin kendi yapısı içerisinde değerlendirilmesini esas almaktadır. Bu kapsamda eserin hem içerik yönü hem de biçimsel özellikleri birlikte ele alınarak metnin edebi bütünlüğü incelenmektedir (bkz. Aktaş, 2007: 138). Araştırma sürecinde, her iki eser metne bağlı inceleme doğrultusunda içerik ve biçim bakımından irdelenmiştir. Suçluluk, otorite ve yabancılaşma izlekleri, metinlerin kurgusal bütünlüğü içinde ele alınıp, karakterlerin iç dünyaları ve çatışmaları nasıl kurguladıkları üzerinden analiz edilmiştir. Bu bağlamda, eserlerin olay örgüsünden ziyade, anlatım teknikleri ve üslup özellikleri aracılığıyla inşa edilen kurmaca gerçeklikleri üzerinde durulmuştur (Aktaş, 2007: 138-139). Bu doğrultuda, Aktaş'ın vurguladığı üzere, metnin yapı bakımından çözümlenmesinden hareketle izleklerin belirlenmesi yoluyla, her iki eserdeki temel çatışmalar karşılaştırmalı bir perspektifle ortaya konulmuştur. Çalışma, Franz Kafka'nın *Dava* ve Sabahattin Ali'nin *İçimizdeki Şeytan* adlı romanları ile bu romanlarda ele alınan suçluluk, otorite ve yabancılaşma izlekleriyle sınırlandırılmıştır. Söz konusu izlekler metin odaklı yöntem doğrultusunda incelenmiş; yazarların yaşamları, eserlerin yazıldığı dönemin tarihsel ve toplumsal koşulları ile yazarların diğer eserleri kapsamlı bir incelemeye dahil edilmemiştir. Bu nedenle değerlendirmeler, seçilen iki romanın metinsel özellikleri ve belirlenen izlekler çerçevesinde gerçekleştirilmiştir.

Bulgular ve Tartışma

Bu bölümde, her iki eser de belirlenen suçluluk, otorite ve yabancılaşma izlekleri doğrultusunda incelenmiştir. Çalışmada öncelikle suçluluk ve otorite izlekleri birlikte değerlendirilip, ardından yabancılaşma izleği ele alınmıştır. Her başlık altında, önce Dava romanından örnekler incelenip, ardından aynı izleğin İçimizdeki Şeytan romanındaki örnekleri incelenmiştir. Böylece, K. ve Ömer karakterlerinin bireysel çatışmaları, otoriteyle kurdukları ilişkileri ve yaşadıkları yabancılaşma süreçleri karşılaştırmalı bir bakış açısıyla ortaya konulmuştur. Bu inceleme sonucunda, her iki romanda da bireyin farklı kaynaklardan beslenen suçluluk duyguları ve otorite baskısı nedeniyle kendisinden, toplumdan ve içinde bulunduğu dünyadan yabancılaştığı görülmüştür.

Suçluluk ve Otorite İzlekleri

Dava Romanında Suçluluk ve Otorite İzlekleri

Franz Kafka'nın Dava ve Sabahattin Ali'nin İçimizdeki Şeytan romanları, suçluluk ve otorite izleklerini, bireyin varoluşsal kaygıları, toplumsal baskılar ve içsel çatışmalar bağlamında ele almaktadır. Kafka'nın eserinde suçluluk, somut bir eylemden ziyade sistemin absürtlüğüyle şekillenir. Nitekim Dava romanında,

suçun somut bir eylemden ziyade niyet üzerinden değerlendirildiği, yargılama sürecinde suçun kendisinden çok sanığın kişiliğinin ön plana çıkarıldığı bir hukuk düzeni tasvir edilmektedir. Bu absürt sistemde, işlediği suç kendisine açıklanmayan sanık, suçsuzluğunu kanıtlamak zorunda bırakılmakta; bir başka deyişle, suçun ne olduğunu öğrenmeye ve kendisine isnat edilen suçu bulmaya çalışmaktadır. Suçluluk izleğini farklı düzlemlerde ele alan bu eserler, bireyin içsel çatışmalarını görünür kılarken insan doğasına dair önemli sorgulamalara da zemin hazırlamaktadır. Buna ek olarak, iki romanda da suçluluk duygusunu oluşturan etkenlerden biri de otorite izleğidir. Otorite, edebiyat eserlerinde bireyin davranışlarını yönlendiren, kontrol eden ve bireyin üzerinde etkide bulunan bir güç olarak farklı biçimlerde karşımıza çıkmaktadır. Dava romanında sebebi ve işleyişi tam olarak anlaşılamayan bürokratik bir yapı şeklinde ortaya çıkarken, İçimizdeki Şeytan romanında ise etkisini daha çok toplumun benimsemiş olduğu davranışlar, ahlaki değerlendirmeler ve bireyin iç dünyasında taşıdığı vicdani baskılar aracılığıyla gösterilmektedir. Dolayısıyla otorite, sadece dış dünyaya ait bir baskı olarak değil, aynı zamanda bireyin iç dünyasında da etkilerini hissettiren bir yapı olarak değerlendirilebilir.

Franz Kafka'nın Dava romanında suç, belirli bir eylemin sonucu değil, varlığın kendisi olarak karşımıza çıkmaktadır. Romanın ana karakteri Josef K., otuzuncu yaş gününde nedenini bilmediği bir suçtan dolayı tutuklandığında, kendisini anlamlandıramadığı bir yargılama sürecinin içinde bulmaktadır. Josef K., herhangi bir yanlış davranışta bulunduğuna dair bilgisi olmamasına rağmen bir sabah tutuklanmasıyla karşı karşıya kalır (Kafka, 2024: 1). Romanın girişinde yer alan bu ifade, Kafkaesk evrenin temel mantığını ortaya koymaktadır. Kişinin kendi masumiyetine olan güçlü inancına rağmen, sistem tarafından suçlu olarak etiketlenmiştir. Bu durum, bireyin kendi öznel gerçekliği ile dışsal otoritenin kurguladığı hukuksuz yapı arasında sıkışarak varoluşsal bir boşluğa düşmesine neden olmaktadır (Koşmak & Angın, 2023).

K.'nın bu durum karşısındaki çaresizliği, rasyonel bir mantık arayışıyla başlar. K., süreci mantıklı bir çerçeveye oturtmaya çalışarak, kendisine yöneltilen suçlamaya rağmen suç işlemediğini savunur. Ancak onun bu direnişi, hukukun rasyonel ve adil bir şekilde işlediği varsayımına dayanmaktadır. Oysa Kafka'nın kurguladığı tekinsiz evrende bu varsayım giderek geçerliliğini yitirir. Nitekim otoritenin ulaşılamaz ve sorgulanamaz yapısı, hukuki sürecin rasyonel bir savunma zemininden kopmasına neden olur; böylece süreç, bireyin kendi suçluluğunu kanıtlamaya zorlandığı metafizik bir labirente dönüşür (Balcı, 2023: 37). K.'nın yüzleştiği sistem, sadece bir suçluluk duygusu yaratmakla kalmayıp, aynı zamanda işleyiş mantığı anlaşılamayan bir otorite mekanizması olarak belirginleşmektedir. Soruşturmanın başlangıcında görevliler, K.'ya süreç hakkında bilgi veremeyeceklerini ve kendisinin beklemesi gerektiğini bildirirler. Bu durum, otoritenin bilgi üzerindeki tam kontrolünü açıkça göstermektedir. K., hem kendisine yöneltilen suçlamanın nedenini öğrenememekte hem de hakkında hüküm veren makama erişim sağlayamamaktadır. Dolayısıyla, birey ile otorite arasındaki ayrım başlangıçtan itibaren netleşmekte ve suçluluk hissini besleyen bir belirsizlik atmosferi oluşmaktadır. Bu bağlamda Kafka, bürokratik mekanizmanın şeffaflıktan uzak yapısını kullanarak bireyin kendi tarihi üzerindeki denetimini nasıl yitirdiğini ve kaçınılmaz bir teslimiyete sürüklendiğini gözler önüne sermektedir (Sala, 2024: 279). Kafka'nın kurguladığı hukuk sistemi, suçluyu arayan bir yapıdan çok, suçun varlığını sürekli yeniden üreten bir otorite olarak karşımıza çıkmaktadır. Bu hiyerarşik yapı, sanığın eylemleri yerine öznelliği ile kurduğu dolaylı ve tekinsiz ilişkiler aracılığıyla anlam üretir; böylece mahkeme, herhangi bir somut kanıta ihtiyaç duymadan K.'nın kendi içsel çelişkilerini bir suç kanıtı gibi kullanır (Dishon, 2024: 970).

Bu otoritenin dikkat çekici özelliklerinden biri, onu temsil eden kişilerin bile sistemin genel işleyişine tam olarak hakim olmamasıdır. Görevliler, K.'nın davasıyla doğrudan ilgisi bulunmayan ve yalnızca kendilerine verilen sınırlı görevleri yerine getiren sıradan kişiler olduklarını belirtmektedirler (Kafka, 2024: 6). Bu ifade, otoritenin belirli kişilerden ziyade, anonim bir işleyişe dayandığını düşündürmektedir. Bu nedenle K.'nın karşısında hesap sorabileceği veya iletişim kurabileceği somut bir güç odağı bulunmamaktadır. Nöbetçinin açıklamaları, mahkemenin suçu bireyin gerçekleştirdiği somut eylemlerden bağımsız biçimde ele aldığını düşündürmektedir. Böylece suç, bireysel davranışın sonucu olmaktan çıkarak sistemin kendi işleyişi içerisinde belirlediği bir unsur haline gelmektedir (Kafka, 2024: 6). Üstelik otoritenin denetimi sadece dava süreciyle sınırlı kalmayıp, bireyin en basit hareketlerine kadar uzanmaktadır. K.'nın sorgulama sırasında oturma

biçiminin dahi görevliler tarafından denetlenmesi, sistemin bireyin en sıradan davranışlarına kadar müdahale ettiğini göstermektedir (Kafka, 2024: 10). Bu durum, otoritenin kişinin yalnızca eylemlerini değil, aynı zamanda bedenini ve hareketlerini de kontrol altına alma çabasını ortaya koymaktadır.

Süreç ilerledikçe, K.'nın masumiyetine olan inancı sarsılmaya başlar. Bu sarsıntının temel nedenlerinden biri, otoritenin giderek daha kapalı ve ulaşılamaz bir nitelik kazanmasıdır Mahkeme çevresindeki görevlilerin, K.'nın davası hakkında yeterli bilgiye sahip olmadıklarını ve kendi konumlarının da sistem içerisinde sınırlı olduğunu ifade etmeleri, otoritenin kapalı yapısını ortaya koymaktadır (Kafka, 2024: 11). Böylece K., kimin karar verdiğini, kararların nasıl alındığını ve hangi kurallara göre yargılandığını bilmediği bir otoriteyle karşı karşıya kalmaktadır. Görevlilerin K.'ya kim oldukları ya da gelecekte başına neler geleceği yerine kendisini düşünmesini ve suçsuzluğunu yüksek sesle dile getirmekten kaçınmasını öğütlemeleri, sistemin bireyi sessiz bir kabullenişe yönelttiğini göstermektedir (Kafka, 2024: 11). Bu uyarı, sistemin bireyi sessiz bir kabullenişe ve içsel bir suçluluk duygusuna nasıl ittiğinin kanıtı olarak karşımıza çıkmaktadır. Mahkeme düzeni içerisinde savunma hakkının bile kısıtlandığı görülmektedir. Romanda savunma hakkının mümkün olduğunca sınırlandırılması ve yargılama sürecinin yalnızca kamuoyundan değil, sanığın kendisinden de gizli yürütülmesi, mahkemenin kapalı ve sorgulanamaz yapısını belirginleştirmektedir (Kafka, 2024: 112). Sanığın kendi davasına ilişkin bilgilere erişememesi, otoritenin mutlak ve sorgulanamaz niteliğini daha da belirgin hale getirmektedir. Bu nedenle K.'nın mücadelesi, yalnızca suçsuzluğunu kanıtlama çabası olmaktan çıkıp neyle suçlandığını anlama arayışına dönüşür. Ancak otoritenin kapalı yapısı karşısında bu çaba giderek sonuçsuz kalır. K., bir noktada sistemin hiyerarşisine açıkça meydan okuyarak asıl sorumluluğun kendisinde değil, mahkemenin örgütlenmesinde ve üst düzey görevlilerde bulunduğunu düşünür (Kafka, 2024: 82). Ne var ki bireysel düzeyde kalan bu isyan, davanın absürt gidişatını değiştirmeye yetmez.

Romanın sonuna doğru, dışsal baskı yerini derin bir içsel şüpheye bırakmaktadır. Rahibin K.'ya davasının kötüye gidip gitmediğini sorması üzerine K., elinden geleni yapmasına rağmen olumlu bir sonuç elde edemediğini belirtir (Kafka, 2024: 199). Sürecin sonunda K.'nın karşı karşıya kaldığı durum, başlangıçtaki masumiyet inancının yerini belirsizliğe bırakmasıdır. Nitekim K., başlangıçta davanın olumlu sonuçlanacağına inanırken süreç ilerledikçe bu beklentisini kaybetmiş ve davanın nasıl sonuçlanacağı konusunda kendisi de kuşku duymaya başlamıştır (Kafka, 2024: 199). Böylece suçluluk, yalnızca dışarıdan yöneltilen bir suçlama olmaktan çıkarak bireyin iç dünyasına yerleşen bir duygu haline gelmektedir. Başlangıçta dışsal bir güç olarak algılanan otorite, bu süreçte bireyin zihninde içselleşerek, görünmez, ulaşılamaz ve sorgulanamaz yapısıyla K.'nın benliğini tamamen kapsamaktadır. Bu bağlamda, romanda suçluluk ve otorite, birbirinden bağımsız iki izlek olarak değil, birbirini besleyen ve anlamlandıran unsurlar olarak karşımıza çıkmaktadır. Bu yönüyle Dava'da suçluluk, bireyi sürekli bir belirsizlik içinde tutan ve kurtulması güç bir varoluşsal çıkmaz olarak karşımıza çıkmaktadır.

İçimizdeki Şeytan Romanında Suçluluk ve Otorite İzlekleri

Sabahattin Ali'nin İçimizdeki Şeytan romanında suçluluk ve otorite izlekleri, Kafka'daki gibi belirsiz ve erişilemez bir dış otoriteden değil, bireyin kendi vicdanında yaşadığı çatışmalar ve ahlaki sorgulamalardan kaynaklanmaktadır. Burada karakterler, devletin kaynaklarını kullanırken kendi mantıksal gerekçeleriyle hareket ederek ahlaki bir çelişkiyle yüzleşirler; zira devlet memuru ile devlet yapısı arasındaki ilişki her zaman doğrusal bir düzlemde ilerlemez (Çelik, 2021: 168). Bu tespit, romandaki ahlaki çatışmaların sadece toplum ve birey arasında değil, kendi tercihlerimizin de belirleyici olduğunu belirtmektedir. Romanın ana karakteri olan Ömer, Josef K.'nın aksine kendi eylemlerinin bilincindedir ancak bu bilinç ona rahatlama sağlamaz, aksine yoğun bir iç sıkıntısına yol açmaktadır. Ömer'in yaşadığı korku, bir otorite korkusundan ziyade, kendi kendisinden duyduğu şüpheden kaynaklanmaktadır. Nitekim Ömer, çevresindeki insanlara karşı duyduğu korkunun zamanla genel bir güvensizliğe dönüştüğünü ve bu durumun kendisine yönelik sorgulamalarını da artırdığını dile getirmektedir (Ali, 2024: 142). Bu durum, Ömer'in yalnızca çevresine değil, kendi benliğine de yabancılaşmaya başladığını göstermektedir. Karakter, yaşadığı sorunların nedenlerini dış dünyada aramak yerine giderek kendi iç dünyasına yönelmekte ve kendisiyle hesaplaşmaktadır. Bu nedenle romanda suçluluk, dışarıdan dayatılan bir yargıdan çok, bireyin kendi vicdanıyla kurduğu çatışmanın bir sonucu olarak ortaya çıkmaktadır. Bununla birlikte roman, bireyin iç dünyasını şekillendiren toplumsal ve kurumsal otorite

mekanizmalarına da dikkat çekmektedir. Çelik'in de belirttiği üzere, özellikle memuriyet kurumunun işleyişinde liyakat yerine kurulan yakın çevre ilişkileri, devletin soyut gücü ile somut özne olan bürokrat arasındaki ahlaki uçurumu derinleştiren bir mekanizma olarak işlemektedir (Çelik, 2021: 168). Ömer'in içinde bulunduğu ortamda birey, sadece kendi tercihleriyle değil, aynı zamanda kurumların ve toplumun beklentileriyle de çevrelenmiş durumdadır. Nitekim romanda, üniversiteye devam eden memurların kurum tarafından hoş karşılanmadığı ve bu kişilerin işten uzaklaştırılmaları için çeşitli gerekçeler arandığı belirtilmektedir (Ali, 2024: 3). Bu durum, bireyin kurumsal otorite karşısındaki güvencesiz konumunu ortaya koymaktadır.

Ömer, modern insanın iradesizliğini ve ahlaki zayıflığını temsil etmektedir. Yaptığı her hatayı ve yanlış davranışı kendinden bağımsız bir şeytana yükleyerek sorumluluktan kaçmaya çalışmaktadır. Ancak bu kaçış, onun kendi iç dünyasıyla yüzleşmesini engellememektedir. Nitekim Ömer, kendisini suçluluk duygusuna sürükleyen düşüncelerin ve kuruntuların etkisi altına girdiğini fark etmektedir (Ali, 2024: 142). Bu farkındalık, onun kendisine yönelik sorgulamalarının arttığını ve yaşadığı iç çatışmanın derinleştiğini ortaya koymaktadır. Ömer'in suçluluğu, yirmi altı yıl boyunca sakladığı karanlık yönlerinin bir anlık parlamasıyla görünür hale gelmesinden kaynaklanmaktadır. Ömer, geçmişte gizlemeyi başardığı olumsuz yönleriyle yüzleşmesinin ardından kendi karakterine duyduğu güveni kaybetmekte ve bu durumun başkalarına inanmasını da güçleştirdiğini düşünmektedir (Ali, 2024: 174). Bu ifadesi ise onun kendi benliği hakkındaki düşüncelerinin zayıfladığını göstermektedir. Böylece romanda suçluluk, dışsal bir yargıdan çok, bireyin kendi kusurlarını fark etmesiyle ortaya çıkan içsel bir hesaplaşma olarak karşımıza çıkmaktadır. K. sistemi sorgularken, Ömer, Tanrı'ya ve kendi varlığına sığınmaya çalışmaktadır. Ömer'in Tanrı'ya yönelerek içinde bulunduğu ruhsal sıkıntıdan kurtulmak için bir çıkış yolu araması (Ali, 2024: 36), onun yaşadığı çaresizlik duygusunu ortaya koymaktadır. Ancak bu yalvarış, samimi bir tövbeden ziyade, bir çaresizliğin ifadesidir. Ömer'in kendi içsel çöküşü karşısındaki dehşeti, kendisinin beklediğinden çok daha aşağı bir noktaya düşebildiğini fark etmesiyle belirginleşmektedir (Ali, 2024: 173). Nitekim bu ifade onun kendi benliğine yönelik farkındalığının aynı zamanda bir utanç ve yabancılaşma duygusuna dönüştüğünü göstermektedir. Acar'ın da ifade ettiği gibi, bu süreçte karakterin kendi iç dünyasındaki bu çelişkileri içimizdeki şeytan olarak rasyonalize etmesi, onun sorumluluktan kaçma girişimiyle birleşerek varoluşsal bir boşluğu derinleştirmektedir (Acar, 2018: 32).

Ömer, kendi sersemliğini kabul etse de bu farkındalık onu eyleme geçirmemekte hatta kendisine yönelik ağır bir öz eleştiri geliştirmesine rağmen (Ali, 2024: 99) davranışlarını değiştirmemektedir. Aksine, suçunu başkalarına yansıtarak hafifletmeye çalışmakta ve kendi kusurlarının başkalarında da bulunduğunu öne sürerek bu durumu olağanlaştırmaya yönelmektedir (Ali, 2024: 102). Bu tutum, onun ahlaki sorumluluktan kaçma eğilimini göstermektedir. Buna ek olarak, Ömer'in dünyasında toplumsal otoritenin baskısı da hissedilmektedir. Müdürün Ömer'i, olayın çevrede duyulmasıyla ortaya çıkabilecek dedikodulardan korumak amacıyla hareket ettiğini belirtmesi (Ali, 2024: 25), bireyin davranışlarının sadece kendi vicdanı tarafından değil, toplumun oluşturduğu gizli denetim mekanizmaları tarafından da değerlendirildiğini göstermektedir. Bu bağlamda otorite, resmi yaptırımlardan çok itibar kaybı, dışlanma ve dedikodu korkusu üzerinden etkisini sürdürmektedir. Dolayısıyla birey, yalnızca kendi vicdanının değil, toplumun yargılarının da baskısı altında yaşamaktadır.

Ömer'in suçluluk duygusu, Macide'nin temsil ettiği saflık ve dürüstlük karşısında daha da belirgin hale gelmektedir. Kendi karanlığını Macide'den saklama çabası, onu giderek derin bir yalnızlığa itmektedir. Ömer, Macide'nin kendisinin geçmişte yaptığı yanlışlardan ve içine düştüğü tehlikeli durumlardan haberdar olmadığını düşünerek kendi gerçekliğini ondan gizlemektedir (Ali, 2024: 142). Nitekim bu tutum, onun Macide'yi bir hayat arkadaşından ziyade kendi vicdani ağırlığını hafifletecek bir kurtarıcı veya bir meta olarak görmesine neden olmaktadır (Küçüksayacıgil & Küçükşen, 2021: 379). Bu mahcubiyet zamanla fiziksel bir tepkiye dönüşmektedir. Macide'nin elini öpmeye yeltenip geri çekilmesi, Ömer'in yaşadığı yoğun suçluluk duygusunun fiziksel bir belirtisi olarak değerlendirilebilir. Nitekim Ömer'in Macide'nin elini öpmek üzereyken bu davranışından vazgeçmesi, içinde bulunduğu ruhsal gerilimin bedensel hareketlerine de yansıdığını göstermektedir (Ali, 2024: 76). Bu bağlamda İçimizdeki Şeytan'da suçluluk; bireyin kendi iradesizliğini hayali bir şeytan kılıfına sokarak aklamaya çalışması ile yaşadığı vicdan azabı arasında

sıkışmasından doğan ahlaki bir çöküş olarak değerlendirilebilir. Sonuç olarak, romanda suçluluk izleği merkezde yer alırken, toplumsal ve kurumsal otorite de bu suçluluğun ortaya çıkardığı ortamı hazırlayan önemli bir unsur olarak karşımıza çıkmaktadır.

Yabancılaşma İzleği

Dava Romanında Yabancılaşma İzleği

Franz Kafka'nın Dava ve Sabahattin Ali'nin İçimizdeki Şeytan romanları, yabancılaşma izleğini, bireyin varoluşsal kaygıları ve sistemle olan uyumsuzluğu ele almaktadır. Yabancılaşma, Cevizci'nin tanımından hareketle birey ile başka kişiler, nesneler veya çevresi arasındaki ilişkinin zayıflaması ve bu unsurlara karşı bir uzaklık geliştirmesi olarak açıklanabilir (Cevizci, 2000: 1099; akt. Çiçek, 2015: 142). Kafka'nın romanında bu durum, bürokrasinin insan kişiliğini hiçe sayması sonucunda, bireyin kendi anlayamadığı yasalarla yönetilen bir dünya tasarımıyla şekillenmektedir (Gündüz, 2011: 85). Sabahattin Ali'nin romanında ise yabancılaşma, kahramanların topluma olan uzaklıkları ve yalnızlığı tercih eden halleri üzerinden ortaya çıkmaktadır (Ulusan, 2019: 1). Bu durum, aynı zamanda bireyin içinde yaşadığı çevrenin yapmacıklığına ve kendi halkına ve kültürüne yabancılaşan aydın tipine yönelik bir eleştiri niteliği taşımaktadır (Ulusan, 2019). Her iki romanda da yabancılaşma, modern toplum mekanizmalarının bireyi asli özünden koparak insanı canlıdan çok bir nesne konumuna sürüklemesi bağlamında anlam kazanmaktadır (Gündüz, 2011: 93). Dolayısıyla yabancılaşma, yalnızca bireysel bir sorun olarak değil, insanın kendisi ve içinde yaşadığı toplumla kurduğu ilişkiyi etkileyen bir durum olarak karşımıza çıkmaktadır.

Bu noktadan hareketle, romanın başlangıcında K.'nın alışılmış yaşam düzeninin ani biçimde kesintiye uğraması, yabancılaşma sürecinin ilk işaretlerini oluşturmaktadır. K.'nın her sabah düzenli biçimde yerine getirilen kahvaltı alışkanlığının bir sabah beklenmedik şekilde aksaması, gündelik yaşamındaki olağan düzenin bozulmaya başladığını göstermektedir (Kafka, 2024: 1). Bu durum, ilk bakışta sıradan bir günlük detay gibi görünse de, aslında K.'nın güven duygusuna dayalı düzenli yaşamının sarsılmaya başladığını göstermektedir. Kafka, gündelik hayatın en basit unsurlarını bile yabancılaşmanın başlangıç noktası haline getirerek, bireyin güvenli alanının nasıl çözülmeye başladığını ortaya koymaktadır. Böylece yabancılaşma yalnızca dava sürecinin doğrudan sonucu değil, yaşamın içine sızan sessiz bir çözülme biçimi olmaktadır. Süreç ilerledikçe K. kendisini giderek daha kapalı ve anlaşılmaz bir bürokratik sistemin içinde bulmaktadır. Bu karmaşık yapı, adaletin yabancılaşan bireyin umurunda olmadığı bir düzeni yansıtarak, hukuksal örgütlenmelerin insanı nasıl birer kurbana dönüştürdüğünü gözler önüne sermektedir (Deligöz, 2024: 65). Bu noktada suçlamanın içeriğini öğrenememesi, yetkililerle doğrudan bir temas kuramaması ve sürekli bir belirsizlik içinde bırakılması, onun sistem karşısında güçsüzleşmesini derinleştirmektedir. Nitekim K.'nın, varlığından haberdar olduğu ancak bir türlü ulaşamadığı mahkeme ve yargıç karşısındaki çaresizliği, otoritenin onun için giderek daha soyut ve erişilemez bir yapıya dönüştüğünü ortaya koymaktadır (Kafka, 2024: 216). Burada mahkeme ve yargıç sadece hukuki kurumlar değil, aynı zamanda bireyin aklında anlamlandıramadığı soyut güçlerin bir karşılığı haline gelmektedir. Bu durum, K.'nın toplumla kurduğu bağın giderek kopmasına ve yabancılaşmasına yol açmaktadır.

Roman boyunca K.'nın yaşadığı değişim yalnızca sistemle olan ilişkisini değil, kendi varlığına bakışını da değiştirmektedir. Bu değişim özellikle *K.*'nın kişisel eşyalarına ve gündelik yaşamına ilişkin konuları önemsememeye başlaması, bütün dikkatini içinde bulunduğu davanın açıklığa kavuşmasına yöneltmesiyle (Kafka, 2024: 4) açıkça görülmektedir. Bu ifade, onun gündelik yaşamdan ve kişisel alanından giderek uzaklaştığını göstermektedir. Normalde bireyin kimliğini ve aidiyetini destekleyen eşyalar, K. için anlamını yitirmektedir. Dava sürecinin yarattığı zihinsel baskı, onun tüm dikkatini tek bir noktaya yoğunlaştırırken, yaşamın geri kalanını silikleştirir ve bu da kendine olan yabancılaşmanın belirgin bir göstergesi haline gelmektedir. K.'nın bu obsesif odaklanışı, mahkemenin esrarengiz yapısı ile bireysel iradesi arasındaki sınırları silerek, onun bir sanıktan ziyade sistemin kendi kendine işleyen bir parçası haline dönüşmesine neden olmaktadır (Dishon, 2024: 970).

Yabancılaşmanın en yoğun biçimi ise K.'nın içine sürüklendiği yalnızlık ve çaresizlik duygusunda kendini göstermektedir. Bu durum, bireyin bir yandan kanunların temsil ettiği otoriteye sığınma arzusu ile diğer yandan

bu baskıcı yapının yarattığı yabancılaşma arasında sıkışıp kalmasından kaynaklanmaktadır (Öztürk & Çipe, 2020: 109). Sistem karşısında giderek silikleşen birey, sadece toplumsal ilişkilerinden değil, hayatla kurduğu bağdan da uzaklaşmaktadır. Böylece yabancılaşma, yalnızca dışsal bir baskı mekanizması olmaktan çıkmakta ve bireyin varoluşunu içsel bir krize dönüştürmektedir. Sonuç olarak Dava romanı, yabancılaşmayı farklı yönleri olan bir durum olarak ele almaktadır. Kafka, K. üzerinden modern bireyin hem otorite karşısında, hem de kendi yaşamı ve kendisiyle arasındaki bağın uzaklaştığını göstermektedir. Süreç ilerledikçe, kimlik ve anlam arayışı karşılıksız kalmakta ve birey kendisini varoluşsal bir boşluk içinde bulmaktadır. Bu durum, Kafkaesk evrenin tipik bir yansıması olarak, bireyin toplumsal normlara ve bürokratik mekanizmalara uyum sağlama çabasının, aslında kendi gerçekliğinden nihai kopuşunu hızlandırdığını kanıtlar niteliktedir (Gündüz, 2011).

İçimizdeki Şeytan Romanında Yabancılaşma İzleği

Sabahattin Ali'nin İçimizdeki Şeytan romanında ise yabancılaşma, bireyin iç dünyasında başlayan ve zamanla toplumsal ilişkilere yayılan bir süreç olarak karşımıza çıkmaktadır. Bu noktada Kafka'da olan dışsal bir sistemin baskısıyla oluşan kopuş, bireyin kendi iç çatışmaları sonucunda derinleşmekte ve dış dünyaya yansımaktadır. Ömer, kararsızlığı ve içsel tutarsızlıklarında dolayı, hem kendisiyle hem de çevresiyle sağlıklı bir bağ kuramaz hale gelmektedir. Ömer'in yabancılaşması, hayatının her alanına yayılan bir sıkılma ve yorgunluk duygusuyla başlamaktadır. Ömer, eğitim hayatından arkadaşlık ilişkilerine kadar gündelik yaşamın farklı alanlarından bunaldığını ve çevresindeki hiçbir unsurun kendisini tatmin etmediğini dile getirmektedir (Ali, 2024: 2). Bu sözleri, onun sadece belirli alanlara değil, hayatın tamamına karşı bir kopukluğa yol açtığını göstermektedir. Bu noktada birey çevresine karşı ait olma duygusu hissedemez ve o duygu giderek yok olmaktadır. Bu içsel huzursuzluk yavaş yavaş varoluşsal bir sorgulamaya dönüşmektedir. Ömer'in hayatın dünyaya geliş amacına ilişkin soruya kesin bir yanıt verememesi ve yaşamın anlamına dair ileri sürülen düşünceleri ikna edici bulmaması (Ali, 2024: 2), onun hayatın anlamı konusunda güvenini kaybettiğini ortaya koymaktadır. Hayatın değerlerinin ikna ediciliğinin kaybı, yabancılaşmayı sadece sosyal değil, varoluşsal bir düzleme de taşımaktadır.

Toplumla kurulan ilişki de bu yabancılaşmanın bir başka boyutunu oluşturmaktadır. Bu bağlamda Ömer'in sokaktan geçen insanları küçümseyici bir bakışla değerlendirmesi ve onların gündelik uğraşlarını anlamsız bulması (Ali, 2024: 4), onun çevresine karşı yabancılaştırıcı ve mesafeli bakışını yansıtmaktadır. Ömer'in bu sert toplumsal eleştirisi, bireyin çevreyle bütünleşme çabasını reddederek kendi yalnızlığını bir kimlik göstergesi haline getirdiğini kanıtlar niteliktedir (Acar, 2018). Bu bakış açısı, bireyin kendini toplumdan ayrı ve üstün görme eğilimini taşısa da, aslında derin bir yabancılaşmanın göstergesi olmaktadır. Romanda yabancılaşma mekanlar aracılığıyla da kendini göstermektedir. Macide'nin bulunduğu evin, zaman geçtikçe ona tanıdık ve ait hissettiren bir yer olmaktan uzaklaşması (Ali, 2024: 17), mekanın bile zamanla yabancılaşabileceğini ortaya koymaktadır. Benzer biçimde, Macide'nin eğitim hayatında karşılaştığı düşünceler ile yaşadığı evin ve aile çevresinin değerleri arasında belirgin bir uyumsuzluk bulunmaktadır (Ali, 2024: 17). Bu durum, bireyin kendisini ait hissedemediğini göstermektedir. Yabancılaşma ilerledikçe, bireyin yaşam enerjisi de zayıflamaktadır. Sonuç olarak İçimizdeki Şeytan romanında yabancılaşma, bireyin hem kendisiyle hem de toplumla kurduğu bağların çözülmesiyle gelişen çok katmanlı bir süreç olarak değerlendirilebilir. Nitekim yabancılaşmanın bireyin toplumdan, Tanrı'dan kopması, kendinden uzaklaşması anlamlarına geldiği belirtilmektedir (Akar, 2022: 134). Bu bağlamda Sabahattin Ali, Ömer ve Macide aracılığıyla bireyin iç çatışmalarının toplumsal ilişkilere nasıl yansıdığını gösterirken, yabancılaşmayı sadece dış dünyadan kopuş olarak değil, aynı zamanda benliğin içsel bir çözülmesi olarak da ifade edebiliriz.

Sonuç ve Öneriler

Bu çalışmada, Franz Kafka'nın Dava ve Sabahattin Ali'nin İçimizdeki Şeytan romanları, karşılaştırmalı edebiyat yöntemi çerçevesinde suçluluk, otorite ve yabancılaşma izlekleri doğrultusunda incelenmiştir. Söz konusu eserler her ne kadar farklı kültürel, toplumsal ve tarihsel koşullarda kaleme alınmış olsalar da, inceleme sonucunda her iki eserin de bireyin modern dünyada yaşadığı sıkışmışlığı, çaresizliği ve aidiyet sorununu benzer izlekler üzerinden ele aldığı görülmüştür. Bununla birlikte eserler, bu izlekleri ortaya koyuş biçimleri

bakımından belirgin farklılıklar göstermektedir. Bir başka deyişle, her iki romanda da aynı temalar işlenmekle birlikte, bu temaların kaynağı ve niteliği birbirinden ayrışmaktadır.

Suçluluk izleği bakımından Dava 'da suçluluk, belirli bir eylemden kaynaklanmayan, dışarıdan gelen ve nedeni açıklanamayan bir durum olarak karşımıza çıkmaktadır. K.'nın hangi suçtan yargılandığını bilmemesi, suçluluk duygusunun giderek derinleşmesine ve varoluşsal bir nitelik kazanmasına yol açmaktadır. Böylece suçluluk, dışsal ve metafizik bir nitelik taşımaktadır. Buna karşılık İçimizdeki Şeytan'da suçluluk, bireyin kendi davranışları ve ahlaki eksiklikleriyle yüzleşmesinden kaynaklanmaktadır. Ömer'in yaşadığı içsel çatışmalar, bu duygunun dışarıdan dayatılan bir yargıdan çok, bireyin kendi iç dünyasında şekillenen ahlaki bir hesaplaşma olduğunu ortaya koymaktadır.

Otorite izleği bakımından da iki eser arasında benzer bir farklılık bulunmaktadır. Dava'da otorite, işleyişi tam olarak belli olmayan, sebebine ulaşılamayan ve bireyin karşısına soyut bir güç olarak çıkan erişilemez bir yapı olarak karşımıza çıkmaktadır. Böylece otorite, sadece bürokratik değil aynı zamanda absürt bir nitelik taşımaktadır. İçimizdeki Şeytan'da ise otorite, toplumsal çevre, ahlaki normlar ve bireyin vicdanı aracılığıyla etkisini göstermektedir. Dolayısıyla Kafka'nın romanında otorite bireyin dışında konumlanırken, Sabahattin Ali'nin romanında otorite bireyin dışında ve ulaşılması güç bir konumda yer alırken, Sabahattin Ali'nin romanında toplumsal yaşamın içinde daha somut ve görünür bir nitelik kazanmaktadır.

Yabancılaşma izleği bakımından her iki eser de, bireyin kendisi ve toplumla kurduğu ilişkinin bozulması üzerinden şekillenmektedir. Ancak Dava'da yabancılaşma, bürokratik sistemin birey üzerinde oluşturduğu baskı sonucunda gelişen sistematik ve varoluşsal bir nitelik taşımaktadır. K., süreç ilerledikçe sadece çevresinden değil, kendisinden ve yaşamına yüklediği anlamlardan da uzaklaşmaktadır. İçimizdeki Şeytan'da ise yabancılaşma, bireyin iç dünyasında başlayan ve toplumsal ilişkilerine yayılan içsel ve toplumsal bir süreç olarak karşımıza çıkmaktadır. Ömer'in yaşadığı aidiyet sorunu ve kendisiyle kurduğu çatışmalı ilişki, bu yabancılaşmanın temel kaynaklarını oluşturmaktadır.

İnceleme sonucunda her iki eser; suçluluk, otorite ve yabancılaşma izlekleri aracılığıyla modern bireyin yaşadığı varoluşsal krizleri merkeze almakla birlikte, bu krizlerin kaynaklarını farklı zeminlerde ortaya koymaktadır. Kafka, bireyi işleyişini anlayamadığı bürokratik ve otoriter sistem karşısında giderek yalnızlaşan ve varoluşsal bir çıkmaza sürüklenen bir özne olarak ele alırken; Sabahattin Ali, bireyin kendi ahlaki sorgulamaları, iradesizliği ve toplumsal çevresiyle kurduğu çatışmalı ilişkiyi ön plana çıkarmaktadır. Bu yönüyle eserler, benzer insanlık durumlarını farklı edebi, düşünsel ve toplumsal bağlamlarda ele alarak karşılaştırmalı edebiyat açısından anlamlı bir benzerlik ve farklılık alanı sunmaktadır.

Bu çalışma, Franz Kafka'nın *Dava* ve Sabahattin Ali'nin *İçimizdeki Şeytan* romanları ile belirlenen üç ana izlek (suçluluk, otorite, yabancılaşma) çerçevesinde yürütüldüğünden, elde edilen bulgular ve varılan sonuçlar incelenen metinlerin kurgusal sınırları dahilinde geçerlidir. Gelecekte gerçekleştirilecek araştırmalarda, söz konusu eserler Varoluşçuluk, Psikanaliz veya Sosyolojik Edebiyat Kuramı gibi farklı teorik yaklaşımlar açısından yeniden incelenebilir. Ayrıca Alman ve Türk edebiyatının yanı sıra farklı ulusal edebiyatlardan benzer izlekleri taşıyan yeni eserlerin karşılaştırmalı analize dahil edilmesi, bireyin otoriteyle ve kendi iç dünyasıyla kurduğu ilişkinin farklı yönleriyle değerlendirilmesine katkı sağlayacaktır.

Teşekkür ve Bilgilendirme Notu
Bu çalışmanın hazırlanma sürecindeki akademik katkıları ve yardımları için Doç. Dr. Fatma Karaman'a teşekkürlerimi sunarım. Eğitim hayatım boyunca sevgilerini, güvenlerini ve desteklerini her zaman yanımda hissettiğim annem Nurgül Martlı'ya ve babam Osman Martlı'ya; bu süreçte sevgisi, anlayışı ve manevi desteğiyle bana güç veren, her koşulda yanımda olan Batuhan Sömen'e en içten teşekkürlerimi ve minnetlerimi sunarım.

Kaynakça

Acar, Genel Müdürlük (2018). Sabahattin Ali'nin romanlarında toplumsal gerçeklik ve kadın. *Tarih ve Günce* , *1* (3), 29-50.

Akar, Ç. (2022). " Beyaz Mantolu Adam" Öyküsünde Ötekileştirmenin Görünümleri. *Edebi Eleştiri Dergisi*, *6*(2), 133-141.

Aktaş, Ş. (2007). Edebî Metinleri Çözümleme Metodolojisi Ve Yapı-Tema İlişkisi Üzerine.

Aşkaroğlu, V. (2020). Yazar Ve Edebiyatın İşlevi Ve İdeolojik/Toplumsal Rolü Üzerine Kuramsal Bir Tartışma. *Karadeniz Uluslararası Bilimsel Dergisi* , (47), 198-221.

Balcı, Y. (2023). Parça-Bütün Diyalektiğinde Çağdan Yazara, Yazardan Kurgu Kişisine Oğuz Atay. *Yeni Türk Edebiyatı Araştırmaları*, (29), 19-39.

Canpolat, T. (2019). Sabahattin Âli'nin "İçimizdeki Şeytan" romanında Nietzsche ve Levinas gerilimi.

Çataloluk, G. (2011). Hukukçunun Hukuk Karşıtı Tutumunun Edebi Dışavurumu: Dr. Franz Kafka Ve "Dava" Sı. *Marmara Üniversitesi Hukuk Fakültesi Hukuk Araştırmaları Dergisi*, *17*(1-2), 235-264.

Çelik, T. (2021). Sabahattin Ali'nin Romanlarında Devlet Memurluğu Ve Memur Odaları. *Dokuz Eylül Üniversitesi Edebiyat Fakültesi Dergisi*, *8*(2), 150-171.

Çiçek, N. (2015). Franz Kafka'nın eserlerinde yabancılaşma sorunu. *Beytülhikme Uluslararası Felsefe Dergisi* , *5* (1), 141-162.

Deleuze, G., Guattari, F., Uçkan, Ö., & Ergüden, I. (2000). Kafka: Minör bir edebiyat için.

Deligöz, E. (2024). Franz Kafka's" The Metamorphosis" story in the context of the concept of alienation and Karl Marx's thoughts. *Uluslararası İnsan ve Sanat Araştırmaları Dergisi*, *9*(1), 65-78.

Dishon, G. (2024). Canavarlardan labirentlere: Frankenstein ve Kafka arasında yapay zekanın sosyoteknik imgeleri. *Postdijital Bilim ve Eğitim* , *6* (3), 962-977.

Franz Kafka. Dava (Çev. Gülperi Sert). İstanbul: Türkiye İş Bankası Kültür Yayınları, 2024.

Gündüz, U. (2011). Kafka Metinlerinde İletişim, İletişimsizlik Ve Yabancılaşma Olgusu Üzerine... *Selçuk İletişim*, *7*(1), 83-95.

Koşmak, F., & Angın, Z. (2023). Dava İle Kırmızı Pazartesi Romanlarında Suç-Suçsuzluk Ekseninde Kötülük Problemi. *Kare*, (16), 27-37.

Küçüksayacıgil, A., & Küçükşen, K. (2021). Tanzimattan Günümüze Türk Edebiyatında Toplumsal Cinsiyet Yansımaları Ve Kadının Konumu. *Edebî Eleştiri Dergisi*, *5*(2), 371-386.

Öztürk, S., & Çipe, b. i. l. g. e. (2020). Kafka, Metamorfoz Ve Emeğin Yabancılaşması. *Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *22*(1), 105-121.

Öztürk, V. K. (2018). Metin Savaş'ın Kurmaca Eserlerinde Metinlerarası İlişkiler.

Sabahattin Ali. İçimizdeki Şeytan. İstanbul: Türkiye İş Bankası Kültür Yayınları, 2024.

Sala, B. (2025). Fatma Dore (Ed.) Ölümünün 100. Yılında Franz Kafka. *Folklor/Edebiyat*, *31*(121), 277-281.

Şahin, C. (2024). Evrensel Hukuk İlkeleri Bağlamında Franz Kafka'nın Dava'sı. *Edebi Eleştiri Dergisi*, *8*(2), 516-536.

Tekin, N., & Bozkurt, K. (2023). Mekân, İnsan ve Edebiyat. *Batman Akademi Dergisi, 7*(2), 238-259.

Ulusan, E. (2019). Sabahattin Ali'nin Romanlarında Yabancılaşma Meselesi. *İstanbul: İstanbul Üniversitesi*.

Uluşahin, E. (2020). Sabahattin Ali'nin İçimizdeki Şeytan Adlı Yapıtının Farklı Basımdaki Diliçi Versiyonlarının Mukayesesi. *Akademik Hassasiyetler, 7*(13), 431-448.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

IN NATURE, BUT WHERE IN THE MIND? THE VISIBILITY AND ECOLOGICAL ROLE OF PLANTS IN HIGH SCHOOL STUDENTS' IDEAS ABOUT NATURE

Selin OTHAN
Arzu ÖNEL
0009-0009-8675-6194, Göle Bedirhan Bey Anatolian Imam Hatip High School, ARDAHAN, TURKEY.
0000-0003-4205-3939, Kafkas University Institue of Scince, Mathemetics and Science Education, KARS, TURKEY.

Abstract

This study aimed to find out how much students notice plants in their ideas about nature and in which situations plants appear. It also examined the place of plants and animals in these ideas, looking at how students' first thoughts, choices, and reasons differed according to their fields of study. A basic qualitative research method was used with 19 Grade 11 students: 12 from science and mathematics, and 7 from the equal-weight field. Data were collected using a 10 item Sentence Completion Form to study students' ideas about nature and the visibility of plants within them.

The results showed that plants were present in students' ideas, though visibility varied across situations. When first thinking of nature or describing a forest, students frequently mentioned trees, green areas, flowers, and plants. However, when identifying "*the most important group of living things in nature*" they mentioned bees and other animals more often. Students connected plants mainly with producing oxygen, providing food, maintaining nature's balance, and supporting other living things. Thus, plants were not invisible, but noticing or appreciating them did not mean seeing them as the most important living things.

Students clearly notice plants as visual, beautiful parts of nature and understand that they help life continue. However, when comparing the importance of different living groups, animals become more prominent. This shows that plant awareness is context-dependent and multifaceted. Plant blindness should not be understood merely as seeing or not seeing plants, but also through how students evaluate plant traits and understand their ecological roles.

Keywords: human nature relationship, plant blindness, plant visibility, mental images of nature, high school students.

DOĞANIN İÇİNDE, ZİHNİN NERESİNDE? LİSE ÖĞRENCİLERİNİN DOĞA TEMSİLLERİNDE BİTKİLERİN GÖRÜNÜRLÜĞÜ VE EKOLOJİK KONUMU

Özet

Bu araştırma, öğrencilerinin zihinsel doğa temsillerinde bitkilerin ne ölçüde ve hangi bağlamlarda görünür olduğunu belirlemek amacıyla yürütülmüştür. Bu temsiller içinde, bitki ve hayvanların göreli konumları; öğrencilerin doğaya ilişkin çağrışım, tercih ve gerekçelerinin öğrenim gördükleri alanlara göre nasıl farklılaştığı ortaya konmuştur. Araştırma, temel nitel araştırma deseniyle yürütülmüştür. Araştırmanın çalışma grubunu 11. sınıflarda öğrenim gören; 12'si sayısal, 7'si eşit ağırlık alanından toplam 19 öğrenci oluşturmuştur. Çalışmada, öğrencilerin doğaya ilişkin zihinsel temsilleri ve bu temsiller içinde bitkilerin görünürlüğü incelenmiştir. Veri toplama aracı olarak araştırmacılar tarafından geliştirilen 10 maddelik Cümle Tamamlama Formu kullanılmıştır.

Elde edilen bulgular, öğrencilerin zihinsel doğa temsillerinde bitkilerin görünür olduğunu, ancak bu görünürlüğün farklı bağlamlarda değiştiğini göstermiştir. Doğaya ilişkin ilk çağrışımlarda ve orman betimlemelerinde ağaç, orman, yeşillik, çiçek ve bitki gibi bitkisel unsurların belirgin biçimde öne çıktığı

görülmüştür. "*Doğadaki en önemli canlı grubu*" değerlendirmelerinde arılar ve diğer hayvan gruplarına yönelik vurguların arttığı görülmüştür. Öğrenciler bitkileri özellikle oksijen üretimi, besin sağlama, ekolojik dengenin sürdürülmesi ve diğer canlıların yaşamını destekleme işlevleriyle ilişkilendirmişlerdir. Bulgular, bitkilerin öğrencilerin doğa temsillerinde görünmez olmadığını; ancak algısal ve estetik görünürlükleri ile canlılar arasındaki önemlerine ilişkin değerlendirmelerin her zaman örtüşmediğini ortaya koymuştur.

Öğrenciler bitkileri doğanın görsel ve estetik bileşenleri olarak belirgin biçimde fark etmekte, yaşamın sürdürülmesindeki işlevlerini de tanımaktadır. Buna karşın canlı gruplarının göreli önemine ilişkin değerlendirmelerde hayvanların daha belirgin hâle gelmesi, bitki görünürlüğünün bağlama bağlı ve çok boyutlu bir yapı sergilediğine işaret etmektedir. Bu sonuçlar, bitki körlüğünün yalnızca "*bitkiyi görme–görmeme*" karşıtlığı üzerinden değil; bitkinin nasıl görüldüğü, hangi özellikleriyle anlamlandırıldığı ve ekolojik sistem içindeki konumunun nasıl değerlendirildiği üzerinden ele alınması gerektiğini düşündürmektedir.

Anahtar kelimeler: insan–doğa ilişkisi, bitki körlüğü, bitki görünürlüğü, zihinsel doğa temsilleri, lise öğrencileri.

1. GİRİŞ

Canlılar, insan algısında her zaman tam karşılığını bulmayabilir. Hareketli oluşları, görünümleri veya uyandırdıkları hisler nedeniyle bazı canlılar çok daha fazla dikkat çekebilmektedirler. Öte taraftan insan algısı ekosistemlerde önemli temel görevleri bulunan diğer bazı canlıları ise aynı ölçüde fark etmeyebilir. Bu durum, canlıların insan zihninde nasıl anlamlandırıldığının, insanlar tarafından nasıl algılandıklarının ve ekolojik bütünlük içerisinde nasıl konumlandırıldığıyla birlikte ele alınmasını gerektirmektedir.

Bitkiler, ekosistemlerin temel üreticileri olmalarına, diğer birçok canlı gruplarına besin üretmelerine, ve madde döngülerindeki önemli rollerine rağmen insanların dikkat ve ilgisinden hak ettikleri karşılığı bulamamaktadırlar. Bu olgu, Wandersee ve Schussler (1999) tarafından bitki körlüğü (plant blindness) kavramıyla ortaya konmuş olup, bitkilerin yeterince fark edilmemesi ve önemlerinin kavranmaması olarak tanımlanmıştır. Parsley (2020), kavramın fiziksel bir eksikliğe işaret ettiğine ilişkin eleştirilerden hareketle bitki körlüğü yerine bitki farkındalığı eşitsizliği (plant awareness disparity) ifadesini önermiştir. Parsley, Daigle ve Sabel (2022) ise bitki farkındalığı eşitsizliğini tutum, dikkat, bilgi ve göreli ilgi boyutları ile ilişkilendirerek bitkilere yönelik farkındalığın çok bileşenli yapısını ortaya koymuştur. Bu yaklaşım, bitkilerin fark edilmesi, tanınması, sevilmesi ve önemsenmesinin birbiriyle ilişkili olmakla birlikte aynı anlama gelmediğini düşündürmektedir.

Araştırmanın Amacı

Bu araştırma, lise öğrencilerinin zihinsel doğa temsillerinde bitkilerin nasıl ve hangi bağlamlarda görünür hâle geldiğini, bitkilere yüklenen anlamların ekolojik önem atfıyla ne ölçüde örtüştüğünü ve bu temsillerin hayvanlara ilişkin değerlendirmelerle nasıl farklılaştığını incelemek amacıyla yürütülmüştür.

Araştırma Soruları

Araştırmanın temel sorusu şöyledir:

Lise öğrencilerinin zihinsel doğa temsillerinde bitkilerin görünürlüğü, bitkilere yüklenen anlamlar ve ekolojik önem atfı arasında nasıl bir ilişki bulunmaktadır?

Bu temel soru doğrultusunda aşağıdaki alt sorulara yanıt aranmıştır:

1. Öğrencilerin doğaya ilişkin ilk çağrışımlarında ve doğa betimlemelerinde bitkiler, hayvanlara kıyasla nasıl bir görünürlük sergilemektedir?
2. Öğrenciler bitki ve hayvanları hangi estetik, duygusal ve ekolojik özellikleri üzerinden anlamlandırmaktadır?

3. Öğrencilerin canlı gruplarına atfettikleri önem ile bitkilerin doğa temsillerindeki görünürlüğü arasında nasıl bir örüntü ortaya çıkmaktadır?
4. Bitkilerin ve hayvanların yokluğuna ilişkin değerlendirmeler, öğrencilerin canlıların ekolojik işlevlerine ve karşılıklı bağımlılıklarına yönelik anlayışlarını nasıl yansıtmaktadır?
5. Öğrencilerin doğaya ilişkin temsilleri ve ekolojik gerekçelendirmeleri, sayısal ve eşit ağırlık alanlarına göre hangi benzerlik ve farklılıkları göstermektedir?

2. YÖNTEM

2.1. Araştırma Deseni

Bu araştırma, nitel araştırma yaklaşımı ile yürütülmüştür. Nitel araştırma, bireylerin olguları nasıl algıladıklarını, anlamlandırdıklarını ve bu anlamları nasıl ifade ettiklerini incelemeye odaklanmaktadır (Merriam & Tisdell, 2016).

Araştırmada öğrencilerin doğaya ilişkin ilk çağrışımları, bitki ve hayvanlara yükledikleri anlamlar, canlı gruplarına atfettikleri önem ve ekolojik gerekçelendirmeleri incelenmiştir. Öğrencilerin verdiği cevaplar, canlıların hangi özellikleriyle tanımlandığı ve doğa içerisinde nasıl konumlandırıldığı açısından da değerlendirilmiştir. Temel nitel araştırma deseninin tercih edilmesinde, öğrencilerin doğaya ilişkin düşüncelerini önceden belirlenmiş yanıt seçenekleriyle sınırlandırmadan, kendi anlamlandırma biçimleri üzerinden inceleme amacı belirleyici olmuştur.

2.2. Katılımcılar

Araştırma, 11. sınıfta öğrenim gören 12'si sayısal (%63,2), 7'si eşit ağırlık (%36,8) alanından toplam 19 öğrenci ile yürütülmüştür. Çalışma grubunun iki farklı akademik alandan oluşması, öğrencilerin doğaya ilişkin zihinsel temsillerinin alanlara göre benzerlik ve farklılıklarının incelenmesine olanak sağlamıştır. Katılımcı sayısının sınırlı olması ve grupların eşit büyüklükte olmaması nedeniyle alanlar arası karşılaştırmalar, genellenebilir farklılıklar olarak değil, çalışma grubuna özgü nitel örüntüler olarak değerlendirilmiştir.

2.3.Veri Toplama Aracı

Araştırmacılar tarafından hazırlanan 10 maddelik *İnsan–Doğa İlişkisi Cümle Tamamlama Formu* veri toplama aracı olarak kullanılmıştır. Form, öğrencilerin doğaya ilişkin ilk çağrışımlarını, bitki ve hayvanlara yönelik değerlendirmelerini, canlıların ekolojik işlevlerine ilişkin düşüncelerini ve doğaya yönelik duygusal tepkilerini ortaya çıkarmayı amaçlayan açık uçlu cümle köklerinden oluşmaktadır.

Katılımcı öğrencilerin doğaya ilişkin ilk çağrışımlarını belirlemeye yönelik "*Doğa denince aklıma ilk gelen... çünkü...*", estetik tercihlerini ortaya çıkarmaya yönelik "*Güzel bir doğa manzarasında mutlaka olması gereken... çünkü...*", doğal ortamlarda dikkatlerini yönelttikleri canlıları belirlemeye yönelik "*Bir ormana gittiğimde ilk baktığım şey...*", ekolojik önem atıflarını sorgulamaya yönelik "*Doğadaki en önemli canlı grubu bana göre...*", bitki ve hayvanlara yönelik algısal, duygusal ve davranışsal tepkilerini ortaya çıkarmaya yönelik "*Bir çiçek gördüğümde...*" ve "*Bir hayvan gördüğümde...*", doğaya ilişkin olumlu ve olumsuz duyguların birlikteliğini incelemeye yönelik "*Doğayı seviyorum ama...*", canlıların yokluğuna ilişkin ekolojik değerlendirmelerini belirlemeye yönelik "*Bitkiler olmasaydı...*" ve "*Hayvanlar olmasaydı...*" ile doğaya yönelik koruyucu tutum ve davranışsal eğilimlerini ortaya çıkarmaya yönelik "*Bir ağacın kesildiğini gördüğümde...*" ifadelerine yer verilmiştir.

2.4. Veri toplama Süreci

Araştırmanın verileri, cümle tamamlama formu aracılığıyla çevrim içi olarak elde edilmiştir. Formda öğrencilerin öğrenim gördükleri akademik alan bilgisi ile doğaya ilişkin 10 açık uçlu ifadeye verdikleri yanıtlar toplanmıştır. Elde edilen veriler elektronik tablo biçiminde düzenlenmiş; 19 katılımcının 10 maddenin tamamını yanıtladığı belirlenmiştir. Böylece araştırmanın veri setini toplam 190 açık uçlu yanıt oluşturmuştur. Anlamlı veri sağlamayan bir yanıt olduğu görülmüş ve geriye kalan anlamlı 189 yanıt değerlendirmeye alınmıştır.

2.5. Veri Analizi

Araştırmada elde edilen veriler, nitel araştırma yaklaşımı ve tematik analiz yöntemiyle değerlendirilmiştir. Tematik analiz, katılımcı ifadelerinde tekrar eden anlam örüntülerinin belirlenmesine ve bu örüntülerin araştırma soruları çerçevesinde yorumlanmasına olanak sağlamaktadır (Braun & Clarke, 2006).

Elde edilen öğrenci ifadeleri; doğaya ilişkin ilk çağrışımlar, bitki ve hayvanların görünürlüğü, estetik ve duygusal değerlendirmeler ile ekolojik önem atfı bakımından ele alınmış, öğrenci ifadelerinden örneklerle desteklenerek yorumlanmıştır. Ayrıca sayısal ve eşit ağırlık alanlarında öğrenim gören öğrencilerin yanıtları arasındaki benzerlik ve farklılıklar karşılaştırılmıştır.

3. BULGULAR

Araştırmada 19 öğrencinin 10 açık uçlu cümle tamamlama maddesine verdiği yanıtlar, araştırma soruları doğrultusunda incelenmiş ve anlamlı veri sağlayan 189 yanıt analize alınmıştır. Bulgular doğa temsillerinde canlıların görünürlüğü, bitki ve hayvanlara yüklenen anlamlar, algısal görünürlük ile ekolojik önem atfı arasındaki örüntüler, canlıların yokluğuna ilişkin değerlendirmeler ve akademik alanlara göre farklılaşmalar olmak üzere beş başlık altında sunulmuştur.

3.1. Öğrencilerin Doğa Temsillerinde Bitkilerin Görünürlüğü

Öğrencilerin doğaya ilişkin ilk çağrışımları, doğa manzarası tercihleri, orman algıları ve canlı gruplarına yönelik önem atıfları incelendiğinde, bitki görünürlüğünün bağlamlara göre farklılaştığı belirlenmiştir (Tablo 1).

Tablo 1. Doğa temsillerinde bitkilerin görünürlüğü

Cümle tamamlama maddesi	Bitki (f)	%
Doğa denince aklıma ilk gelen	13	68,4
Güzel bir doğa manzarasında mutlaka olması gereken	5	26,3
Bir ormana gittiğimde ilk baktığım şey	14	73,7
Doğadaki en önemli canlı grubu	4	21,1

Bitki kategorisine; ağaç, orman, çiçek, bitki, kozalak, yeşillik ve bağlamı bitkilere açıkça gönderme yapan yeşil ifadelerini alınmıştır. Tablo 1'e göre bitkiler, öğrencilerin orman algılarında (%73,7) ve doğaya ilişkin ilk çağrışımlarında (%68,4) belirgin biçimde yer almaktadır. Fakat güzel bir doğa manzarasında bulunması gereken ögeler arasında bitkilere öğrencilerin %26,3'ünün yer verdiği, doğadaki en önemli canlı grubunu bitkiler olarak belirten öğrencilerin oranının ise %21,1 olduğu görülmüştür. Doğaya ilişkin ilk çağrışımlarda ağaç, orman, çiçek, bitki ve yeşillik ifadelerinin öne çıktığı, güzel bir doğa manzarasında deniz, gökyüzü, göl ve gün batımı gibi unsurların tercih edildiği görülmüştür. Bu veriler, bitkilerin doğanın genel temsilinde görünür olduğunu ancak estetik tercihlerin yalnızca bitkilerle sınırlı olmadığını göstermektedir. Öğrenci ifadeleri bu durumu somutlaştırmaktadır:

- "*Ağaçlar çünkü doğa denilince akla yeşil geliyor*." (EA02)
- "*Bitki geliyor çünkü doğa çoğunlukla bitkilerden oluşur*." (S12)
- "*Deniz çünkü sesi kokusu güzelliğiyle bütünleyicidir*." (S12)
- "*Ağaçların uzunluğu çünkü bence bir ormanı görkemli kılan da tam olarak bu*." (S19)

Aynı öğrencinin doğa algısında bitkiler bulunmasına rağmen güzel bir doğa manzarasında bitkileri değil de başka bir unsuru tercih etmesi, doğa temsilinin değerlendirme bağlamına göre değişebildiğini göstermektedir. Dolayısıyla bitkilerin görünürlüğü, öğrencilerin bütün doğa değerlendirmelerinde aynı düzeyde ortaya çıkan sabit bir özellik olmadığı görülmüştür.

3.2. Bitki ve Hayvanlara Yüklenen Estetik, Duygusal ve Ekolojik Anlamlar

Öğrencilerin bitki ve hayvanlarla karşılaşmalarına ilişkin sorulara verdikleri yanıtların, canlılara yükledikleri anlamların farklı boyutlarda yapılandığı görülmüştür. Çiçeklerle ilgili ifadelerinde duyusal ve estetik özellikler ile olumlu duygular öne çıkarken, hayvanlarla ilgili ifadelerinde sevgi, yakınlaşma, gözlem, temkin ve korku gibi farklı tepkiler olduğu tespit edilmiştir ve bu bağlamdaki bulgular Tablo 2'de verilmiştir.

Tablo 2. Çiçekle karşılaşmaya ilişkin yanıtların baskın tepki kategorilerine göre dağılımı

Tepki kategorisi	f	%
Koklama ve kokuya yönelme	6	31,6
Olumlu duygusal tepki	5	26,3
Koparma	3	15,8
İnceleme ve görsel gözlem	3	15,8
Fotoğraflama	1	5,3
Alerjik tepki	1	5,3
Toplam	19	100

Tablo 2'ye göre; Çiçekle karşılaşmaya ilişkin yanıtlarda koklama davranışı en sık belirtilen tepki olmuştur (f=6). Mutluluk ve neşe gibi olumlu duygusal tepkiler (f=5) ile çiçeği koparma davranışını (f=3) göstermektedirler. Öğrenci ifadelerinde bu farklı yönelimler açıkça görülmektedir:

- "*Koklarım çünkü doğayı hissetmemi sağlar.*" (EA02)
- "*Beğenirsem koparırım çünkü çiçek toplamayı severim.*" (S06)
- "*Fotoğraf çekmek isterim çünkü renkleri dikkat çeker.*" (EA14)
- "*Bir çiçek gördüğümde rengi dikkatimi çeker çünkü eğer ki nadir görülen bir renge sahipse bu onu daha da ilgi çekici kılar.*" (S19)

Bu ifadeler, bitkilere yönelik ilginin her zaman aynı davranışsal yönelimle sonuçlanmadığını göstermektedir. Çiçeğin estetik özelliklerini beğenme, onu inceleme veya fotoğraflama davranışıyla birlikte görülebildiği gibi, koparma davranışıyla da ilişkilendirilebilmektedir. Hayvanlarla karşılaşmaya ilişkin yanıtlar ise daha geniş bir duygusal çeşitlilik sergilemiştir. Bazı öğrenciler hayvanları sevme, onlarla bağ kurma veya onları gözlemleme isteği belirtirken, bazıları korku ve belirsizlik nedeniyle temkinli davranacaklarını ifade etmiştir.

3.3. Bitkilerin Görünürlüğü ile Ekolojik Önem Atfı Arasındaki Örüntüler

Araştırmanın temel sorularından biri, bitkilerin doğa temsillerinde görünür olmasının, onların ekolojik bakımdan öncelikli konumlandırılmasıyla ne ölçüde örtüştüğüdür. Bu amaçla öğrencilerin doğaya ilişkin ilk çağrışımları ile "*Doğadaki en önemli canlı grubu bana göre...*" maddesine verdikleri yanıtlar birlikte değerlendirilmiş ve bulgular Tablo'3'te verilmiştir.

Tablo 3. Öğrencilerin en önemli olarak belirttikleri canlı grupları

Canlı grubu	f	%
Hayvanlar	13	68,4
Bitkiler	4	21,1
İnsan	1	5,3
Tek hücreliler	1	5,3
Toplam	19	100

Tablo 3'e göre; öğrencilerin büyük bölümü doğadaki en önemli canlı grubunun hayvanlar (%68,4) olduğunu ifade etmişlerdir. Bitkileri en önemli canlı grubu olarak belirten öğrencilerin oranı ise %21,1'dir. Bu sonuç, canlı gruplarına yönelik önem değerlendirmelerinde bitkilerin hayvanlardan daha fazla öncelendiğini göstermektedir. Öğrencilerin gerekçeleri incelendiğinde, canlı gruplarına atfedilen önemin farklı ölçütlere dayandığı anlaşılmaktadır. Örneğin:

- "*Arılardır. Doğaya can verir. Tozlaşmayı sağlar*." (EA02)
- "*Arılar böcek grupları çünkü ekosistemin devamlılığını sağlarlar.*" (S12)
- "*Tek hücreliler, bizden daha işlevliler.*" (S15)
- "*Ağaç çünkü oksijen kaynağı.*" (S09)
- "*Bitkilerdir çünkü yaşamın devamını sağlarlar.*" (EA14)

Doğadaki en önemli canlı grubunun bitkiler olduğunu ifade eden öğrenciler gerekçe olarak oksijen üretimi, besin üretimi ve yaşamın sürdürülmesi gibi işlevlere vurgu yapmışlardır.

3.4. Bitki ve Hayvanların Yokluğuna İlişkin Ekolojik Değerlendirmeler

Öğrencilerin "*Bitkiler olmasaydı...*" ve "*Hayvanlar olmasaydı...*" şeklindeki sorulara verdikleri yanıtlar ile, canlıların ekolojik işlevlerine ilişkin değerlendirmeleri karşılaştırılmıştır. Bitkilerin olmamasının oksijenin yokluğu, yaşamın son bulması, besinsizlik, ekolojik dengenin bozulması ve doğanın estetik özelliklerini yitirmesi gibi anlamlara geldiğini ifade etmişlerdir. On öğrenci bitkilerin yokluğunu açık biçimde oksijen veya solunumla ilişkilendirmiştir. Örneğin:

- "*Ölürdük oksijen azalırdı*." (EA01)
- "*Ekosistemimiz bozulurdu çünkü bize oksijen sağlıyorlar*." (S06)
- "*Oksijen sıkıntısı olurdu, hayvanlar aç kalırdı*." (S07)
- "*Birçok canlı yaşayamazdı çünkü besin kaynağıdır*." (EA17)

Bu ifadeler, öğrencilerin bitkilerin hayati önem arz ettiklerini bildiklerini göstermektedir.

Bununla birlikte bazı öğrenciler bitkilerin olmamasını doğanın renk ve güzelliğini kaybedeceği şeklinde açıklamıştır. "*Dünya renkli bir yer olmazdı çünkü bitkiler bizim hayatımıza renk katar*" (S05) ifadesi, bitkilerin estetik değerinin ön planda olduğu bir algıyı ortaya koymaktadır.

Hayvanların olmamasının ise ekolojik dengenin bozulması, besin ağlarının zarar görmesi, yaşamın eksik kalması ve duygusal kayıp gibi farklı anlamlara geldiğini ifade etmişlerdir. Öğrencilerin bazı ifadeleri şöyledir:

- "*Besin piramidi bozulurdu çünkü bütün hayvanların doğaya faydası vardır.*" (S06)
- "*Doğa dengede kalamazdı hepsinin bir sorumluluğu var*." (S11)
- "*Sıkıcı olurdu çünkü hayvanlar eğlencelidir.*" (EA08)
- "*Birçok besin türü olmazdı çünkü et yumurta süt bu tarz önemli besin türleri hayvanlardan geliyor.*" (S12)

Bu bulgular, öğrencilerin hem bitkilerin hem de hayvanların yokluğunu olumsuz sonuçlarla ilişkilendirdiğini, ancak gerekçelendirmelerinde farklı işlev ve değerlerin öne çıkabildiğini göstermektedir.

3.5. Sayısal ve Eşit Ağırlık Alanlarına Göre Doğa Temsillerinin Karşılaştırılması

Öğrencilerin doğaya ilişkin ilk çağrışımları, estetik tercihleri, orman algıları ve canlı gruplarına yönelik önem değerlendirmeleri akademik alanlarına göre karşılaştırılmıştır (Tablo 4).

Tablo 4. Akademik alanlara göre bitki algısı

İncelenen bağlam	Sayısal (n=12)	Eşit ağırlık (n=7)
Doğa çağrışımı	10 (%83,3)	3 (%42,9)
Güzel doğa manzarası	3 (%25,0)	2 (%28,6)
Ormanda ilk dikkat edilen	9 (%75,0)	5 (%71,4)
En önemli canlı grubu	1 (%8,3)	3 (%42,9)

Tablo 4'e göre sayısal alanda öğrenim gören öğrenciler, doğaya ilişkin ilk çağrışımlarında bitkileri eşit ağırlık öğrencilerine göre daha sık ifade etmiştir. Buna karşılık en önemli canlı grubu olarak bitkileri seçen öğrencilerin oranı eşit ağırlık grubundan daha yüksektir. Ormanda güzel doğa manzarasının ilk dikkat ettikleri unsur olduğunu, bitkilerin daha çok dikkatlerini çektiğini belirtmişlerdir.

Bu bulgular, akademik alanlara göre farklılaşmanın bütün maddelerde aynı yönde gerçekleşmediğini göstermektedir. Özellikle sayısal öğrencilerin ilk doğa çağrışımlarında bitkilerin yüksek görünür olduğunu, buna rağmen canlı gruplarına yönelik önem değerlendirmelerinde bitkileri daha az önemsedikleri dikkat çekmektedir.

4. SONUÇ

Araştırmanın tüm bulguları birlikte ele alındığında, öğrencilerin zihinsel doğa temsillerinde bitkilerin bütünüyle görünmez olmadığı, ancak bitkilerin öğrenci zihninde ve algısındaki görünürlüklerinin sorunun bağlamına göre değiştiği anlaşılmıştır. Bitkilerin özellikle öğrencilerin doğaya ilişkin ilk çağrışımlarında ve orman algılarında belirgin biçimde yer alırken, canlı gruplarına yönelik önem değerlendirmelerinde hayvanlar kadar önemsenmediği görülmüştür.

Ayrıca öğrenciler bitkileri oksijen, besin ve yaşamın sürdürülebilirliğiyle ilişkilendirmeleri, bitkilerin ekolojik işlevlerinin de farkında olduklarını göstermiştir. Dolayısıyla bitkilerin canlı grupları arasında daha az önemsenmesinin, onların ekolojik öneminin bütünüyle bilinmediği anlamına gelmediği de söylenebilir.

Çiçeklere yönelik estetik beğenilerinin olması ama aynı zamanda onları koparma eğilimlerinin de bulunması, bitkilerin beğenilmesi ile onları koruma yöneliminin her zaman örtüşmediğini düşündürmektedir. Bu bulgu, doğa algısının zaman zaman karşıt duygusal değerlendirmeler içerebildiğini göstermektedir.

Sonuç olarak bulgular, öğrencilerin doğa temsillerinde algısal görünürlük, ekolojik anlamlandırma ve ekolojik öncelik atfının birbirleriyle ilişkili olmakla birlikte her zaman örtüşmeyen değerlendirme düzeyleri olarak ele alınabileceğine işaret etmektedir. Bu ayrım, bitki farkındalığının yalnızca bitkilerin görülüp görülmediği üzerinden değil, hangi bağlamlarda fark edildiği, nasıl anlamlandırıldığı ve canlılar arasındaki önem ilişkilerinde nasıl konumlandırıldığı üzerinden incelenmesinin gerekliliğini ortaya koymaktadır.

5. TARTIŞMA

Bu araştırmanın bulguları, lise öğrencilerinin zihinsel doğa temsillerinde bitkilerin görünür olduğunu, ancak bu görünürlüğün onlara atfedilen ekolojik önemle her zaman örtüşmediğini ortaya koymuştur. Öğrencilerin doğaya ilişkin ilk çağrışımlarda bitkilerin belirgin biçimde görünür olmasına rağmen, en önemli canlı grubu değerlendirmelerinde hayvanlar kadar önemsenmemesi, bitki farkındalığının yalnızca algısal görünürlük üzerinden açıklanamayacağını düşündürmektedir.

Schussler ve Olzak (2008), üniversite öğrencilerinin bitki ve hayvan görsellerini hatırlama düzeylerini karşılaştırdıkları araştırmada, hayvan görsellerinin bitki görsellerine göre daha fazla hatırlandığını ortaya koymuştur. Balding ve Williams (2016) ise bitkilere yönelik algısal ve kültürel yanlılıkların bitki koruma çalışmalarına yönelik toplumsal ilgiyi etkileyebileceğine dikkat çekmiştir. Bu çalışmalar, bitkilerin ekolojik önemleri ile insan algısındaki konumları arasında bir farklılaşma bulunabileceğini göstermektedir. Bununla birlikte mevcut araştırmada bitkilerin doğa çağrışımlarında belirgin biçimde yer alması, bitki farkındalığındaki farklılaşmanın her durumda bitkilerin fark edilmemesi şeklinde ortaya çıkmadığını düşündürmektedir.

Öğrencilerin bitkileri oksijen üretimi, besin sağlama ve yaşamın sürdürülebilirliğiyle ilişkilendirmelerine rağmen hayvanları daha fazla önemsemeleri, ekolojik işlev bilgisi ile önem atfının birbirinden ayrılabildiğine işaret etmektedir. Bu değerlendirme, bitki farkındalığını tek boyutlu bir eksiklik yerine farklı düzeylerde ortaya çıkabilen bir olgu olarak ele alan Parsley'nin (2020) yaklaşımıyla örtüşmektedir. Stagg ve Dillon (2022) da bitki farkındalığının bireylerin bitkilerle kurdukları ilişkiler ve bitkileri yaşamları açısından anlamlı bulmalarıyla bağlantılı olduğunu vurgulamaktadır.

Öte yandan öğrencilerin çiçeklere yönelik estetik beğenileriyle koparma davranışını birlikte ifade etmeleri, bitkileri fark etmenin veya beğenmenin koruyucu davranış yönelimini kendiliğinden sağlamadığını düşündürmektedir. Bu nedenle bitki farkındalığının geliştirilmesinde yalnızca bitkilerin tanıtılması değil, ekolojik ilişkiler içindeki rollerinin ve koruma gerekçelerinin de görünür kılınması önem taşımaktadır.

Sonuç olarak bu araştırma, bitki farkındalığının algısal görünürlük, ekolojik anlamlandırma ve önem atfı bakımından birlikte değerlendirilmesi gerektiğine ilişkin nitel bulgular sunmaktadır. Bununla birlikte sınırlı çalışma grubu ve açık uçlu yanıtların kapsamı, bu boyutlar arasındaki ilişkilerin genellenmesine olanak vermemektedir. Söz konusu ayrımın daha geniş örneklemlerde ve farklı veri toplama araçlarıyla incelenmesi, bitki farkındalığının kavramsal olarak açıklanmasına katkı sağlayabilir.

Öneriler

Bu çalışma, bitkilerin görünürlüğünün, ekolojik anlamlandırmanın ve önem atfının birbirinden ayrılabilen boyutlar olduğunu düşündüren öğrenci ifadelerini ortaya koymuştur. Bu boyutlar henüz doğrulanmış bir ölçme modeli veya yeni bir kuram olarak sunulmamıştır. Bulgular, bu boyutların ileride daha geniş örneklemlerde incelenebileceğine ilişkin nitel kanıt sağlamaktadır. Çalışma böylece, daha kapsamlı araştırmalarda sınanabilecek özgün bir kavramsal önerme oluşturabilir.

Çalışma grubunun sınırlı büyüklüğü ve iki alan arasındaki katılımcı sayısı farklılığı nedeniyle bu örüntüler akademik alanın doğa algısı üzerindeki etkisi olarak yorumlanmamıştır. Bulgular, yalnızca araştırmaya katılan öğrencilerin yanıtlarında gözlenen betimsel farklılıkları ortaya koymuştur. Daha geniş örneklem ile ve eşit katılımcıdan oluşan karşılaştırmalı gruplarla yapılacak çalışmalar öğrencilerin doğa algısında bitkilerin yerini çok daha iyi ortaya koyabilecektir.

Kaynakça

Balding, M., & Williams, K. J. H. (2016). Plant blindness and the implications for plant conservation. *Conservation Biology, 30*(6), 1192–1199. https://doi.org/10.1111/cobi.12738

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.

Parsley, K. M. (2020). Plant awareness disparity: A case for renaming plant blindness. *Plants, People, Planet, 2*(6), 598–601. https://doi.org/10.1002/ppp3.10153

Parsley, K. M., Daigle, B. J., & Sabel, J. L. (2022). Initial development and validation of the Plant Awareness Disparity Index. *CBE—Life Sciences Education, 21*(4), ar64. https://doi.org/10.1187/cbe.20-12-0275

Schussler, E. E., & Olzak, L. A. (2008). It's not easy being green: Student recall of plant and animal images. *Journal of Biological Education, 42*(3), 112–119. https://doi.org/10.1080/00219266.2008.9656123

Stagg, B. C., & Dillon, J. (2022). Plant awareness is linked to plant relevance: A review of educational and ethnobiological literature (1998–2020). *Plants, People, Planet, 4*(6), 579–592. https://doi.org/10.1002/ppp3.10323

Stagg, B. C., & Dillon, J. (2022). Plant awareness is linked to plant relevance: A review of educational and ethnobiological literature (1998–2020). *Plants, People, Planet, 4*(6), 579–592. https://doi.org/10.1002/ppp3.10323

Wandersee, J. H., & Schussler, E. E. (1999). Preventing plant blindness. *The American Biology Teacher, 61*(2), 82–86. https://doi.org/10.2307/4450624

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

PROOF OF MARRIAGE IN THE LATE OTTOMAN EMPIRE: THE CASES OF EMİNE AND SAFİNAZ

Hacer YILMAZ
Asst. Prof. Dr. Hacer YILMAZ, Fırat University, Faculty of Humanities and Social Sciences, Department of History, Elazığ-Türkiye
ORCID: 0000-0002-0898-3764

Abstract

In the late Ottoman Empire, claims concerning the existence of an earlier marriage could give rise to disputes involving both sharia courts and administrative authorities. The resolution of such disputes depended on establishing whether the alleged marriage had taken place, determining the legal status of a subsequent marriage, and examining the evidence submitted by the parties. This paper investigates these issues through two marriage disputes that arose during the reign of Abdülhamid II: the case of Safinaz in Salonica (1891) and that of Emine in Kayseri (1902). The principal sources are two files of official correspondence preserved in the Ottoman Archives of the Presidency of the Republic of Türkiye Directorate of State Archives (DH.MKT. 550/51 and Y.MTV. 57/35). The cases are examined comparatively with particular attention to claims of prior marriage, the burden of proof, witness testimony, and judicial procedure. In Emine's case, the distinction between a childhood betrothal and an alleged marriage became central to the dispute, as the court refused to sanction her separation from her existing husband before the earlier marriage had been established by credible witnesses. In Safinaz's case, the invocation of *istinkâh* as a defence against a claim of prior marriage, together with questions surrounding the examination of witnesses, prompted an inquiry into the conduct of the local court. The surviving records indicate that an assertion of marriage did not in itself alter a woman's marital status; its legal consequences depended upon the examination of evidence in accordance with judicial procedure. Although neither file contains a final judgment, the correspondence documents how marriage disputes passed between local courts, provincial officials, and central authorities. The paper thus examines the proof of marriage through the workings of late Ottoman judicial and administrative institutions.

Keywords: Ottoman family law, marriage, proof, witness testimony, judicial procedure

Introduction

Under Ottoman law, marriage (nikâh) was a contract concluded through the mutual declarations of the contracting parties in the presence of witnesses. Although Islamic law did not require a judge or religious official to officiate at a marriage, Ottoman authorities entrusted the kadis with supervising marriage contracts to ensure their conformity with legal requirements. Kadis could conclude such contracts themselves or authorise others to do so under their supervision (Aydın, 1982, p. 5–6). The requirement to obtain a marriage licence (izinnâme) from the kadi and the registration of marriages formed part of the Ottoman administration's efforts to regulate marriage procedures. The legal validity of a marriage contracted without such a licence, however, was a separate matter from the penalties incurred for failing to comply with the prescribed procedure. During the nineteenth century, further regulations extended the registration of marriages and imposed new reporting obligations. Penalties were prescribed for those who contracted or officiated at marriages without judicial authorisation, while imams and religious officials of non-Muslim communities were required to report marriages to the population registration authorities (Ekinci, 2006, p. 45–49). Legislation introduced during and after the Tanzimat addressed marriage expenses, the conduct of marriage procedures, and penalties for failure to comply with registration requirements (Çakıcı, 2022, p. 133). Despite these regulations, disputes over the existence and validity of marriage continued to arise. When a man claimed that a woman married to another man was already his lawful wife, the existence of the alleged earlier marriage had to be established before the legal status of her subsequent marriage could be determined.

The legal requirements for concluding a valid marriage must therefore be distinguished from those governing the proof of its existence in court. In disputes of this kind, women could challenge claims of prior marriage through several forms of legal defence. One such defence, recognised in Hanafi jurisprudence, was istinkâh, a term denoting a proposal of marriage. If a man had proposed marriage to a woman after the date on which he subsequently claimed to have married her, and she had rejected his proposal, the contradiction between his earlier conduct and his later claim could constitute grounds for challenging the admissibility of his suit. Eighteenth-century court registers from Adana contain several instances in which women invoked istinkâh against claims of prior marriage (Korkmaz, 2025, p 25, 27–29). Its invocation in a marriage dispute heard in Salonica towards the end of the nineteenth century provides an opportunity to examine the application of this defence in the late Ottoman period (BOA, Y.MTV. 57/35). This paper examines two marriage disputes that came before Ottoman judicial and administrative authorities during the reign of Abdülhamid II. In the case of Safinaz, heard in Salonica in 1891, the defendants invoked istinkâh in response to a claim of prior marriage. The manner in which the local court conducted the proceedings, particularly its examination of witnesses, subsequently became the subject of an inquiry ordered by the office of the Sheikh al-Islam (Meşihat) (BOA, Y.MTV. 57/35). In Kayseri, official correspondence concerning Emine began in 1902 following a claim of marriage that centred on the disputed nature of a childhood betrothal. The immediate question was whether Emine could be separated from her existing husband before the alleged earlier marriage had been proved (BOA, DH.MKT. 550/51). Drawing on these two archival files, the study compares the claims advanced by the parties, the evidence required to establish an earlier marriage, and the exchanges between local courts, provincial officials, and central authorities. Particular attention is paid to the distinction between asserting a marital right and establishing it through judicial proceedings. Since neither file contains a final judgment, the inquiry is confined to the conduct of the proceedings and the actions of the authorities involved rather than the ultimate resolution of the disputes.

Marriage Contracts and the Proof of Marriage in Ottoman Law

In Hanafi jurisprudence, which formed the basis of Ottoman family law, a marriage contract was concluded through corresponding declarations of offer and acceptance (îcâb and kabûl). The validity of the contract required that these declarations be made during the same contractual session, that witnesses possessing the requisite qualifications be present, and that no legal impediment to marriage exist between the parties. Their personal attendance was not indispensable, since a marriage could also be contracted through a guardian or an authorised representative (Ekinci, 2006, p 42–44). What distinguished a marriage from an agreement to marry was the conclusion of a legally valid contract. Neither a proposal of marriage nor a betrothal established a marital bond. A person claiming marital rights on the basis of an earlier betrothal was therefore required to demonstrate that a marriage contract had in fact been concluded (Ekinci, 2006, p. 42; Korkmaz, 2025, p 23–28). Hanafi law permitted guardians to contract marriages on behalf of minors, subject to rules concerning legal capacity and guardianship. In marriages concluded during childhood, the identity of the guardian and the circumstances under which the contract had been made affected the minor's right to seek its dissolution upon reaching puberty. Known as the option of puberty (bulûğ muhayyerliği), this right allowed a person married during childhood to seek the annulment of the marriage under certain conditions (Atasoy, 2024, p. 238; Korkmaz, 2019, p 456–457). Its exercise, however, presupposed the existence of a marriage contract. The repudiation of a childhood betrothal upon reaching puberty was legally distinct from the dissolution of a marriage contracted during minority. Court registers from Trabzon dating to the first half of the nineteenth century record instances in which girls who had been married by their families during childhood petitioned the court to dissolve their marriages after reaching puberty. While their families sought to uphold the earlier arrangements, the girls challenged the continuation of the marital relationship (Saydam, 2018, p 137–141). Such disputes required the court to consider the existence and validity of the original marriage contract alongside the grounds on which its dissolution was sought. The Kayseri correspondence concerning Emine presents a different legal problem. The relationship established during her childhood was described in the provincial correspondence as a betrothal, whereas Mustafa Çavuş claimed that Emine was his lawful wife. Whether a marriage contract had ever been concluded between them remained a matter of

dispute (BOA, DH.MKT. 550/51). Despite the extension of marriage registration during the late Ottoman period, witness testimony retained its place in litigation concerning the existence of a marriage. A distinction must be drawn between the witnesses present when a marriage was contracted and those called upon to establish its existence in subsequent judicial proceedings. Under Hanafi law, the witnesses to a marriage were required to hear the declarations of offer and acceptance made by the contracting parties (Çakıcı, 2022, p. 131). Their presence was a condition of the validity of the contract. In subsequent litigation, by contrast, testimony served to establish whether the alleged marriage had actually taken place. Testimony was among the principal means of establishing facts in Ottoman judicial proceedings. The admissibility of evidence (beyyine) depended on the qualifications of the witnesses and their compliance with the prescribed procedure. Testimony given by legally qualified witnesses in accordance with these requirements was binding upon the judge (Yurtseven, 2018, p 86–88). Merely naming witnesses did not establish the truth of a claim. Before reaching a judgment, the court had to consider the relevance of their statements to the dispute and determine whether their testimony met the legal conditions for acceptance. Written documents also occupied a place in Ottoman judicial practice. The documents known as hüccets, issued by kadis in connection with the registration of legal transactions and rights, could be produced in subsequent disputes. Hanafi jurists had nevertheless addressed the possibility that written documents might be imitated or altered, raising questions about the conditions under which documentary evidence could establish a claim. In Ottoman practice, a hüccet could be submitted as evidence before the court, but witnesses might still be called if the opposing party denied the right recorded in the document (Ülker, 2025, p. 817). The registration of a marriage and the proof of its existence in contested proceedings were thus distinct legal matters. These rules acquired particular significance when a man claimed that a woman married to another man had previously been his wife. Hanafi family law prohibited marriage to a woman whose existing marriage remained in force (Ekinci, 2006, p. 43). Applying this prohibition to a disputed marriage required the prior marital bond to be established. The claimant's assertion that the woman was his lawful wife could not be treated as equivalent to a judicial finding that the alleged marriage had taken place and remained valid. Until that claim had been substantiated, it could not in itself alter the legal status of her existing marriage.

A Marriage Dispute: The Question of Emine's Marriage

In the summer of 1902, a claim concerning the marriage of a woman named Emine, a resident of the village of Aydın in the sancak of Kayseri, became the subject of correspondence between the Grand Vizierate and the provincial authorities. Mustafa, a senior sergeant (*serçavuş*) serving in the First Company of the Engineering Battalion of the First Imperial Division, submitted a petition to the sultan in which he claimed that Emine was his lawful wife. According to his account, three inhabitants of the village, named Nuh, Ömer, and Abdülkerim, had deceived Emine and handed her over to a man named Kara Mehmet in Kayseri, with whom she was still residing. Mustafa's appeal for justice was referred to the Grand Vizierate. In a memorandum dated 20 Rebîülâhir 1320, Grand Vizier Said Pasha requested that the Ministry of the Interior issue the necessary instructions to the local authorities concerning the situation reported to be contrary to the sharia and the law (BOA, DH.MKT. 550/51).

Following Mustafa's complaint, the Ministry of the Interior instructed the province of Ankara to remove Emine from Kara Mehmet's residence without delay and return her to her village. The provincial authorities were also required to take measures to prevent similar incidents and to report the outcome of their intervention (BOA, DH.MKT. 550/51). The initial correspondence from Istanbul proceeded on the basis of Mustafa's claim that Emine was his lawful wife, although it made no reference to a *hüccet* or a court judgment establishing the existence of their marriage. The assumption that Emine's presence in Kara Mehmet's household was unlawful rested upon Mustafa's account of the affair.

The reply from the province of Ankara presented a rather different account of Emine's past. Information obtained through correspondence with the governor of Kayseri indicated that Emine's mother had betrothed her to Mustafa Çavuş when she was five years old. Upon reaching puberty, she had reportedly repudiated the betrothal before a judge and subsequently married another man of her own free will. These details, derived

from the account of her subsequent husband, were conveyed in the provincial authorities' letter to the Ministry of the Interior:

Emine, said to have been the betrothed of Senior Sergeant Mustafa, had been betrothed to Mustafa Çavuş by her mother when she was five years old. Upon reaching puberty, however, she repudiated before a judge the betrothal made by Mustafa. Her subsequent husband stated that she had married him of her own consent four years earlier and was still his lawful wife (BOA, DH.MKT. 550/51).

The terminology employed in the two accounts was consequential. Whereas Mustafa had referred to Emine as his lawful wife (*menkûha*), the provincial correspondence described her as "said to have been his betrothed" (*nişanlusu denilen*). For Mustafa to establish a marital right over Emine, he would have had to prove that their childhood betrothal had been followed by the conclusion of a marriage contract.

The surviving documents do not provide sufficient grounds for interpreting Emine's circumstances as an exercise of the option of puberty (*bulûğ muhayyerliği*). The account conveyed by the provincial authorities, based on the statement of her subsequent husband, referred to the repudiation of a childhood betrothal rather than the dissolution of a marriage contracted during minority. Mustafa's assertion that a marriage had taken place between them remained to be established before the court (BOA, DH.MKT. 550/51).

The statement that Emine had married of her own consent four years earlier suggests that her subsequent marriage took place around 1898. Whereas Mustafa had portrayed Kara Mehmet as a man in whose custody Emine was being held, the provincial correspondence identified him as her husband. This discrepancy called into question the account upon which Mustafa's original complaint rested. It is not possible, however, to reconstruct from Emine's own testimony either the circumstances in which she repudiated her betrothal or those surrounding her decision to marry Kara Mehmet. The information in the provincial letter came from her subsequent husband. Nor does the file contain the original court record of her reported repudiation of the betrothal (BOA, DH.MKT. 550/51).

The position taken by the Kayseri sharia court differed from the initial administrative instruction ordering Emine's removal from Kara Mehmet's household. The court held that a woman whose marriage was recognised could not be separated from her husband unless the alleged earlier marriage had been established by legally qualified witnesses. Its position was reported in a memorandum addressed by the Ministry of the Interior to the Meşihat on 18 Cemâziyelâhir 1320:

The sharia court has stated that the separation of a wife whose marriage is recognised from her husband depends upon the establishment of the alleged earlier marriage through testimony given by upright witnesses, and that it would therefore be impermissible to separate the woman from her husband without judicial proceedings (BOA, DH.MKT. 550/51).

The immediate question before the court was whether a marital bond had existed between Emine and Mustafa. Hanafi family law did not permit marriage to a woman who remained lawfully married to another man (Ekinci, 2006, p. 43). Had Mustafa established that his alleged marriage to Emine had taken place and remained in force, the legal status of her marriage to Kara Mehmet would have required reconsideration. The court, however, would not sanction her separation from Kara Mehmet before the claim of an earlier marriage had been judicially examined and established.

The reference to *şuhûd-i 'udûl*, or witnesses possessing the requisite moral probity, reveals the importance attached to the legal qualifications of witnesses in establishing the existence of a marriage. In Ottoman judicial practice, the binding character of testimony depended upon the qualifications of those who gave it and their compliance with the prescribed procedure (Yurtseven, 2018, p. 88). It would therefore have been insufficient for Mustafa merely to produce witnesses in support of his complaint; their testimony would also have had to satisfy the court's requirements for acceptance. The surviving file does not identify the witnesses Mustafa may have intended to produce, nor does it record any testimony they might have given.

Mustafa's legal representative objected to the procedure prescribed by the court. He insisted that Emine be separated from Kara Mehmet before the hearing and declared that he would not proceed with the case unless this condition was met. The letter from the province of Ankara recorded his demand that:

The aforementioned woman be separated from her husband before the trial, and that he would not proceed with the hearing unless the separation had taken place (BOA, DH.MKT. 550/51).

The representative's demand reversed the sequence of proceedings required by the court. For him, Emine's separation from Kara Mehmet was to precede the hearing of Mustafa's claim; for the court, it could follow only upon the judicial establishment of the alleged earlier marriage. Had the representative's demand been granted, Emine would have been separated from Kara Mehmet before the existence of a marital bond between her and Mustafa had been proved.

The disagreement between the sharia court and Mustafa's representative prompted the provincial authorities in Ankara to seek instructions from the Ministry of the Interior concerning the procedure to be followed. The ministry subsequently forwarded the provincial reply to the Meşihat, requesting guidance on the matter. What had initially been treated as a complaint requiring Emine's removal from Kara Mehmet's household had become a dispute over the proof of an earlier marriage and the conditions under which a court could order her separation (BOA, DH.MKT. 550/51).

In his reply dated 17 Şaban 1320, Sheikh al-Islam Mehmet Cemaleddin Efendi reported that instructions had been conveyed to the Kayseri sharia judicial office through the Council of Sharia Review (*Meclis-i Tedkikât-ı Şer'iyye*). Mustafa Çavuş's marriage suit was to be expedited "in accordance with the lawful procedures, with due care for the protection of rights" (*usûl-i meşrû'a dâiresinde tesrî'-i mu'âmelesiyle muhâfaza-i hukûka i'tinâ olunması*) (BOA, DH.MKT. 550/51). Upon receiving the reply from the Meşihat, the Ministry of the Interior informed the province of Ankara of the action taken (BOA, DH.MKT. 550/51).

The Sheikh al-Islam's reply contained no instruction to separate Emine from Kara Mehmet or to hand her over to Mustafa. It called instead for an expeditious hearing in accordance with the prescribed legal procedures and for the protection of the rights at issue. Since the surviving correspondence contains no final judgment, it remains unknown whether Mustafa's claim was eventually rejected or whether Emine's marriage to Kara Mehmet continued.

A Marriage Suit: Safinaz's Defence of Istinkâh

In 1891, a marriage suit heard in Salonica came under the scrutiny of the Meşihat on account of the evidence submitted by the parties and the manner in which the local court had conducted the proceedings. Yusuf Şinasi Efendi, a resident of Salonica, brought an action before the local sharia court, claiming that Safinaz was his lawful wife and that Musa Haşmet Efendi had subsequently contracted a marriage with her. He sought to have the subsequent marriage declared invalid on the grounds that his own marriage to Safinaz remained in force and requested that she be returned to him. The early stages of the suit are documented in a report prepared by Ataullah Ahmed Efendi, the newly appointed naib (deputy judge) of Salonica, following his examination of the court records and related documents (BOA, Y.MTV. 57/35). Ataullah Ahmed Efendi recorded Yusuf Şinasi's claim as follows: Although the aforementioned Safinaz was his lawfully wedded wife, Musa Haşmet Efendi had recently contracted a marriage with her. On the grounds that the existence of the first marriage entailed the invalidity of the second, he requested that his aforementioned wife be handed over to him (BOA, Y.MTV. 57/35). Before this argument could have any legal effect upon Safinaz's existing marriage, Yusuf Şinasi had to establish that a valid marriage between himself and Safinaz had taken place and remained in force. The representatives of Safinaz and Musa Haşmet Efendi denied his claim and advanced a defence based on his earlier conduct. They maintained that Yusuf Şinasi had previously proposed marriage to Safinaz. The report records that, "by way of defence, they stated that the aforementioned claimant had sought her hand in marriage" (makâm-ı def'de mudde'î mûmâ-ileyh mezbûreyi istinkâh eyledigini tezkâr eylemiş) (BOA, Y.MTV. 57/35). In Hanafi jurisprudence, istinkâh could denote a man's proposal of marriage to a woman. The term also appears in Ottoman court records in the sense of marrying

or entering into a marriage contract. Its precise meaning must therefore be determined from the circumstances in which it was used (Korkmaz, 2025, p 25–26). In Safinaz's case, the fact that istinkâh was invoked makâm-ı def'de (by way of defence) following the denial of Yusuf Şinasi's marriage claim suggests that the term referred to a proposal of marriage. The representatives appear to have argued that Yusuf Şinasi's previous conduct was inconsistent with his subsequent assertion that Safinaz was already his wife. The use of istinkâh as a defence against a marriage claim rested upon the Hanafi legal principle of contradiction (tenâkuz). If a man had proposed marriage to a woman after the date on which he subsequently alleged that their marriage had taken place, and the woman had rejected his proposal, his earlier conduct contradicted his later claim. By seeking her hand in marriage, he had implicitly acknowledged that no marital bond existed between them at the time of the proposal. If the woman could establish these circumstances, the court might decline to hear his marriage claim on the grounds of contradiction (Korkmaz, 2025, p 27–28). The sharia court registers of Adana from the first half of the eighteenth century contain cases in which women invoked istinkâh against men claiming to be their husbands. In several of the cases dating from 1710 to 1753, the women established through witness testimony that the claimants had previously proposed marriage to them and that they had rejected those proposals. Once the defence had been established, the court could dismiss the marriage claim on the grounds of the contradiction between the claimant's conduct and his assertion of an existing marital bond. Under these circumstances, there was no need to hear the witnesses whom the claimant had intended to produce in support of the alleged marriage (Korkmaz, 2025, p 25, 29). The defence advanced in Safinaz's case may be compared with these earlier examples from Adana. More than a century later, a claim of prior marriage against a woman who was married to another man was again challenged on the basis of the claimant's earlier proposal. Unlike the Adana cases, however, the Salonica file contains no judgment establishing that the defence of istinkâh had been proved. The report does not specify when Yusuf Şinasi made the alleged proposal, whether Safinaz rejected it, or which witnesses were called to establish the circumstances of the proposal. What can be established from the surviving record is that the representatives of Safinaz and Musa Haşmet Efendi denied the alleged earlier marriage and invoked istinkâh in their defence (BOA, Y.MTV. 57/35). The course of the suit changed when Aziz Bey, the former naib of Salonica, left office without delivering a judgment. By that time, both parties had submitted the names of numerous witnesses in support of their respective claims. In Ataullah Ahmed Efendi's account, the parties had "submitted the names of a considerable number of persons" whom they wished to call as witnesses (BOA, Y.MTV. 57/35). The examination of witnesses remained an issue when the suit passed to Aziz Bey's successor, Haydar Efendi. Questions concerning Haydar Efendi's conduct of the proceedings eventually prompted the intervention of the Meşihat. Before Ataullah Ahmed Efendi departed for Salonica to assume his new appointment, the Meşihat instructed him to investigate the manner in which the suit had been handled. He was also to ascertain whether the parties had any ulterior motive in seeking to establish their claims through public notoriety and widely transmitted testimony (şöhret ve tevâtür). Sheikh al-Islam Mehmet Cemaleddin Efendi ordered that the matter be investigated thoroughly and confidentially and that the findings be reported to his office. Upon reaching Salonica, Ataullah Ahmed examined the records of the proceedings and the relevant documents before undertaking an inquiry into the judicial procedure followed by Haydar Efendi (BOA, Y.MTV. 57/35). The question of testimony based on şöhret and tevâtür deserves particular attention in examining Safinaz's suit. Knowledge of a marriage contracted in the past might extend beyond those who had witnessed the contract itself. The circulation of information concerning a marriage, however, was a separate matter from its admissibility as evidence before a court. In the Salonica proceedings, the parties' efforts to substantiate their claims through widely transmitted testimony became the subject of scrutiny after Haydar Efendi sought to hear witnesses on these grounds. As the surviving file does not contain the full statements of the witnesses, it is impossible to ascertain whether they had personally witnessed the marriage, how they had acquired their knowledge of it, or whether their statements were independent of one another. Ataullah Ahmed Efendi's criticism of Haydar Efendi centred on the attention he had given to extraneous statements made by the parties' representatives and his decision to hear witnesses whose testimony the investigating naib considered unnecessary to the resolution of the suit. In his report, Ataullah Ahmed described his predecessor's conduct in the following terms: Instead of directing his attention to the substance of the matter, he lent an attentive ear to the extraneous statements of the

representatives and proceeded, without sufficient cause, to hear witnesses on the basis of tevâtür from both parties (BOA, Y.MTV. 57/35). The expressions rûh-ı mes'ele (the substance of the matter) and bi-lâ-mûcib (without sufficient cause) indicate the grounds upon which Ataullah Ahmed criticised the proceedings. His objection concerned both the failure to concentrate on the central issue of the suit and the recourse to a means of proof for which he considered there to be insufficient justification. Ataullah Ahmed attributed Haydar Efendi's decision to hear witnesses on the basis of tevâtür to his carelessness (lâübâlilik). He also reported that the representatives of the parties had introduced extraneous matters into the proceedings in their efforts to clarify the dispute. Nevertheless, his inquiry uncovered no evidence that Haydar Efendi or the other individuals concerned had acted with an ulterior motive or in bad faith. Towards the end of his report, he stated that "nothing had been detected to indicate an ulterior motive or bad intention, nor had any clue been obtained in this regard" (BOA, Y.MTV. 57/35). Ataullah Ahmed's criticism should not be construed as a general rejection of testimony based on tevâtür in Ottoman judicial practice. His report concerned Haydar Efendi's handling of a particular marriage suit and the grounds for admitting such testimony in that suit. Nor does the surviving document specify whether, in referring to the substance of the matter, Ataullah Ahmed had in mind the defence of istinkâh, the proof of the alleged earlier marriage, or the relationship between the two. His criticism of the proceedings cannot therefore be interpreted as a finding that Safinaz's defence ought to have been upheld. Having completed his inquiry, Ataullah Ahmed Efendi submitted his report to the Meşihat on 7 Cemâziyelevvel 1309. In a communication dated 13 Cemâziyelevvel 1309, Sheikh al-Islam Mehmet Cemaleddin Efendi informed the sultan that the newly appointed naib had been instructed to investigate the marriage suit, the documents of which had already been brought to the sultan's attention. He then presented Ataullah Ahmed's report for imperial consideration (BOA, Y.MTV. 57/35). A suit heard before the sharia court of Salonica had thus become the subject of a confidential inquiry into judicial procedure, the findings of which passed from the local court to the Meşihat and ultimately to the palace. The surviving Salonica file contains no judgment indicating whether the defence of istinkâh was established or how Yusuf Şinasi's marriage claim was ultimately resolved. Ataullah Ahmed Efendi's report documents the means of proof employed during the proceedings and the manner in which the local court handled them, rather than the final determination of Safinaz's marital status.

4. The Intervention of the Ministry of the Interior and the Meşihat in Marriage Disputes

In Ottoman administrative practice, the petition (arzuhal) provided a means by which individuals could bring their grievances and requests before the sultan or the relevant state authorities. During the reign of Abdülhamid II, the Marûzât-ı Rikâbiye İdaresi was established to examine petitions submitted to the sultan, refer them to the appropriate ministries, and oversee their responses (Şahin, 2025, p 470–474). The correspondence initiated by Mustafa Çavuş's petition illustrates how a personal marriage dispute could pass from the Imperial Secretariat (Mâbeyn-i Hümâyun Başkitâbeti) to the Grand Vizierate and subsequently, through the Ministry of the Interior, to the province of Ankara. Although Mustafa's military rank and the unit in which he served were recorded in the correspondence, there is insufficient evidence to suggest that his complaint received preferential treatment on account of his military position (BOA, DH.MKT. 550/51). The Emine correspondence allows us to examine relations between the central government and the provincial authorities through the initial administrative instructions and the subsequent response from Kayseri. Acting upon Mustafa's complaint, the Ministry of the Interior ordered that Emine be removed from Kara Mehmet's household. The Kayseri sharia court, however, maintained that her separation from her husband depended upon proof of the alleged earlier marriage. The provincial authorities in Ankara consequently sought further instructions from the ministry. The legal opinion expressed by the local court thus prompted a reconsideration of the initial administrative response, and the matter was referred to the Meşihat. The correspondence reveals that relations between Istanbul and the provinces did not consist simply of the transmission and execution of administrative orders. Information supplied by provincial officials and legal opinions expressed by local courts could also redirect proceedings at the centre (BOA, DH.MKT. 550/51). The Meşihat's involvement in Emine's suit must be considered in relation to the changes that took place within the Ottoman judicial administration following the Tanzimat. The establishment of the nizamiye courts during the nineteenth century gradually brought about a distinction between their jurisdiction and that of the

sharia courts (Ünal, 2023, p 845–846). In 1861, the Council of Sharia Review (Meclis-i Tedkikât-ı Şer'iyye) was established within the office of the Sheikh al-Islam to review judgments delivered by the sharia courts. In matters falling within sharia jurisdiction, it assumed the functions formerly exercised by the Friday Council (Cuma Divanı), which, before the Tanzimat, had convened under the presidency of the grand vizier (Ünal, 2023, p. 847). The Emine correspondence, however, records an intervention distinct from the council's appellate function. According to the Sheikh al-Islam's reply, instructions had been conveyed through the council to the sharia judicial office in Kayseri, requiring that Mustafa's marriage suit be heard without delay, in accordance with lawful procedures and with due regard for the protection of rights. Since the file contains no judgment submitted for appellate review, the council's involvement in this instance cannot be characterised as an appeal (BOA, DH.MKT. 550/51). In Safinaz's case, the Meşihat intervened by ordering an inquiry into the conduct of the local court in Salonica. The instructions given to the newly appointed naib, Ataullah Ahmed Efendi, concerned the manner in which his predecessor had handled the suit and the parties' attempts to substantiate their claims through şöhret and tevâtür. His investigation led to criticism of Haydar Efendi's conduct of the proceedings, although no evidence was found to suggest that the parties or the judicial officials concerned had acted with an ulterior motive. The presentation of Ataullah Ahmed's report to the sultan through the Sheikh al-Islam demonstrates how the conduct of proceedings in a provincial sharia court could become a matter of scrutiny at the highest levels of Ottoman government. The surviving correspondence does not, however, disclose the circumstances in which the suit was first brought to the attention of the palace or identify the petition or communication that prompted the inquiry (BOA, Y.MTV. 57/35). The archival provenance of the two files also bears upon the historical study of Ottoman marriage disputes. The correspondence concerning Emine, preserved among the records of the Correspondence Office of the Ministry of the Interior (Dâhiliye Nezareti Mektubî Kalemi), documents exchanges between the Grand Vizierate, the Ministry of the Interior, the provincial administration, and the Meşihat. The records concerning Safinaz, preserved in the miscellaneous papers of the Yıldız Palace (Yıldız Mütenevvi Evrakı), document the transmission to the palace of an inquiry into the proceedings of a sharia court. Neither file preserves the court's final judgment. Their historical value lies instead in documenting stages of the disputes that extend beyond the proceedings recorded in the sharia court registers. They make it possible to examine how provincial officials responded to complaints concerning marriage, how questions of judicial procedure reached the central authorities, and how the Meşihat intervened in cases that had yet to be resolved.

Conclusion and Recommendations

The marriage disputes concerning Emine and Safinaz reveal the difficulties involved in establishing marital status in the late Ottoman Empire when a man claimed to have married a woman before her subsequent marriage to another man. In Kayseri, the discrepancy between Mustafa Çavuş's claim of marriage and the account of a childhood betrothal conveyed by the provincial authorities raised the question of whether a marriage contract had ever been concluded. In Salonica, the invocation of istinkâh against Yusuf Şinasi Efendi's claim of prior marriage brought the claimant's earlier conduct into consideration as a possible ground for challenging his suit. The appearance of this defence in the Salonica proceedings of 1891, more continued presence in Ottoman judicial practice (Korkmaz, 2025, p 25, 27–29). The surviving documents do not, however, establish whether Safinaz's defence satisfied the legal conditions required for its acceptance. The distinction between the two disputes becomes particularly apparent in the conduct of judicial proceedings and the nature of the intervention by the central authorities. In Emine's case, the Kayseri sharia court refused to sanction her separation from her husband before the alleged earlier marriage had been established through the testimony of legally qualified witnesses. The intervention of the Meşihat was confined to instructions that the suit be expedited in accordance with lawful procedure and with due regard for the protection of rights. In Safinaz's case, by contrast, the Meşihat ordered an inquiry into the manner in which the local court had conducted the proceedings, particularly its recourse to testimony based on tevâtür. The criticism expressed by Ataullah Ahmed Efendi concerned the handling of evidence and the failure to concentrate on the substance of the dispute. It did not amount to a judgment on the validity of either marriage

or on the merits of Safinaz's defence. In both instances, the surviving correspondence documents interventions by the central authorities concerning the conduct of local judicial proceedings rather than a final determination of the women's marital status. The evidentiary limits of the two files must also be taken into account. Much of what is known about Emine and Safinaz derives from administrative correspondence conveying the statements of male claimants, husbands, and legal representatives. Neither woman's account of her circumstances survives in her own words within these records, and neither file contains the court's final judgment. It is consequently impossible to determine the eventual legal status of their marriages or to reconstruct their personal choices in full. What the documents do establish is that a claim of prior marriage did not in itself determine a woman's marital status. Its legal consequences depended upon the examination of the claim and the evidence advanced in its support. The history of marriage in the late Ottoman Empire must therefore be studied not simply through the substantive provisions of family law, but also through the procedures by which marital claims were examined and the relations between local courts, provincial officials, and central authorities.

References

Archival Sources Presidency of the Republic of Türkiye, Directorate of State Archives, Ottoman Archives (BOA).

BOA, Dâhiliye Nezareti Mektubî Kalemi (DH.MKT.), 550/51.

BOA, Yıldız Mütenevvi Maruzat Evrakı (Y.MTV.), 57/35.

Secondary Sources

Atasoy, A. (2024). İslâm ve Osmanlı hukukunda buluğ muhayyerliği. Adalet Dergisi, (72), 229–273. https://doi.org/10.57083/adaletdergisi.1484009

Aydın, M. A. (1982). Osmanlı hukukunda nikah akitleri. Osmanlı Araştırmaları, (3), 1–12. Çakıcı, M. (2022). Osmanlı Devleti'nde nikâh muameleleri (1876–1922). Hazine-i Evrak Arşiv ve Tarih Araştırmaları Dergisi, 4(4), 129–151.

Ekinci, E. B. (2006). Osmanlı hukukunda izinnâme ile nikâh. Türk Hukuk Tarihi Araştırmaları, (2), 41–60.

Korkmaz, Ö. (2019). Osmanlı uygulamaları ışığında küçüklerin evlendirilmesi ve veli izinsiz nikâh. bilimname, (37), 453–475. https://doi.org/10.28949/bilimname.476671

Korkmaz, Ö. (2025). Hanefî fıkhında evlilik iddialarına karşı kadının savunma aracı: Adana şer'iyye sicillerinde istinkâh delili. Dokuz Eylül Üniversitesi İlahiyat Fakültesi Dergisi, (62), 23–38. https://doi.org/10.21054/deuifd.1744563

Saydam, A. (2018). Ailenin seçtiği kocaya itiraz: Trabzonlu kızlar mahkemede. History Studies, 10(5), 137–153. https://doi.org/10.9737/hist.2018.625

Şahin, G. (2025). Yönetime yakınlık uyandırmak mı, yönetimi kişiselleştirmek mi? Sultan II. Abdülhamid döneminde Marûzât-ı Rikâbiye İdaresi. Amme İdaresi Dergisi, 58(3), 469–498.

Ülker, İ. (2025). Osmanlı yargılama hukukunda yazılı delil olarak hüccet. Selçuk Üniversitesi Hukuk Fakültesi Dergisi, 33(1), 817–847. https://doi.org/10.15337/suhfd.1634965

Ünal, M. (2023). İslam hukukunda temyiz: Ceride-i İlmiyye kapsamında Meclis-i Tedkîkât-ı Şer'iyye örneği. İslam Tetkikleri Dergisi, 13(2), 837–861. https://doi.org/10.26650/iuitd.2023.1215958

Yurtseven, Y. (2018). İslam-Osmanlı muhakeme hukukunda şahitlik müessesesi. Yıldırım Beyazıt Hukuk Dergisi, (2), 85–139.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

REPRODUCING STORIES FROM TRADITIONAL MINIATURE PAINTING THROUGH AI-ASSISTED ANIMATION

Hasan Atakan YILDIRIM
ORCID ID: 0000-0003-3045-3468, Department of Traditional Turkish Arts, Faculty of Fine Arts, Akdeniz University, Antalya, Türkiye.

Abstract

This study examines the possibilities of reproducing stories from traditional Ottoman miniature painting through AI-assisted animation techniques while preserving their original formal and narrative characteristics. The research relies mainly on a literature review and an evaluation of existing digital production practices. Accordingly, the study addresses the basic aesthetic features of miniature painting, namely its non-perspectival conception of the picture surface, vertical perspective and stacked composition, the principle of hierarchical scaling, tahrir (contour) lines, and flat color, and it discusses how these features can be preserved in contemporary digital visualization and animation processes. It also evaluates generative AI tools, in particular techniques such as Stable Diffusion and LoRA, together with digital restoration, layering, and two-dimensional (2D) animation practices, in the context of turning traditional miniatures into moving visual narratives. A review of existing studies and applied examples points to the potential of AI for creating new scenes and visual narratives based on historical miniatures, for adding limited movement to static compositions, and for increasing the accessibility of cultural heritage in digital environments. At the same time, several requirements stand out: preserving historical and iconographic accuracy, ensuring that the traditional style is not distorted in AI-generated images, avoiding the misrepresentation of cultural memory, and addressing problems of copyright and originality. In this context, the study aims to set out the possibilities that AI-assisted 2D animation offers for reinterpreting Ottoman miniature painting through contemporary technologies and passing it on to future generations, and to contribute to evaluating this process within the principles of historical accuracy, aesthetic integrity, ethical responsibility, and human oversight.

Keywords: Ottoman miniature painting, artificial intelligence, digital animation, cultural heritage, visual narrative, digital reproduction.

Introduction

Traditional arts are deeply rooted fields of cultural expression that transmit the historical experiences, cultural memories, aesthetic values, and intellectual worlds of societies across generations. Among them, the miniature is an accomplished art of book illustration that conveys the historical events, literary stories, court life, and social rituals narrated in manuscripts through a distinctive visual language. Developed particularly within the Seljuk and Ottoman arts of the book, the miniature is not merely a passive form of illustration that supports the text but an independent medium of visual narrative in which events, people, and places are composed in a symbolic and hierarchical order. Because miniatures visualize the historical accounts in manuscripts, they must be treated as "visual documents" and "carriers of collective memory" that reflect the sociocultural, political, and intellectual structure of the period in which they were produced (Aşılıoğlu, 2025; Karahan, 2025; Mercan, 2022).

The narrative structure of miniature painting offers unique opportunities for reconsidering these works in contemporary visual communication, digital media, and animation. In miniatures, different stages or time periods of a story can be presented simultaneously on the same compositional plane. Unlike the single-focus linear perspective with a vanishing point that characterizes classical Western art, the construction of time and space in miniature painting is shaped through the techniques of "stacked/overlapping composition," "vertical perspective," "sequencing," and "clustering" (Akbulut, 2006; Mercan, 2022; Sözen & Tanyeli, 1992). Figures

are sized not according to their real-world scale but according to their hierarchical importance within the narrative, and flat areas of color and sharp contours are preferred to light, shade, and volume (Güleryüz, 2025; Karahan, 2025; Karapekmez & Gülaçtı, 2025). This turns the miniature from a static picture that freezes a single moment into a dynamic field of visual narrative in which relations of time, space, and action are expressed on multiple layers (Güleryüz, 2025; Mercan, 2022).

Transferring the traditional visual narration of miniatures to contemporary moving-image media, however, is not simply a technical operation of setting a static image in motion. Such a transfer raises the question of how the original compositional order of the work, the stylized forms of its figures, its shadowless color palette, and its historical context will be represented in new digital media (Aydıngüler & Türkmenoğlu, 2021; Türkmenoğlu et al., 2018). Digitizing traditional works and converting them into 2D/3D animations, digital game concepts, or virtual reality applications also raises debates about preserving the "aura" and authenticity of the work (Benjamin, 2016; Karapekmez & Gülaçtı, 2025; Küçükusta, 2024).

In recent years, the entry of artificial intelligence (AI) and deep learning algorithms (Stable Diffusion, Generative Adversarial Networks [GANs], etc.) into visual art production has added an innovative dimension to the reproduction and preservation of traditional arts. By learning the stylistic and linear characteristics of historical court painters (*nakkaş*) such as Nakkaş Osman, Nakkaş Levni, and Enderunlu Fazıl from datasets, AI models make it possible to reproduce historical scenes that were never illustrated in the past, literary texts, or vanished architectural structures in a manner consistent with the aesthetics of the court atelier (*nakkaşhane*) of the relevant period (Karapekmez & Gülaçtı, 2025). This technological possibility makes it easier to integrate traditional miniature painting into digital games (for example, the platform game *Ferhat ile Şirin*), animated films (animations of the *Surname-i Vehbi* or the example of *Malek Khorshid*), and digital archive projects (Aydıngüler & Türkmenoğlu, 2021; Bostan & Eyvazi, 2025; Küçükusta, 2024).

The transformation of miniature stories into AI-assisted digital animation therefore marks out an interdisciplinary field of research that requires art history, visual communication design, computer vision, semiotics, and the aesthetics of the moving image to be considered together.

The main aim of this study is to analyze the formal and narrative codes specific to Ottoman miniature painting (non-perspectival representation, hierarchical scaling, multiple viewpoints, layered composition) and to develop a methodological model of reproduction that preserves the original aesthetic structure of traditional stories by using AI-based image generation models (Stable Diffusion) and two-dimensional (2D) vector animation techniques. In this respect, the study tests how historical and artistic accuracy can be maintained while the traditional language of the miniature is brought to life with digital tools, and it discusses the academic and artistic possibilities of transmitting cultural heritage sustainably in the digital age.

Conceptual and Theoretical Framework

Visual Narrative and Story Construction in Traditional Miniature Painting

The miniature is not a secondary ornament that merely supports the statements in the text but an independent narrative medium that constructs social, political, religious, and aesthetic values through its own visual codes (Atasoy, 1998; Mercan, 2022). The court painter transferred objects and figures onto the two-dimensional surface not as they appear in optical reality but in terms of their mental and symbolic essence (Akbulut, 2006; Konak, 2007).

Table 1: Formal and Narrative Principles of Traditional Miniature Painting

Category / Principle	Application and Formal Characteristics
Composition and Perspective	• Vertical / stacked perspective (layering) • Sequencing, clustering, and screening techniques
Scaling and Figurative Narration	• Hierarchical scaling (priority of meaning) • Typological and idealized figures

Category / Principle	Application and Formal Characteristics
Construction of Time and Space	• Simultaneous narration (multiple time and space) • Multiple viewpoints (bird's-eye view and frontal view)
Color and Line Aesthetics	• Sharp contours (tahrir) and flat colors • Shadowless, symbolic, and saturated pigments

In miniature painting, the construction of space differs from the single-focus perspective of Western art and is shaped through the methods of "vertical perspective" or "stacked/overlapping composition" (Arseven, 1993; Konak, 2007; Tanındı, 1996). In this compositional structure, the surface is layered from bottom to top in parallel bands: nearby elements are placed in the lower part of the page and distant ones in the upper part (Akbulut, 2006; Keskiner, 2004). This arrangement prevents figures from covering one another and allows the viewer to perceive every element of the scene at an equal level (Mercan, 2022). In the Ottoman miniature tradition, this design language, which Nakkaş Osman and the other masters of the period standardized, was applied through systematic compositional techniques such as the "stacking technique," the "sequencing technique," the "clustering technique," and the "screening technique" (Akbulut, 2006; Tulum, 2019).

One of the most distinctive qualities of miniature compositions is the principle of hierarchical scaling (Atasoy, 1989; Karahan, 2025). The size of the figures and architectural elements in a scene is determined not by physical distance but by political power, social status, or dramatic role in the narrative (Güçbilmez, 2023; Konak, 2007). Sultans, rulers, and central characters are drawn on a larger scale and in vivid colors, whereas servants and ordinary people are depicted at smaller sizes (Mercan, 2022). Bearing typological and idealized rather than individual portrait features, the figures steer the dramatic flow of the narrative through the gestures of their hands and arms and the posture of their bodies (Aşılıoğlu, 2025; Keskiner, 2004).

Time and space in the miniature are not confined to a linear flow but are constructed simultaneously (Tanındı, 1996). Different stages or periods of a story can be brought together on the same compositional plane through the paneling (*paftalama*) technique (Mercan, 2022). By using bird's-eye and frontal viewpoints together in the same scene, the painter offers the viewer the chance to grasp the whole space in which the event takes place (Güçbilmez, 2023; Konak, 2007). In terms of color and line aesthetics, the miniature rests on shadowless flat color surfaces bounded by sharp contours (*tahrir*) (Holtzschue, 2009; Şen, 2018). Vivid, saturated colors obtained from natural pigments (red, navy blue, turquoise, gold leaf) strengthen the visual hierarchy and symbolic expression (Atasoy, 1989; Elmas, 1998).

Digital Cultural Heritage and the Reinterpretation of Traditional Arts

In the information age, knowledge is produced, preserved, and transmitted through digital technologies and new media tools (Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025). Taking traditional arts out of physical manuscripts and museum archives, digitizing them, and converting them into 2D/3D animation, digital games, and virtual reality (VR) applications is of strategic importance for the sustainability of cultural heritage (Aşılıoğlu, 2025; Küçükusta, 2024). Digital transformation prevents the loss of traditional visual memory, makes it possible to reach wide audiences, and raises the cultural awareness of younger generations (Karapekmez & Gülaçtı, 2025; Türkmenoğlu et al., 2019).

Table 2: Digital Cultural Heritage and the Axis of Theoretical Debates

Theoretical Framework and Concepts	Digital Transfer and Narrative Analysis
Collective Memory and Transmission (Halbwachs, Assmann)	Reconstruction of collective memory by transferring visual documents to new media.

Theoretical Framework and Concepts	Digital Transfer and Narrative Analysis
Reproduction and Digital Aura (Benjamin)	Creation of a new "digital aura" by adding movement to the work through technology.
Simulation and the Risk of Hyperreality (Baudrillard)	The risk that the digital image detaches from reality; the need for academic oversight and accuracy.

In terms of cultural memory theory, keeping collective memory alive depends on the continuous reproduction of visual documents from the past in contemporary communication media (Assmann, 2011; Halbwachs, 1992). However, moving a traditional work into the digital environment and animating it brings aesthetic and theoretical debates with it (Karapekmez & Gülaçtı, 2025). The concept of "aura," which Walter Benjamin used to express the uniqueness of the work of art in the age of technical reproduction, is being debated anew in the context of digitization (Benjamin, 2016). Digital animation techniques add the dimensions of movement, time, sound, and interaction to miniature painting, giving the work a new "digital aura" and bringing manuscripts that are physically difficult to access closer to the viewer (Aydıngüler & Türkmenoğlu, 2021; Karapekmez & Gülaçtı, 2025).

By contrast, within the framework of the theory of simulation developed by Jean Baudrillard, there is a risk that images produced in digital environments lose their link with reality, become "simulacra," and create "hyperreality" (Baudrillard, 1994). Departing from the historical context in miniature animations, or adding elements that contradict the original, may lead to the distortion of cultural memory (Karapekmez & Gülaçtı, 2025). To prevent this risk, digitization and animation projects should take care to preserve historical accuracy and should maintain an interdisciplinary mechanism of academic oversight (Aşılıoğlu, 2025; Karahan, 2025).

The literature includes prominent successful examples of reinterpreting traditional miniature painting in contemporary media:

Digital Game Adaptations: In the study carried out by Küçükusta (2024), traditional miniature aesthetics and the narrative of the Seven Sleepers were transformed into the concept of the platform game *Ferhat ile Şirin*, which gave static miniature images an interactive character.

Animations and Animated Adaptations: In the studies conducted by Aydıngüler and Türkmenoğlu (2021) and Türkmenoğlu et al. (2018), the miniatures in Nakkaş Levni's *Surname-i Vehbi* were digitized and animated with 2D vector animation techniques. Similarly, Bostan and Eyvazi (2025) animated examples of Iranian miniature painting (*Malek Khorshid*) on the basis of semiotic analyses.

Digital Data Art: The AI data sculpture *Machine Hallucinations: Istanbul*, produced by Anadol (2021), draws conceptual parallels with the principles of multilayered narrative, symbolic density, and multiple time and space in miniature painting, and carries traditional aesthetics onto the digital plane.

AI-Assisted Visual Production and Animation

One of the most innovative applications of AI in Ottoman miniature painting is teaching the stylistic qualities of historical court painters (Nakkaş Osman, Nakkaş Levni, Bozoklu Osman Şakir Efendi, Enderunlu Fazıl, etc.) to AI models (Karapekmez & Gülaçtı, 2025). In the experimental study conducted by Karapekmez and Gülaçtı (2025), historical events, architectural structures, and social scenes that were not depicted, or were little represented, in Ottoman-period miniatures were produced with AI:

The Construction of the Fatih Complex: With a Stable Diffusion model trained on 20 different miniatures by sixteenth-century court painters as reference, the construction process was visualized in a manner consistent with the style of the period's court atelier (Karapekmez & Gülaçtı, 2025).

Hezarfen Ahmet Çelebi's Flight: The 32 miniatures in Bozoklu Osman Şakir Efendi's *İran Sefaretnâmesi* (the Iran embassy account) were used as the dataset, and the scene of the flight from the Galata Tower was synthesized with the color palette and line texture of the period (Karapekmez & Gülaçtı, 2025).

Ottoman Farming Scenes: Thirty miniatures were taken as references from the styles of Nakkaş Levni and Enderunlu Fazıl, and the theme of Ottoman rural life and farming was produced (Karapekmez & Gülaçtı, 2025).

Prompt engineering plays a fundamental role in AI-based image production (Karapekmez & Gülaçtı, 2025). To improve visual quality and historical accuracy, many iterations are run depending on hardware capacity, and the raw images obtained are optimized through digital restoration and manual editing (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

To preserve the non-perspectival, two-dimensional character of the work, two-dimensional (2D) animation techniques are preferred when animating miniatures that are produced by AI or scanned from manuscripts (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021; Türkmenoğlu et al., 2018). The animation process comprises the technical stages outlined below.

Transferring Traditional Miniature Aesthetics to Animation

Looking at the historical origins of transferring traditional miniature aesthetics to the medium of animation, the work *Amentü Gemisi*, produced in 1969 by Tonguç Yaşar under the consultancy of Sezer Tansuğ, is regarded as the first example of animation nourished by traditional visual codes in the history of Turkish cinema and animation (Türkmenoğlu et al., 2018). Similarly, at the international level, the short animated film *Malek Khorshid* (The King of the Sun), made in 1975 by the Iranian artist Ali Akbar Sadeghi with inspiration from the epics of the *Shahnameh*, is among the first high-quality examples of turning Eastern miniature aesthetics into moving images (Bostan & Eyvazi, 2025).

Table 3: Stages of Adapting Miniature Aesthetics to Animation

Stage / Process	Application and Technical Details
1. Digitization and Restoration	High-resolution scanning (600 ppi); cleaning of stains and wear (Photoshop).
2. Cutting Out and Layering	Separation of background, figures, architecture, and limbs; repair of texture gaps.
3. Preservation of Aesthetic Codes	Maintenance of the non-perspectival, stacked composition and shadowless color structure.
4. 2D Rigging and Motion Design	Skeletal rigging (puppet tool); plain, minimalist design of gestures and facial expressions (12–18 fps).
5. Sound, Lip-Sync, and Final Edit	Character Animator; integration of traditional Ottoman music and ambient sound effects.

Transforming miniature painting into digital animation is not a technical operation that amounts to adding arbitrary movements to a static image (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021). Certain methodological principles must be applied to preserve the miniature's original compositional approach, figurative structure, and cultural context (Karapekmez & Gülaçtı, 2025; Mercan, 2022). The aesthetic and technical dimensions of this transfer take shape around the following basic principles:

In traditional miniature painting, space is constructed on a two-dimensional plane without the use of light and shade or perspective (Güleryüz, 2025; Sözen & Tanyeli, 1992). Adding to the work during animation the three-dimensional volumetric shading or the deep linear perspective with vanishing points that are peculiar to

Western painting corrupts the miniature's original style and distances the work from its authenticity (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). For this reason, two-dimensional (2D) vector animation techniques are preferred in animation design, and the sense of depth is based on the rules of stacked/overlapping composition, layer order, and color transitions rather than on optical perspective (Aşılıoğlu, 2025; Türkmenoğlu et al., 2018).

In addition, in sizing the figures, the principle of hierarchical scaling of traditional miniature painting is preserved in place of realistic anatomy and distance relations (Güçbilmez, 2023; Karahan, 2025). The sultan, princes, or main characters of central importance in the narrative are kept at a large scale and with detailed drawing, while surrounding figures are kept smaller, so that the visual hierarchy is maintained (Mercan, 2022; Türkmenoğlu et al., 2018).

The first technical step in transferring the miniature to a moving medium is high-resolution digitization (Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025). The miniature pages in manuscripts are scanned at a resolution of 600 ppi with industrial scanners such as Konica Minolta and transferred to the digital environment (Aydıngüler & Türkmenoğlu, 2021). Ink stains, wear, and physical damage that have accumulated over time are repaired faithfully to the original with digital restoration software (Adobe Photoshop) (Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025).

To make animation possible, the elements of the miniature composition must be cut out and separated into layers (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). The background architecture, natural elements (trees, sea, clouds), accessories, and figures in the scene are cut into mutually independent layers (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021). The gaps (loss of texture) that appear in the background when figures are cut out are filled with digital texture completion (inpainting) techniques that take the color tones and brush texture of the original miniature as reference, so that the gap behind a figure does not become visible when the figure moves (Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025).

Skeletal rigging is applied in animating the miniature figures once they have been separated into layers (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). The limbs of the figures, such as the head, torso, arms, hands, and legs, are separated at the joints and fitted with a digital bone structure (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021).

Because a static and stylized narrative language is inherent to miniatures, exaggerated and rapid movements are avoided in animation (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). The gestures and facial expressions of the characters are designed at a minimal level consistent with the style of the period (Aşılıoğlu, 2025). Micro-movements such as turning the head, shifting the direction of the gaze, and the limited swing of the hand and arm are shaped with the puppet tool and frame-by-frame drawing techniques (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). To strike a balance between the aesthetic stillness of the miniature and dynamism, the overall speed of the animation is kept between 12 and 18 frames per second (fps) (Aşılıoğlu, 2025). Environmental animation effects such as rippling water, rising smoke, drifting clouds, waving flags, and trembling leaves are added to bring dynamism to the scene (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025).

In the final stage of the animation, the visual flow is supported with auditory elements (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). In scenes containing dialogue, automatic and manual lip synchronization is carried out with Adobe Character Animator so that the characters' mouth movements match the voice recordings (Aşılıoğlu, 2025).

To strengthen the atmosphere of the visual narrative, traditional Ottoman music appropriate to the spirit of the period (compositions by Tuluyhan Uğurlu or period *makams*) and fitting ambient sounds (seagulls, waves, *mehter* rhythms, the hum of crowds) are incorporated into the edit with Adobe Audition and Premiere Pro (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021; Karapekmez & Gülaçtı, 2025).

The prominent applied studies in the literature on transferring traditional miniature aesthetics to animation demonstrate that Ottoman cultural heritage, from the festival scenes of the *Surname-i Vehbi* to the historical architectural transformation of Istanbul (the Süleymaniye Mosque, the Maiden's Tower, the Galata Tower), can be carried into the digital environment across a wide range, and that cultural memory can be transmitted

to younger generations in a sustainable way (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021; Türkmenoğlu et al., 2018).

Method And Implementation

This research is based on a qualitative and experimental applied research design that aims to reproduce traditional stories through AI and two-dimensional (2D) digital animation techniques while preserving the visual and formal codes specific to Ottoman miniature painting (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). The methodology is built on an interdisciplinary, holistic workflow model that brings together art history, digital communication design, computer vision, and the aesthetics of the moving image (Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025).

The study combined document analysis, archival research, iconographic analysis, and stylistic analysis, which are qualitative data collection methods (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). While the traditional composition of the miniatures was examined, an experimental application method was adopted for the generative AI and animation stages (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

The study's basic methodological approach rests on preventing images produced in digital environments from detaching from reality and becoming "simulacra," in line with Baudrillard's theory of simulation, and on preserving the historical and artistic originality of the work within the framework of Benjamin's concept of "aura" (Baudrillard, 1994; Benjamin, 2016; Karapekmez & Gülaçtı, 2025). Accordingly, each visual output obtained in the digitization and AI production processes was submitted to the oversight of art historians and experts and underwent historical and formal verification (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

So that AI models (Generative Adversarial Networks [GANs] and generative diffusion models) could learn the stylistic and linear characteristics specific to Ottoman miniature painting, a high-quality image dataset was first compiled (Kalin, 2018; Karapekmez & Gülaçtı, 2025). The miniatures in manuscripts held in archives such as the Topkapı Palace Museum Library, the Istanbul University Rare Books Library, and the Süleymaniye Library were digitized at high resolution (600 ppi) (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021).

The categorization of the dataset was based on the court atelier styles of each period (Karapekmez & Gülaçtı, 2025).

Classical Period Style (Sixteenth Century): Twenty reference images compiled from the architectural, topographic, and ceremonial miniatures of Nakkaş Osman and Matrakçı Nasuh (for training on the scene of the construction of the Fatih Complex) (Karapekmez & Gülaçtı, 2025).

Late Period and the Influence of Westernization (Eighteenth Century): Thirty reference images compiled from the human figures, costume details, and daily-life scenes of Nakkaş Levni and Enderunlu Fazıl (for training on the Ottoman farming scenes) (Karapekmez & Gülaçtı, 2025).

Nineteenth-Century Embassy Account Style: The 32 miniatures in Bozoklu Osman Şakir Efendi's manuscript of the *İran Sefaretnâmesi*, dated 1811 (for the scene of Hezarfen Ahmet Çelebi's flight from the Galata Tower) (Karapekmez & Gülaçtı, 2025).

The high-resolution images obtained were preprocessed, with their pixel dimensions and color balance optimized, and were then used to train, with the Low-Rank Adaptation (LoRA) technique on the open-source Stable Diffusion architecture, custom weight files capable of producing the court painters' styles (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

Detailed text prompts were composed to obtain historically and aesthetically accurate images from the trained AI models (Karapekmez & Gülaçtı, 2025). In writing the prompts, key terms defining the basic qualities of miniature painting and negative prompts were used simultaneously (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

Obtaining the final images in the production process was not limited to a single processing cycle; many iterations were run within the capacity of the hardware infrastructure (GPU/CPU processing power)

(Karapekmez & Gülaçtı, 2025). From among the images synthesized by AI, those closest to the original court painters' style in terms of compositional order, color palette, and figure posture were selected and passed to the digital restoration stage (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

Adobe Photoshop was actively used in preparing for animation the miniatures that were produced by AI or scanned from manuscript books (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021). In the first stage, physical wear, color degradation, and staining in the images were cleaned in a manner faithful to the original (Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025).

The vector and digital images whose layering was complete were imported into Adobe After Effects, and the two-dimensional (2D) animation process began (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). To preserve the two-dimensional, non-perspectival character of the miniature, limited animation and vector rigging methods were applied in place of three-dimensional (3D) volumetric techniques (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021; Karapekmez & Gülaçtı, 2025).

In animating the figures, exaggerated movements were avoided and plain, rhythmic gestures consistent with the style of miniature painting were preferred (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). The flow of movement in the scenes was achieved through frame-by-frame drawings and keyframe interpolation (Aşılıoğlu, 2025; Karahan, 2025).

In the final stage of the animation, the visual and auditory elements were synchronized (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025):

Lip-Sync: Adobe Character Animator was used in scenes containing dialogue so that the characters' mouth movements matched their voice recordings (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). To avoid disturbing the stylized structure of the miniature, excessive facial expressions were avoided and basic vocalization movements were applied (Aşılıoğlu, 2025).

Sound Editing and Effects: Cleaning the dialogue and processing the ambient sounds (waves, seagulls, street noise, wind) and the musical timbres appropriate to the Ottoman period (compositions by Tuluyhan Uğurlu or period *makams*) were carried out with Adobe Audition (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025).

Editing and Export: All the prepared visual layers, motion designs, and audio channels were combined on the timeline in Adobe Premiere Pro and edited (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). After comprehensive checks, the work was completed by exporting it in a high-resolution video format (MOV / MP4) (Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025).

Findings And Discussion

The findings obtained from the digitization, AI synthesis, and animation applications carried out within the study show that preserving the visual language specific to Ottoman miniature painting is the main determinant of success in transferring the work to digital media (Aşılıoğlu, 2025; Karahan, 2025). The aesthetic codes that miniature painting developed over its history differ entirely from the light-and-shade modulation, anatomical volume, and single-focus linear perspective of classical Western art (Güleryüz, 2025; Sözen & Tanyeli, 1992).

The findings from the experimental applications and analyses took shape around the following basic principles:

Non-Perspectivality and Two-Dimensional Surface Construction: The two-dimensional planar structure of the miniature was maintained in the AI (Stable Diffusion) production and 2D animation stages (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). In adding a sense of depth to the scene, the traditional "vertical perspective," layer order, and rules of stacked composition were applied instead of three-dimensional (3D) optical vanishing points (Akbulut, 2006; Aydıngüler & Türkmenoğlu, 2021).

Hierarchical Scaling: The principle that figurative scales in the narrative are shaped by a figure's political and dramatic importance rather than by physical distance was sustained (Güçbilmez, 2023; Karahan, 2025). While

the sultan, princes, or central characters were kept at a large scale, secondary figures and surrounding elements were arranged in keeping with hierarchical proportions (Mercan, 2022; Türkmenoğlu et al., 2018).

Shadowless Color Palette and Tahrir Aesthetics: The sharp contours (tahrir) and the volumeless, saturated flat color fields that are defining elements of miniature painting were reproduced with digital vector drawing and AI prompt engineering tools (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

The findings confirm that digital transfers carried out in fidelity to the traditional visual language can reach contemporary audiences without damaging the historical and artistic identity of the work (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021).

Transforming miniature images, which appear statically on handmade manuscript paper, into a dynamic narrative by giving them dimensions of time and movement marks a qualitative leap for the sustainability of visual culture (Aşılıoğlu, 2025; Türkmenoğlu et al., 2019). In the application process, static miniature scenes were cut out and separated into layers and were animated with 2D rigging techniques (Aydıngüler & Türkmenoğlu, 2021; Karapekmez & Gülaçtı, 2025).

The prominent findings in the transition from stillness to moving narrative are as follows:

Rhythmic and Minimal Movement Design: Excessive and exaggerated movements were avoided so as not to damage the stillness of the miniatures' original style (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025). Micro-gestures such as turning the head, changing the direction of the gaze, and moving the hands and arms in the characters' postures were designed frame by frame (Aşılıoğlu, 2025).

Environmental Atmospheric Effects: Atmospheric effects such as rippling water, rising smoke, drifting clouds, and waving banners were added to bring liveliness to the scene, which supported the visual rhythm (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025).

Auditory Integration and Lip-Sync: To increase the emotional effect of the narrative, traditional Ottoman music and ambient sound effects were included in the edit, and lip synchronization was carried out in dialogue scenes with Adobe Character Animator (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021).

This transformation has turned the miniature from a static document examined on museum and library shelves into a cinematic storytelling tool (Bostan & Eyvazi, 2025; Türkmenoğlu et al., 2018).

One of the important findings of the study is the transformative role of generative AI technologies (Stable Diffusion, GANs, and LoRA models) in traditional art production processes (Kalin, 2018; Karapekmez & Gülaçtı, 2025). AI has not only made it possible to digitize existing miniatures but has also enabled scenes that were never made into miniatures, or remained incomplete, in historical archives to be reproduced in the style of the period's court painters (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

The findings on the function of AI in the creative process show that algorithms can analyze, through datasets, the aesthetic accumulation formed by the master-apprentice relationship and manual craftsmanship, but that the final artistic quality depends on human intervention (prompt engineering, digital restoration, academic oversight) (Karahan, 2025; Karapekmez & Gülaçtı, 2025). The many iterations run in the production process, depending on hardware capacity, reveal that AI is not a decision maker on its own but a powerful "co-creator" that enhances the artist's competence (Karapekmez & Gülaçtı, 2025).

Transferring traditional arts to the digital environment offers great possibilities for keeping alive the processes of "collective memory" and "cultural memory" conceptualized by Maurice Halbwachs and Jan Assmann (Assmann, 2011; Halbwachs, 1992; Karapekmez & Gülaçtı, 2025). The animations and AI productions made help younger generations and broad audiences engage with traditional Ottoman visual culture (Aşılıoğlu, 2025; Küçükusta, 2024; Smith, 2006).

However, the findings show that the problem of "historical reliability" is of vital importance in digital reproduction processes (Karapekmez & Gülaçtı, 2025). The arbitrary details to which AI is prone (hallucinations) and unfounded additions made during the animation stage carry the risk of distorting historical reality and causing misinformation (Karahan, 2025; Karapekmez & Gülaçtı, 2025). For this reason, in digital

cultural heritage projects, comparing written archival documents with visual material and operating oversight mechanisms made up of art historians and expert academics emerge as a necessity (Karahan, 2025; Karapekmez & Gülaçtı, 2025).

AI-assisted image production and digital animation practices bring with them debates on copyright, originality, and ethical responsibility from the standpoint of the philosophy of art and of law (Kalin, 2018; Karapekmez & Gülaçtı, 2025). The ownership and authorship status of the new images produced by models trained on the works of historical court painters does not rest on a clear legal footing (Karapekmez & Gülaçtı, 2025).

Conclusion And Recommendations

This study has presented a holistic and interdisciplinary methodology for reproducing traditional stories through generative AI and two-dimensional (2D) digital animation techniques while preserving the formal and narrative codes specific to Ottoman miniature painting (Aşılıoğlu, 2025; Karahan, 2025; Karapekmez & Gülaçtı, 2025). The main results obtained in this study, which brings together theory, technology, and artistic practice, can be summarized as follows:

The two-dimensional conception of the surface that Ottoman miniature painting developed over centuries, its "vertical/stacked perspective" construction, the principle of hierarchical scaling, the aesthetics of tahrir (sharp contours), and shadowless flat color fields were successfully preserved in the digital animation and AI production processes (Aşılıoğlu, 2025; Karahan, 2025). By avoiding the three-dimensional volume and single-focus vanishing-point perspective peculiar to Western art, the authentic aesthetic structure of the work was maintained (Güleryüz, 2025; Sözen & Tanyeli, 1992).

Deep learning algorithms (Stable Diffusion) and Low-Rank Adaptation (LoRA) techniques were able to learn the linear and color characteristics of historical masters such as Nakkaş Osman, Nakkaş Levni, and Bozoklu Osman Şakir Efendi (Karahan, 2025; Karapekmez & Gülaçtı, 2025). Through this technology, historical events that had not been depicted in manuscripts or had remained incomplete (the construction of the Fatih Complex, the flight of Hezarfen Ahmet Çelebi, etc.) were resynthesized in fidelity to the style of the period's court atelier (Karapekmez & Gülaçtı, 2025).

Through vector cutting out, layering, and 2D rigging techniques, the dimensions of time, movement, and sound were added to static manuscript images (Aşılıoğlu, 2025; Aydıngüler & Türkmenoğlu, 2021). The limited animation speed of 12–18 frames per second (fps) and the plain design of gestures created a balanced synthesis between the aesthetic stillness of the miniature and the dynamism of the moving image (Aşılıoğlu, 2025; Karapekmez & Gülaçtı, 2025).

Manuscript miniatures that had remained closed to a limited academic circle in physical museum and library archives were opened to access by broad audiences and younger generations through digitization and animation techniques (Aşılıoğlu, 2025; Karahan, 2025; Mercan, 2022). In line with Walter Benjamin's concept of "aura," the movement and auditory layers added to the work gave the traditional heritage a contemporary "digital aura" (Benjamin, 2016; Karapekmez & Gülaçtı, 2025).

Within the framework of Jean Baudrillard's theory of simulation, the risk that AI-generated images detach from reality and become "simulacra" was identified; to prevent this risk, every stage of the production process was subjected to verification by art historians and expert academics (Baudrillard, 1994; Karahan, 2025; Karapekmez & Gülaçtı, 2025).

In line with the findings and results obtained in the research, the following concrete recommendations are offered for sustaining and developing traditional miniature painting in digital media:

Theoretical and applied courses titled "Digital Miniature and the Reinterpretation of Traditional Arts" should be opened in the illustration, graphic design, and animation departments of faculties of fine arts, design, and communication (Karahan, 2025; Mercan, 2022). Teaching traditional drawing techniques and digital tools in balance will enable students to produce original designs nourished by cultural identity (Karahan, 2025).

The miniature animations and AI images produced should be transferred to Unreal Engine / Unity game engines, augmented reality (AR), virtual reality (VR), and digital game concepts (as in the example of the platform game *Ferhat ile Şirin*) to offer viewers interactive and immersive experiences (Karahan, 2025; Küçükusta, 2024).

High-resolution (600+ ppi) digital archives of manuscript miniatures should be created through cooperation among the Ministry of Culture and Tourism, the Manuscripts Institution, and universities; trained AI LoRA models and style datasets should be offered to researchers through open-access portals (Aydıngüler & Türkmenoğlu, 2021; Karahan, 2025).

In historical structures (Topkapı Palace, the Galata Tower, the Maiden's Tower, etc.), projection mapping, augmented reality tours, and interactive exhibition spaces should be set up so that miniature animations become an effective element of cultural tourism and digital diplomacy (Aşılıoğlu, 2025; Türkmenoğlu et al., 2019).

In miniature content produced or expanded with AI, the notice "synthesized with artificial intelligence" should be used explicitly; ethical, copyright, and historical accuracy standards should be secured through academic and legal frameworks (Karapekmez & Gülaçtı, 2025).

References

Akbulut, C. (2006). *Minyatür sanatında kompozisyon teknikleri ve biçimsel düzenlemeler* [Composition techniques and formal arrangements in miniature art]. Sanat Yayınları.

Anadol, R. (2021). *Machine hallucinations: Istanbul* [Artificial intelligence data sculpture]. Pilevneli Gallery.

And, M. (2002). *Osmanlı tasvir sanatları 1: Minyatür* [Ottoman pictorial arts 1: Miniature]. Türkiye İş Bankası Kültür Yayınları.

Arseven, C. E. (1993). *Sanat ansiklopedisi* [Encyclopedia of art]. Milli Eğitim Bakanlığı Yayınları.

Assmann, A. (2011). *Cultural memory and Western civilization: Functions, media, archives*. Cambridge University Press.

Aşılıoğlu, S. (2025). *16 ile 18. yüzyıllar arasındaki İstanbul temalı minyatürlerin animasyon yoluyla canlandırılarak İstanbul'un dönüşümünün gösterilmesi amacıyla bir tanıtım filmi oluşturulması* [Creating a promotional film to show the transformation of Istanbul by animating Istanbul-themed miniatures of the 16th to 18th centuries] [Unpublished master's thesis]. Yıldız Technical University, Graduate School of Social Sciences, Istanbul.

Atasoy, N. (1989). *Osmanlı minyatür sanatı* [Ottoman miniature art]. Akbank Yayınları.

Atasoy, N. (1998). *Minyatürlerde görsel anlatım dili* [The visual narrative language of miniatures]. Sanat Tarihi Derneği Yayınları.

Atıl, E. (1980). *Levni and the Surname: The story of an Ottoman festival*. Koçbank.

Aydıngüler, M. H., & Türkmenoğlu, D. (2021). Minyatürlerin dijital dönüşümü: Animasyon uygulaması [The digital transformation of miniatures: An animation application]. *Yıldız Sosyal Bilimler Enstitüsü Dergisi, 5*(1), 1–11.

Baudrillard, J. (1994). *Simulacra and simulation* (S. F. Glaser, Trans.). The University of Michigan Press.

Benjamin, W. (2016). *Tekniğe dayalı yeniden üretim çağında sanat eseri* [The work of art in the age of technical reproduction] (A. Cemal, Trans.). Telos Yayınları.

Bostan, E., & Eyvazi, F. (2025). İran minyatür animasyonu ve göstergebilimsel analiz örneği: Malek Khorshid [Iranian miniature animation and an example of semiotic analysis: Malek Khorshid]. *Lokum Sanat ve Tasarım Dergisi, 3*(1), 69–82.

Elmas, N. (1998). Minyatür sanatında renk ve sembolizm [Color and symbolism in miniature art]. *Sanat Dergisi, 8*, 45–52.

Güçbilmez, B. (2023). Minyatür estetiğinde bakış ve ölçek ilişkisi [The relationship between gaze and scale in miniature aesthetics]. *Sanat ve Tasarım Dergisi, 13*(2), 35–48.

Güleryüz, B. (2025). *Minyatür sanatının illüstrasyon tasarımına etkisi* [The influence of miniature art on illustration design] [Unpublished master's thesis]. Haliç University, Graduate Education Institute, Istanbul.

Halbwachs, M. (1992). *On collective memory* (L. A. Coser, Trans.). The University of Chicago Press.

Holtzschue, L. (2009). *Understanding color: An introduction for designers*. John Wiley & Sons.

Kalin, M. (2018). *Generative art and artificial intelligence in contemporary visual culture*. Springer.

Karahan, A. N. (2025). Osmanlı minyatürlerinin dijital evrimi [The digital evolution of Ottoman miniatures]. *Mardin Artuklu Üniversitesi Sanat ve Tasarım Dergisi (MUJAD), 16*(1), 1–23.

Karapekmez, A. V., & Gülaçtı, İ. E. (2025). Minyatürden animasyona: Osmanlı sanatının dijital teknolojilerle yeniden yorumlanması [From miniature to animation: Reinterpreting Ottoman art with digital technologies]. *Kesit Akademi Dergisi, 11*(42), 1–36.

Keskiner, C. (2004). *Minyatür sanatında kompozisyon ve uygulama* [Composition and practice in miniature art]. Kültür Bakanlığı Yayınları.

Konak, R. (2007). Osmanlı minyatür sanatında kompozisyon düzeni [Compositional order in Ottoman miniature art]. *Yüzüncü Yıl Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 10*, 1–15.

Küçükusta, O. (2024). *Geleneksel minyatür sanatının dijital oyunlara uyarlanması: "Ferhat ile Şirin" platform oyunu konsept tasarımı* [Adapting traditional miniature art to digital games: Concept design for the platform game "Ferhat ile Şirin"] [Unpublished proficiency-in-art thesis]. Ankara Hacı Bayram Veli University, Graduate Education Institute, Ankara.

Mercan, E. (2022). Minyatür sanatında kompozisyon ve anlatı teknikleri [Composition and narrative techniques in miniature art]. *Akademik Sanat Dergisi, 7*(14), 28–42.

Smith, M. (2006). *Digital heritage and cultural preservation*. Routledge.

Sözen, M., & Tanyeli, U. (1992). *Sanat kavram ve terimleri sözlüğü* [Dictionary of art concepts and terms]. Remzi Kitabevi.

Şen, E. (2018). Tasarım ilke ve öğelerinin minyatürde kullanımı [The use of design principles and elements in miniatures]. *İdil Sanat ve Dil Dergisi, 7*(46), 775–781.

Tanındı, Z. (1996). *Osmanlı resim sanatında mekân ve zaman kurgusu* [The construction of space and time in Ottoman painting]. T.C. Kültür Bakanlığı Yayınları.

Tulum, M. (2008). *Vehbi Surname Sultan Ahmet'in düğün kitabı* [Vehbi's Surname: The wedding book of Sultan Ahmed]. Kabalcı Yayınevi.

Türkmenoğlu, D., Kamacıoğlu, B., Alacatlı, S., Kanar, A. A., & Birsel, Ç. (2018). Geleneksel ögelerin animasyonlarda kullanımı bağlamında Surname-i Vehbi elyazması [The Surname-i Vehbi manuscript in the context of the use of traditional elements in animations]. *Uluslararası Sosyal Araştırmalar Dergisi, 11*(57), 206–212.

Türkmenoğlu, D., Uçan, B., & Kamacıoğlu, B. (2019). Animasyon aracılığıyla kültürel ögelerin yeniden canlandırılması [Reviving cultural elements through animation]. *Uluslararası Sosyal Araştırmalar Dergisi, 12*(66), 567–574.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ASSESSMENT OF GROWTH PERFORMANCE AND PIGMENT CONTENT IN *DUNALIELLA SALINA* CULTURES GROWN IN CLOSED PHOTOBIOREACTOR SYSTEMS AT 40 G L^{-1} SALINITY

Asel Irmak FIÇICIOĞLU
Muazzez GÜRGAN ESER
Çetin YAĞCILAR
0009-0000-3773-5498, Tekirdağ Namık Kemal University, Faculty of Arts and Sciences, Department of Biology, Tekirdağ, Türkiye.
0000-0002-2966-1510, Tekirdağ Namık Kemal University, Faculty of Arts and Sciences, Department of Biology, Tekirdağ, Türkiye.
0000-0002-4683-820X, Tekirdağ Namık Kemal University, Faculty of Arts and Sciences, Department of Biology, Tekirdağ, Türkiye.

Abstract

Dunaliella salina is an important microalgal species for biotechnological applications, owing to its remarkable tolerance of high salinity and its capacity to produce biomass rich in valuable biopigments, particularly carotenoids. In this study, *Dunaliella salina* cultures grown in 4 L closed photobioreactors at a salinity of 40 g L^{-1} were evaluated to determine their growth performance and photosynthetic pigment content. During the experimental period, the microalgal cultures were maintained under controlled conditions of temperature, illumination, and aeration. Culture growth was monitored at regular intervals using a spectrophotometric method by measuring the optical density at 670 nm (OD_{670}), and growth curves were then constructed. At the end of the cultivation period, pigment extraction was performed from the harvested biomass, and the contents of chlorophyll a, chlorophyll b, and total carotenoids were quantified using spectrophotometric methods. The results showed that D. salina cultures successfully adapted to the 40 g L^{-1} salinity and maintained stable, continuous growth throughout the cultivation period. OD_{670} values increased markedly throughout the cultivation period, indicating a progressive rise in cell density over time. Pigment analyses showed that the cultures-maintained chlorophyll a and chlorophyll b synthesis throughout the cultivation period, while carotenoid accumulation reached substantial levels. The findings indicate that elevated salinity promotes carotenoid biosynthesis, thereby increasing the biotechnological potential of *D. salina*. In conclusion, *D. salina* cultures grown in closed photobioreactor systems at a salinity of 40 g L^{-1} showed satisfactory growth and efficient pigment production, highlighting their potential for biotechnological applications. The findings of this study offer valuable insights into the potential of *D. salina* as a natural pigment producer and a source of functional biomass for biotechnological applications.

Keywords: *Dunaliella salina*, salinity, optical density, chlorophyll a, chlorophyll b, total carotenoids.

Introduction

Dunaliella salina is a unicellular, photosynthetic green microalga belonging to the phylum *Chlorophyta*, distinguished by its remarkable ability to tolerate and adapt to highly saline environments through specialized physiological and biochemical mechanisms (Oren, 2014; El-Baz, Aly & Salama, 2019; Jiang et al., 2023) (Figure 1).

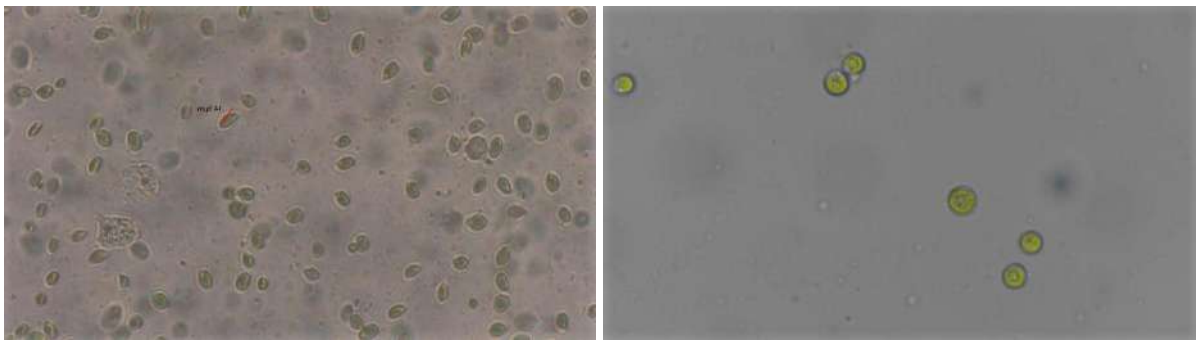


Figure 1. Changes in OD_{670} values of *Dunaliella salina* cultured in a closed photobioreactor system at a salinity of 40 g L^{-1}, measured at three-day intervals

One of the most distinctive physiological characteristics of *D. salina* is its exceptional capacity to maintain cellular viability and sustain photosynthetic activity under hypersaline environmental conditions (Ramachandran et al., 2023; Jo et al., 2024). This physiological adaptability makes *D. salina* an important model organism for investigating cellular responses to salinity stress and elucidating the mechanisms underlying microalgal adaptation to environmental stressors (Zhang et al., 2023; Singh et al., 2025). Furthermore, hypersaline conditions have been shown to exert pronounced effects on the photosynthetic performance and cellular stress responses of *D. salina*.

A key biotechnological feature of *Dunaliella salina* is its exceptional capacity for the biosynthesis and intracellular accumulation of substantial amounts of natural β-carotene (Dipak & Lele, 2005). Consequently, *Dunaliella salina* is regarded as one of the most commercially significant microalgal species for the industrial-scale production of natural β-carotene (Harvey & Ben-Amotz, 2020). β-Carotene synthesized by *D. salina* has been reported to comprise both 9-*cis* and all-*trans* isomeric forms (Xu & Harvey, 2019; Mazzucchi, Xu & Harvey, 2020). Nevertheless, the capacity for β-carotene biosynthesis and accumulation varies considerably among *D. salina* strains, while intracellular carotenoid levels have been closely associated with the enhancement of photoprotective capacity under high-light conditions (Faraloni & Torzillo, 2017).

Pigment accumulation in *Dunaliella salina* is closely associated with environmental and nutritional conditions (Wu, Duangmanee, Zhao, Juntawong & Ma, 2016). In particular, stress conditions such as nutrient limitation may suppress cellular growth and photosynthetic activity while inducing substantial alterations in carotenoid metabolism (Sun, M., Ren, Zhao, Ji & Huang, 2018). Studies investigating nitrogen, phosphorus, and sulfur deprivation have demonstrated that combined nutrient deficiencies can enhance total carotenoid accumulation, with certain stress combinations resulting in greater β-carotene accumulation than individual nutrient limitations (Minhas, Hodgson, Barrow, & Adholeya, 2016). These findings suggest that distinct cultivation strategies may be required to achieve an appropriate balance between biomass production and the accumulation of target metabolites in *D. salina* cultures.

Taken together, these characteristics establish *Dunaliella salina* as a microalgal species of considerable biotechnological importance, particularly owing to its exceptional tolerance to high salinity and its capacity for natural β-carotene production. In particular, the optimization of cultivation conditions to enhance biomass productivity and regulate pigment accumulation represents a key research priority for maximizing the biotechnological potential of this microalga.

Materials and Methods

To evaluate the growth performance of *Dunaliella salina* cultures, optical density measurements were performed at predetermined sampling intervals. The absorbance of culture samples was measured spectrophotometrically at 670 nm (OD_{670}), using distilled water as the blank. The resulting OD_{670} values were used to monitor temporal changes in culture density and to characterize the growth profile of *D. salina* throughout the cultivation period.

For the determination of pigment contents, including chlorophyll a (Chl a), chlorophyll b (Chl b), and total carotenoids, pigments were extracted from 10 mg of dried biomass using 1 mL of 90% (v/v) acetone. The samples were vortexed for 20 s and subsequently centrifuged at 10,000 × g for 2 min. The extraction procedure was repeated until the biomass was completely decolorized and the resulting extraction solution became colorless, indicating the exhaustive removal of pigments from the biomass (Xi, Wang, Chu, Chi & Xue, 2020).

The absorbance values of chlorophyll a (Chl a), chlorophyll b (Chl b), and total carotenoids in the resulting extracts were measured at wavelengths of 662, 645, and 470 nm, respectively, using a UV/Vis spectrophotometer (Jasco V-530, JASCO Corporation, Japan).

$$C_{chla}(mg\ L^{-1}) = 11.75(A_{662}) - 2.35(A_{645})$$

$$C_{chlb}(mg\ L^{-1}) = 18.61(A_{645}) - 3.96(A_{662})$$

$$Total\ carotenoids\ (mgL^{-1}) = \frac{1000(A_{470}) - 2.270Chla - 81.4Chlb}{198}$$

Findings and Discussion

In this study, the growth performance and pigment content of *Dunaliella salina* cultures cultivated in a closed photobioreactor system at a salinity of 40 g L^{-1} were evaluated. Culture growth was monitored based on temporal changes in optical density, while the photosynthetic pigment profile was characterized by determining chlorophyll a, chlorophyll b, and total carotenoid contents. The obtained results enabled a comprehensive assessment of the relationship between growth dynamics and pigment production in *D. salina* under the specified cultivation conditions.

Within this context, the growth of *D. salina* cultures was evaluated based on OD_{670} measurements, and temporal changes throughout the cultivation period were characterized by constructing a growth curve. Following the assessment of growth performance, the concentrations of chlorophyll a, chlorophyll b, and total carotenoids were determined. These parameters were collectively evaluated to characterize the cellular growth and pigment accumulation of *D. salina* cultivated in a closed photobioreactor system at a salinity of 40 g L^{-1}.

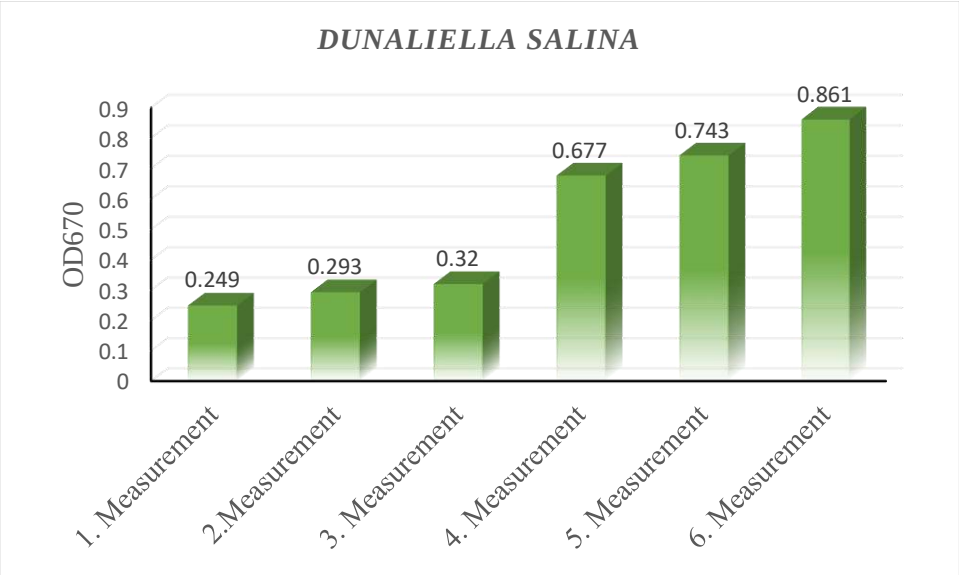


Figure 2. Changes in OD_{670} values of *Dunaliella salina* cultured in a closed photobioreactor system at a salinity of 40 g L^{-1}, measured at three-day intervals.

The growth performance of *Dunaliella salina* cultures was monitored through OD_{670} measurements performed at three-day intervals (Figure 2). The optical density increased from an initial value of 0.249±0.007 to 0.293±0.024 and 0.320±0.029 at the second and third measurements, respectively. The relatively modest increase observed during the first three measurement points indicated a gradual increase in culture density. Subsequently, a pronounced increase was recorded at the fourth measurement, with the OD_{670} value reaching 0.677±0.083. Notably, the approximately 112% increase in OD_{670} between the third and fourth measurements indicates that the increase in culture density was substantially greater during this interval than during the preceding measurement periods.

The increasing trend in OD_{670} persisted after the fourth measurement, reaching 0.743±0.121 at the fifth measurement and a maximum value of 0.861±0.117 at the sixth and final measurement. Comparison of the initial and final measurements revealed an approximately 3.46-fold increase in OD_{670}, corresponding to an overall increase of approximately 246%. Collectively, these findings demonstrate a continuous increase in culture density throughout the monitoring period, with no apparent decline under closed photobioreactor cultivation at a salinity of 40 g L^{-1}.

Nevertheless, rather than definitively assigning specific growth phases based solely on OD_{670} measurements, the observed changes should be interpreted more cautiously as relative variations in culture density. In particular, the pronounced increase observed between the third and fourth measurements suggests a period of accelerated culture growth, whereas the continued increase in OD_{670} at the final measurement indicates that a distinct plateau had not yet been reached. Complementing OD_{670} measurements with additional growth parameters, such as cell density or dry biomass concentration, would provide a more comprehensive and robust assessment of the growth performance of *D. salina*.

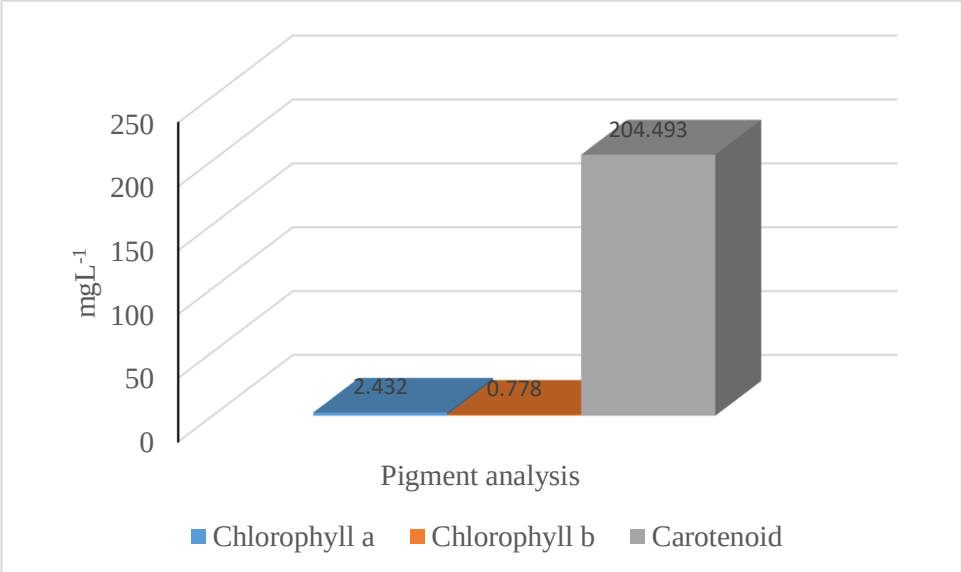


Figure 3. Pigment Composition of *Dunaliella salina* Cultured in a Closed Photobioreactor System at 40 g L^{-1} Salinity

Analysis of the pigment profile of *Dunaliella salina* revealed chlorophyll a and chlorophyll b concentrations of 2.432±0.205 and 0.778±0.132 mg L^{-1}, respectively, whereas the total carotenoid content was determined to be 204.493±10.856 mg L^{-1} (Figure 3). Among the chlorophyll pigments, the concentration of chlorophyll a was approximately 3.1-fold higher than that of chlorophyll b. This distribution indicates that chlorophyll a constituted the predominant chlorophyll pigment in the *D. salina* culture under the investigated cultivation conditions.

The most notable feature of the pigment profile was the substantially higher total carotenoid content compared with the concentrations of chlorophyll a and chlorophyll b (Xu, Ibrahim, Wosu, Ben-Amotz & Harvey, 2018). *Dunaliella salina* is well recognized for its capacity to accumulate high levels of carotenoids, and pigment production in this species has been reported to be influenced by cultivation conditions, particularly salinity and harvesting time. Sedjati et al. (2019) demonstrated that chlorophyll a, chlorophyll b, and carotenoid production in *D. salina* varied across different salinity levels and harvesting periods, highlighting the important role of salinity conditions in modulating pigment production.

In the present study, the total carotenoid concentration of 204.493±10.856 mg L^{-1} indicates that *Dunaliella salina* exhibited a carotenoid-rich pigment profile when cultivated in a closed photobioreactor system at a salinity of 40 g L^{-1}. However, in the absence of comparative salinity treatments, it would be more appropriate to interpret the observed carotenoid level as a characteristic of the pigment profile obtained under the applied cultivation conditions rather than as a direct physiological response to salinity stress at 40 g L^{-1}. This cautious interpretation is supported by previous studies demonstrating that carotenoid accumulation in *D. salina* can vary substantially in response to cultivation conditions, including salinity, light intensity, nutrient availability, and strain-specific responses.

When considered together with the OD_{670} results, which showed an increase in culture density from 0.249 to 0.861, the findings indicate that *Dunaliella salina* maintained sustained growth under the applied closed-photobioreactor conditions, while the harvested biomass exhibited a notable pigment profile, particularly with respect to carotenoid content. Collectively, these observations highlight the importance of evaluating growth performance and pigment production concurrently to provide a more comprehensive assessment of the cultivation performance and biotechnological potential of *D. salina*.

Conclusion and Recommendations

The findings of the present study demonstrate that *Dunaliella salina* biomass can be successfully produced in a closed photobioreactor system at a salinity of 40 g L^{-1} and that the resulting biomass exhibits a noteworthy pigment profile, particularly in terms of carotenoid content. Further validation of these findings under different cultivation conditions and through scale-up studies would provide a more comprehensive understanding of the potential of *D. salina* for sustainable, pigment-oriented biotechnological production systems.

References

Dipak, P., & Lele, S. (2005). Carotenoid production from microalga, *Dunaliella salina*. *Indian J. Biotechnol*, *4*(1), 476-483.

El-Baz, F. K., Aly, H. F., & Salama, A. A. (2019). Toxicity assessment of the green *Dunaliella salina* microalgae. *Toxicology reports*, *6*, 850-861.

Faraloni, C., & Torzillo, G. (2017). *Synthesis of antioxidant carotenoids in microalgae in response to physiological stress* (pp. 143-157). United Kingdom: IntechOpen.

Harvey, P. J., & Ben-Amotz, A. (2020). Towards a sustainable *Dunaliella salina* microalgal biorefinery for 9-cis β-carotene production. *Algal Research*, *50*, 102002.

Jiang, X., Yang, L., Wang, Y., Jiang, F., Lai, J., & Pan, K. (2023). Proteomics provide insight into the interaction between selenite and the microalgae *Dunaliella salina*. *Processes*, *11*(2), 563.

Jo, C. R., Cho, K., An, S. M., Do, J. M., Hong, J. W., Kim, J. H., ... & Kang, N. S. (2024). Taxonomical, physiological, and biochemical characteristics of *Dunaliella salina* DSTA20 from hypersaline environments of Taean Salt Pond, Republic of Korea. *Microorganisms*, *12*(12), 2467.

Mazzucchi, L., Xu, Y., & Harvey, P. (2020). Stereoisomers of colourless carotenoids from the marine microalga *Dunaliella salina*. *Molecules*, *25*(8), 1880.

Minhas, A. K., Hodgson, P., Barrow, C. J., & Adholeya, A. (2016). A review on the assessment of stress conditions for simultaneous production of microalgal lipids and carotenoids. *Frontiers in microbiology*, *7*, 546.

Oren, A. (2014). The ecology of Dunaliella in high-salt environments. *Journal of Biological Research-Thessaloniki*, *21*(1), 23.

Ramachandran, P., Pandey, N. K., Yadav, R. M., Suresh, P., Kumar, A., & Subramanyam, R. (2023). Photosynthetic efficiency and transcriptome analysis of *Dunaliella salina* under hypersaline: a retrograde signaling mechanism in the chloroplast. *Frontiers in Plant Science*, *14*, 1192258.

Sedjati, S., Santosa, G. W., Yudiati, E., Supriyantini, E., Ridlo, A., & Kimberly, F. D. (2019, March). Chlorophyll and carotenoid content of *Dunaliella salina* at various salinity stress and harvesting time. In *IOP Conference Series: Earth and Environmental Science* (Vol. 246, No. 1, p. 012025). IOP Publishing.

Singh, S., Singh, P., Prasad, N., Singh, S., Singh, A., Singh, P. K., ... & Asthana, R. K. (2025). Photoautotrophic Growth and the Transcriptome of the Halotolerant Model Microalga *Dunaliella salina* MCC43 Under Salt Stress. *Physiologia Plantarum*, *177*(5), e70545.

Sun, X. M., Ren, L. J., Zhao, Q. Y., Ji, X. J., & Huang, H. (2018). Microalgae for the production of lipid and carotenoids: a review with focus on stress regulation and adaptation. *Biotechnology for biofuels*, *11*(1), 272.

Wu, Z., Duangmanee, P., Zhao, P., Juntawong, N., & Ma, C. (2016). The effects of light, temperature, and nutrition on growth and pigment accumulation of three *Dunaliella salina* strains isolated from saline soil. *Jundishapur journal of microbiology*, *9*(1), e26732.

Xi, Y., Wang, J., Chu, Y., Chi, Z., & Xue, S. (2020). Effects of different light regimes on *Dunaliella salina* growth and β-carotene accumulation. *Algal Research*, *52*, 102111.

Xu, Y., & Harvey, P. J. (2019). Red light control of β-carotene isomerisation to 9-cis β-carotene and carotenoid accumulation in *Dunaliella salina*. *Antioxidants*, *8*(5), 148.

Xu, Y., Ibrahim, I. M., Wosu, C. I., Ben-Amotz, A., & Harvey, P. J. (2018). Potential of new isolates of *Dunaliella salina* for natural β-carotene production. *Biology*, *7*(1), 14.

Zhang, B., Deng, C., Wang, S., Deng, Q., Chu, Y., Bai, Z., ... & He, Q. (2023). The RNA landscape of *Dunaliella salina* in response to short-term salt stress. *Frontiers in Plant Science*, *14*, 1278954.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

INVESTIGATION INTO THE EFFECTS OF TWO DIFFERENT PHOTOPERIOD REGIMES ON EARLY DEVELOPMENT IN ZEBRAFISH (*DANIO RERIO*)

Bilge PEHLİVAN
Muazzez GÜRGAN ESER
Çetin YAĞCILAR
0009-0005-8425-9240, Tekirdağ Namık Kemal University, Faculty of Arts and Sciences, Department of Biology, Tekirdağ, Türkiye.
0000-0002-2966-1510, Tekirdağ Namık Kemal University, Faculty of Arts and Sciences, Department of Biology, Tekirdağ, Türkiye.
0000-0002-4683-820X, Tekirdağ Namık Kemal University, Faculty of Arts and Sciences, Department of Biology, Tekirdağ, Türkiye.

Abstract

Photoperiod is an important environmental cue that plays a crucial role in regulating growth, development, metabolism, and behaviour throughout the different stages of the life cycle of aquatic organisms. Changes in light and dark cycles play a significant role in regulating numerous physiological and behavioural processes in aquatic organisms, beginning at the embryonic stage of development. Photoperiod is widely recognised as a fundamental environmental cue that influences embryonic development and other physiological processes during the early life stages of aquatic organisms. This study aimed to determine the effects of different photoperiod conditions on the early developmental processes of zebrafish (*Danio rerio*) embryos. Fertilised embryos obtained from healthy adult zebrafish were used in this study and divided into two experimental groups. Throughout the 72 hpf exposure period, zebrafish embryos were maintained under standard E3 culture conditions and exposed to two photoperiod regimes: continuous darkness (24 h dark:0 h light) and a regime consisting of 10 h darkness and 14 h light, while their developmental progression was periodically monitored using stereomicroscopy. At 24 hpf, survival rate, morphological development, and spontaneous tail coiling activity were assessed, with tail coiling frequency recorded over a 1-minute period and used as an indicator of early embryonic motor function. Embryonic developmental progression and hatching performance were assessed at 48 and 72 hpf, and cardiac activity was evaluated by measuring heart rate at 72 hpf to determine the effects of photoperiod exposure on cardiovascular development. Embryos exposed to the 14L:10D photoperiod exhibited significantly higher spontaneous tail coiling activity at 24 hpf than those maintained under continuous darkness ($p = 0.014$), whereas cardiac activity at 72 hpf was significantly higher under continuous darkness ($p = 0.002$). These contrasting responses suggest that photoperiod may differentially affect behavioural and physiological processes during the early embryonic development of zebrafish (*Danio rerio*).

Keywords: *Danio rerio*, photoperiod, embryonic development, tail coiling, cardiac activity.

Introduction

Light is a key environmental factor that regulates the life cycle and physiological processes of aquatic organisms (Ruchin, 2021). Photoperiod, determined by the daily light–dark cycle, acts as a key environmental timing cue that facilitates the adaptation of organisms to environmental conditions (Bradshaw & Holzapfel, 2010). Particularly during early life stages, alterations in environmental conditions can significantly influence developmental and behavioural processes (Uddin, da Silva Junior, Ritu, Niyogi & Chivers, 2026). Therefore, photoperiod represents an important environmental variable that should be considered in the assessment of embryonic and larval development in fish (Sacksteder & Kimmey, 2022). Recent studies have also investigated the effects of photoperiod stress during early life stages, particularly in relation to developmental and behavioural responses (Arambam et al., 2020; Santos-Villadangos, Sellés-Egea, Robles & Valcarce, 2025).

Zebrafish (*Danio rerio*) is widely used as a vertebrate model for studying early life stages because of its rapid embryonic development and the ease with which developmental processes can be directly observed (Siddiqui, Siddiqui, Riguene & Nomikos, 2025). Particularly during embryonic development, the ability to directly assess motor and cardiac activity provides a valuable means of investigating the effects of environmental factors on developmental processes (Pereira et al., 2026). Spontaneous movements observed during early embryonic development in zebrafish are commonly used as behavioural indicators for assessing developmental motor activity (Li et al., 2025; Ma et al., 2025). Furthermore, spontaneous tail coiling activity in zebrafish embryos has been widely used as an indicator for behavioural assessment during early developmental stages.

Alongside behavioural parameters, cardiac activity represents an important physiological endpoint for evaluating embryonic development (Santoso et al., 2020). The rapid and easily observable cardiac development of zebrafish provides a valuable opportunity to assess cardiac function during embryonic development. The non-invasive assessment of heart rate in zebrafish embryos also facilitates the use of cardiac activity as a quantitative endpoint in experimental studies (Chan, Lin & Cheng, 2009). Therefore, the integrated assessment of multiple endpoints, such as survival, morphological development, spontaneous tail coiling activity, hatching, and heart rate, may provide a more comprehensive understanding of developmental changes occurring during the embryonic period.

Understanding the effects of photoperiod conditions during early development is particularly important for elucidating the developmental, behavioural, and physiological responses of embryos to changes in the light–dark cycle. The comparison of continuous darkness with a normal light–dark cycle is important for elucidating the responses of early developmental processes to different photoperiod conditions. In this context, evaluating functional parameters such as early motor behaviour and cardiac activity alongside morphological development may provide a more comprehensive understanding of the effects of photoperiod.

The present study aimed to investigate the effects of continuous darkness (0L:24D) and a 14 h light:10 h dark (14L:10D) photoperiod regime on early embryonic development in zebrafish (*Danio rerio*). Accordingly, multiple developmental endpoints were evaluated, including embryonic development and survival, spontaneous tail coiling (STC) activity at 24 hpf, hatching at later developmental stages, cardiac activity, and larval growth.

Thus, the study aimed to comprehensively evaluate the potential effects of different light–dark conditions on morphological, behavioural, and physiological endpoints during early zebrafish development.

Materials and Methods

Zebrafish (*Danio rerio*) Husbandry, Breeding, and Embryo Collection

Five-month-old adult zebrafish (*Danio rerio*, AB/AB strain) were maintained under controlled laboratory conditions and provided with appropriate husbandry conditions prior to their use for breeding (Figure 1).

Figure 1. General view of zebrafish (*Danio rerio*) maintained in an experimental aquarium system under laboratory conditions.

Under routine husbandry conditions, zebrafish were maintained at a water temperature of 28.5 °C and exposed to a 14 h light:10 h dark (14L:10D) photoperiod. Healthy, sexually mature zebrafish were selected and transferred to breeding tanks for embryo production. Following spawning, fertilised eggs were collected for use in the subsequent experimental procedures (Figure 2).

Figure 2. General view of the zebrafish (*Danio rerio*) breeding tank equipped with a mesh-based spawning and egg-separation system.

Following fertilisation, embryos younger than 6 hpf were examined under a stereomicroscope (DMSZ7 Series Digital Microscope), and morphologically healthy embryos showing normal development were selected for subsequent experimental procedures (Figure 3).

Figure 3. Developmental appearance of a zebrafish (*Danio rerio*) embryo at 6 hpf.

At the start of the experiment, the selected embryos were randomly allocated to two photoperiod treatments: continuous darkness (0L:24D) and a 14 h light:10 h dark (14L:10D) cycle (Figure 4).

Figure 4. Incubator system used for the incubation of zebrafish (*Danio rerio*) embryos under controlled photoperiod conditions.

To assess the effects of different photoperiod conditions on embryonic development, multiple developmental endpoints, including survival, morphological development, spontaneous tail coiling (STC) activity, hatching success, and heart rate, were evaluated throughout the developmental period. Spontaneous tail coiling (STC) activity was evaluated at 24 hpf as an indicator of early motor activity, whereas the remaining developmental parameters were assessed at their respective embryonic developmental stages. Morphologically healthy zebrafish (*Danio rerio*) embryos exhibiting normal development were randomly allocated to two photoperiod treatment groups. Each group consisted of four compartments, with five embryos placed in each compartment

(n = 20 embryos per photoperiod treatment). The photoperiod conditions were continuous darkness (0L:24D) and a 14 h light:10 h dark (14L:10D) cycle (Figure 5).

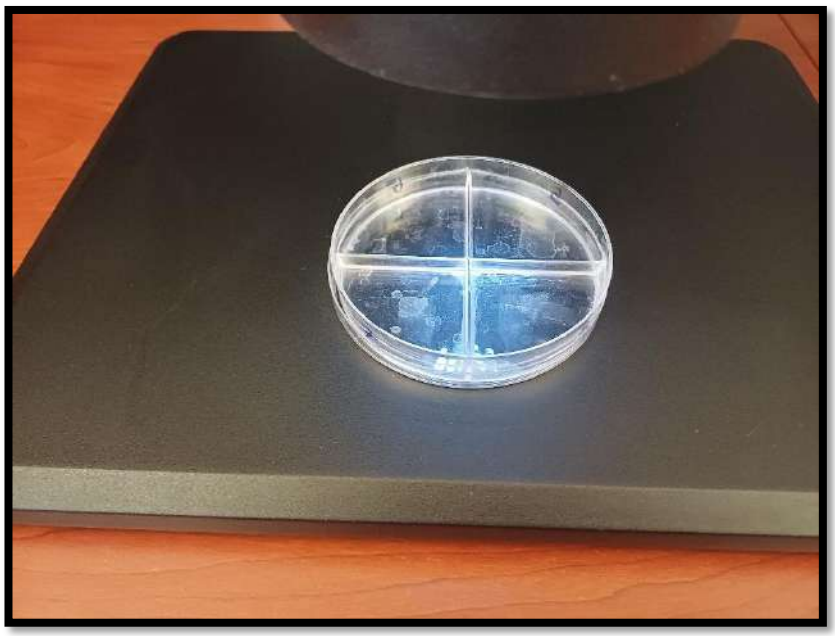


Figure 5. Zebra balığı (*Danio rerio*) embriyolarının deneysel fotoperiyot uygulamalarında inkübasyonu için kullanılan dört bölmeli Petri kabı.

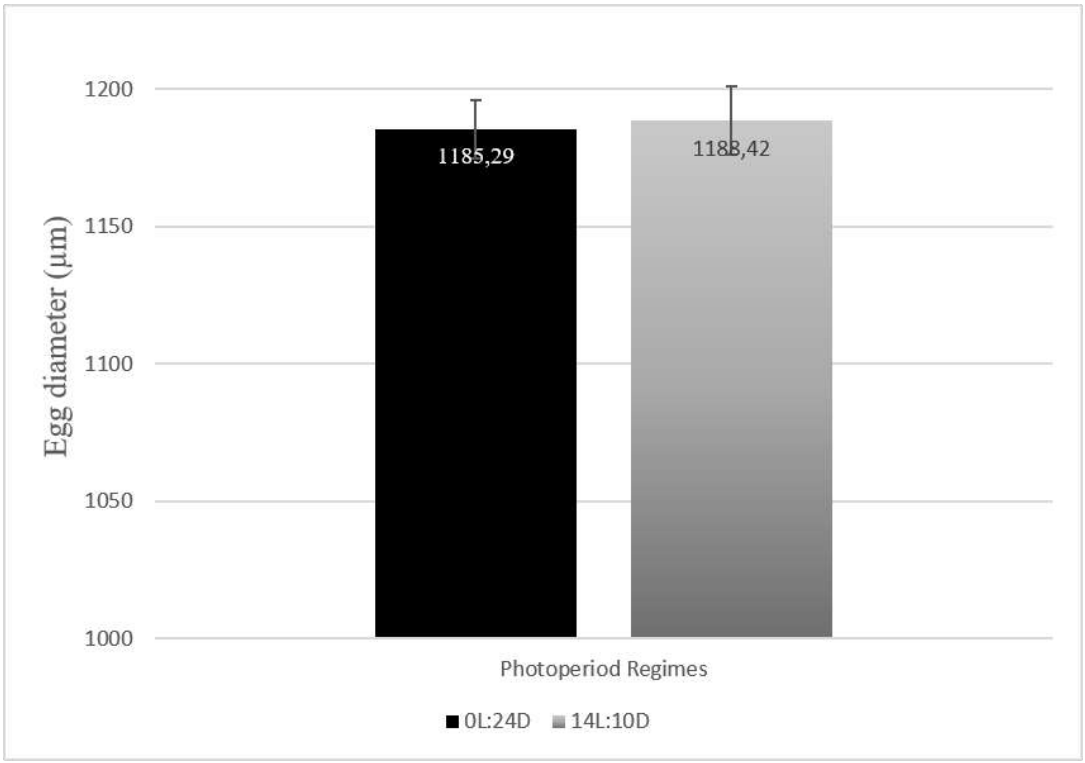
Throughout the experimental period, the embryos were maintained at 28.5 °C, and survival and developmental characteristics were regularly monitored during embryonic development. As an early behavioural endpoint, spontaneous tail coiling (STC) activity was assessed at 24 hpf, whereas hatching success and cardiac activity were evaluated at the corresponding developmental stages. The obtained data were compared between the experimental groups to assess the effects of different photoperiod regimes on early embryonic development in zebrafish.

Statistical Analysis

The normality of the data was assessed using the Anderson–Darling normality test. A p-value greater than 0.05 was considered to indicate no statistically significant deviation from normality. After confirming the assumption of normality, differences between the experimental groups were analysed using an independent two-sample t-test. Mean differences were evaluated using 95% confidence intervals (CIs), and statistical significance was set at $p<0.05$. Data are presented as mean ± standard deviation (mean ± SD).

Findings and Discussion

At the beginning of the experiment (0 h), the mean egg diameters of embryos exposed to continuous darkness (0L:24D) and the 14L:10D photoperiod were 1185.29 ± 10.79 µm and 1188.42 ± 12.49 µm, respectively (Figure 6). Although a slight numerical difference in mean egg diameter was observed between the groups, this difference was not statistically significant ($p = 0.387$). This finding indicates that the two photoperiod groups were comparable in terms of egg diameter at the beginning of the experiment.



*L: light; D: dark

Figure 6. Comparison of egg diameters of zebrafish (*Danio rerio*) embryos at 0 h under different photoperiod regimes.

Assessment of Spontaneous Tail Coiling (STC) Activity

In zebrafish (*Danio rerio*) embryos, spontaneous tail coiling (STC) activity was evaluated at 24 hpf as an early behavioural endpoint. At the start of the experiment, fertilised embryos were allocated to two photoperiod treatments: continuous darkness (0L:24D) and a 14 h light:10 h dark (14L:10D) cycle. At 24 hpf, spontaneous tail coiling (STC) activity was recorded under a stereomicroscope at 3× magnification for the designated observation period, and the number of tail coiling movements was quantified for each embryo (Figure 7). The data were statistically compared between the experimental groups to assess the effects of different photoperiod conditions on spontaneous motor activity during early embryonic development.

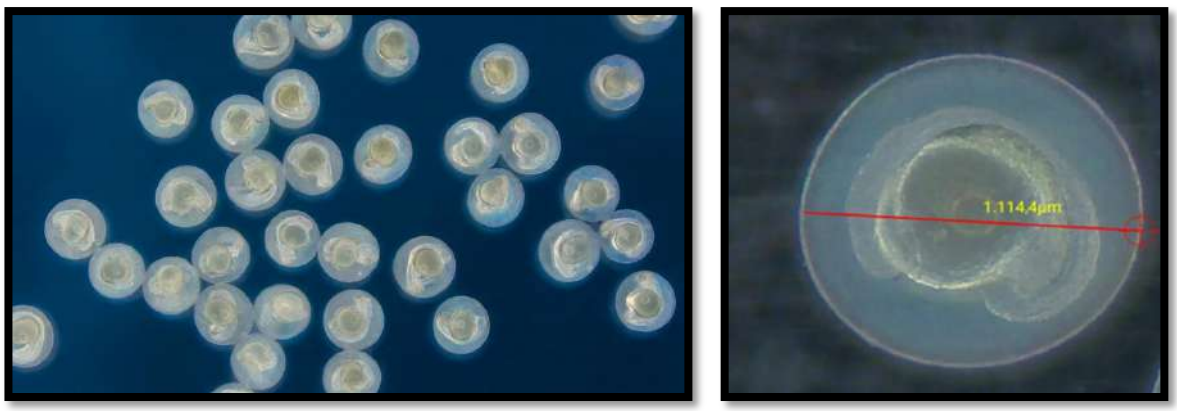
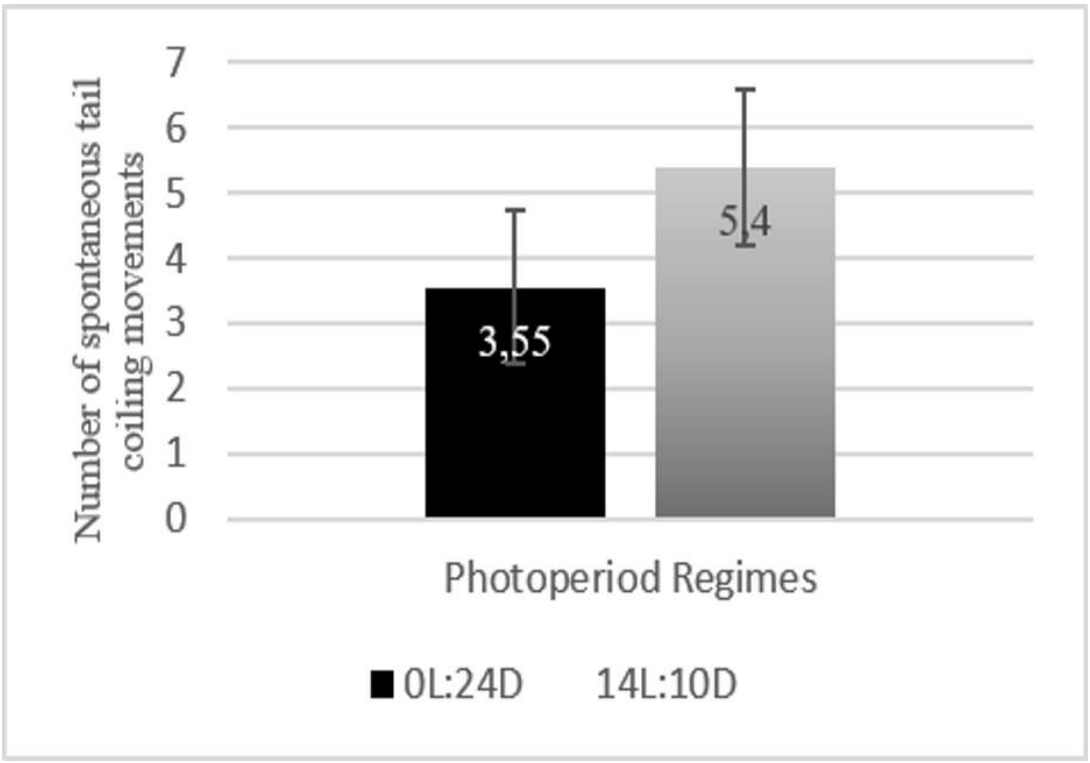


Figure 7. Developmental appearance of a zebrafish (*Danio rerio*) embryo at 24 hpf.

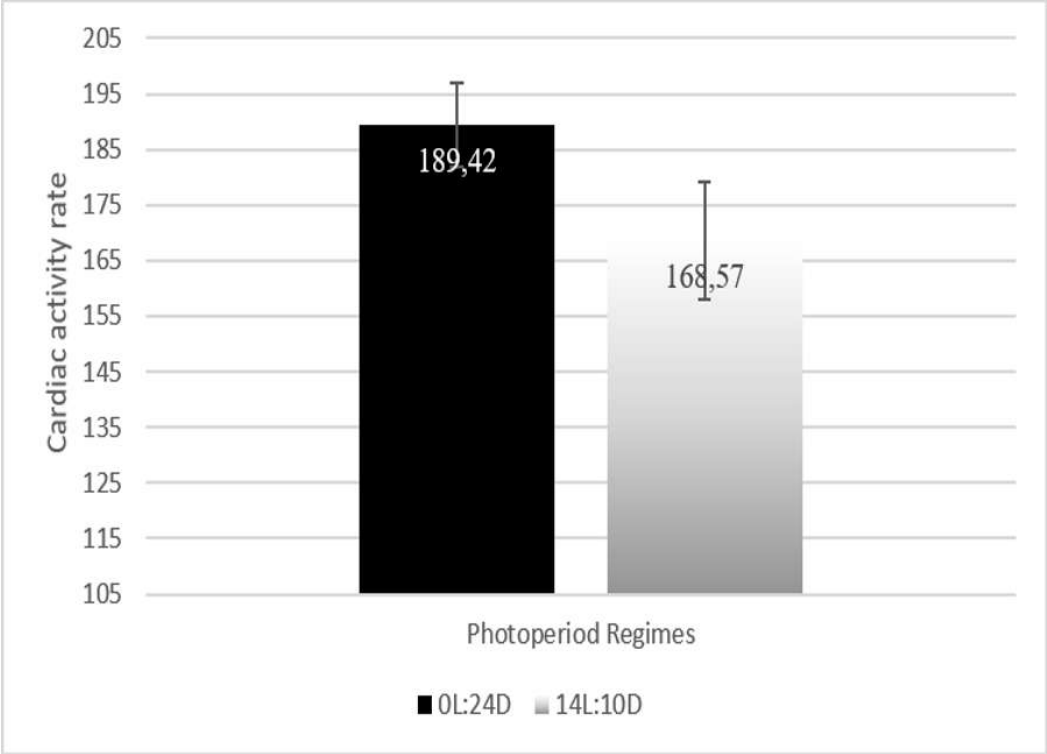


*L: light; D: dark

Figure 8. Effects of different photoperiod regimes on spontaneous tail coiling (STC) activity of zebrafish (*Danio rerio*) embryos at 24 hpf.

At 24 hpf, the mean spontaneous tail coiling (STC) activity was 3.55 ± 1.17 movements in the 0L:24D group and 5.40 ± 1.18 movements in the 14L:10D group. Embryos exposed to the 14L:10D photoperiod exhibited significantly higher STC activity than those maintained under continuous darkness (0L:24D) ($p<0.001$). This finding suggests that the 14L:10D photoperiod regime is associated with increased spontaneous motor activity in zebrafish embryos at 24 hpf. Heart rate was assessed at 72 hpf to evaluate the effects of different photoperiod regimes on cardiac activity in zebrafish (*Danio rerio*) embryos (Figures 9 and 10).

Figure 9. General view of a zebrafish (*Danio rerio*) larva at 72 hpf and a magnified image of the cardiac region used for heart rate assessment.

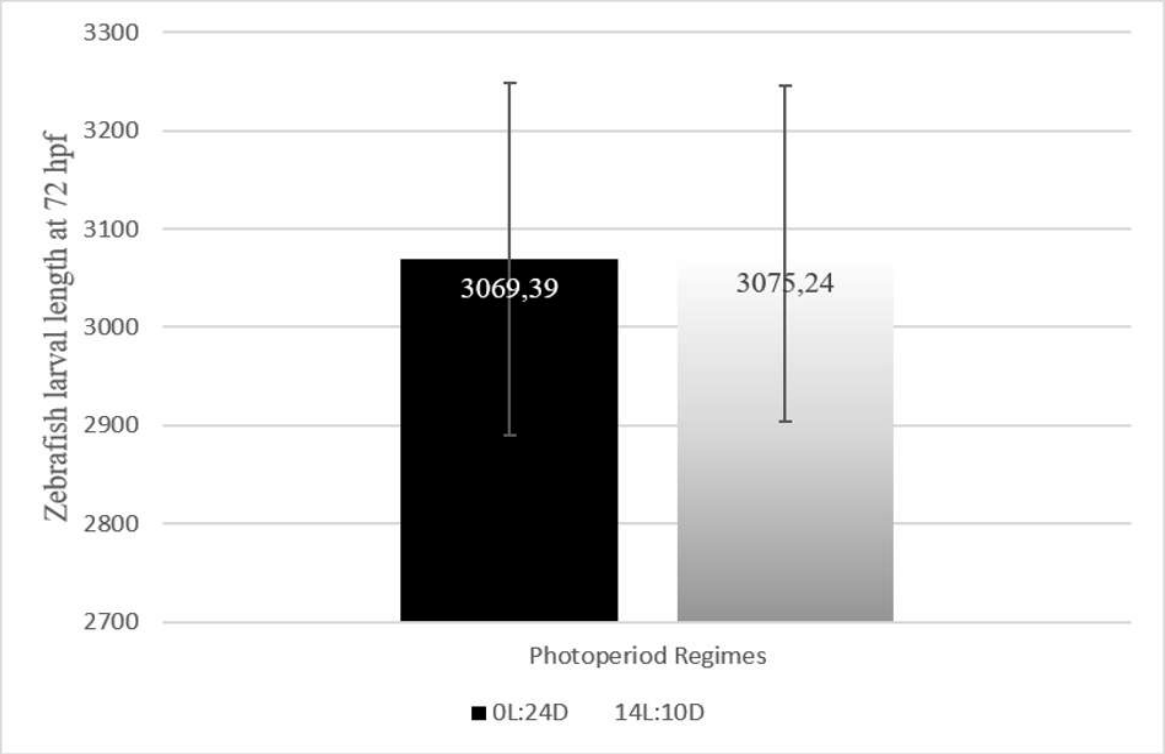


*L: light; D: dark

Figure 10. Comparison of heart rates of zebrafish (*Danio rerio*) larvae under different photoperiod regimes.

The findings indicate that cardiac activity in zebrafish (*Danio rerio*) embryos at 72 hpf differs depending on the photoperiod regime (Figure 10). At 72 hpf, the mean heart rate of zebrafish embryos was 168.60 ± 10.50 in the 14L:10D photoperiod group, whereas it was 189.43 ± 7.63 in the continuous darkness (0L:24D) group. Accordingly, cardiac activity in the 14L:10D photoperiod group was approximately 11% lower than that in the continuous darkness (0L:24D) group. According to the two-sample t-test, the difference between the groups was statistically significant ($p = 0.002$). These findings indicate that embryos maintained under continuous darkness exhibited significantly higher cardiac activity at 72 hpf compared with those exposed to the 14L:10D photoperiod.

At 72 hpf, the mean body length of zebrafish (*Danio rerio*) larvae was 3069.39 ± 179.51 µm in the 0L:24D group and 3075.24 ± 170.99 µm in the 14L:10D group (Figure 11). Although a slight numerical increase in larval body length was observed in the 14L:10D group compared with the 0L:24D group, this difference was not statistically significant ($p = 0.913$). These findings indicate that the photoperiod regimes examined did not result in a significant difference in larval body length at 72 hpf.



*L: light; D: dark

Figure 11. Comparison of body length of zebrafish (*Danio rerio*) larvae at 72 hpf under different photoperiod regimes.

Conclusion and Recommendations

The findings indicate that the photoperiod regimes did not affect all parameters to the same extent during the early developmental stages of zebrafish (*Danio rerio*), whereas behavioural and cardiac endpoints appeared to exhibit greater sensitivity to photoperiod conditions. Notably, the increased spontaneous tail coiling (STC) activity observed at 24 hpf under the 14L:10D photoperiod, together with the higher cardiac activity recorded at 72 hpf under continuous darkness, suggests that photoperiodic conditions may influence physiological and behavioural processes during early embryonic development. In contrast, the lack of a significant difference in larval length suggests that, within the 72-hour developmental period examined, photoperiod-related responses may have been more evident in certain functional endpoints than in morphometric growth. This interpretation is based on the findings obtained in the present study.

In conclusion, the findings of the present study indicate that photoperiod should be considered an important experimental variable when assessing early motor and cardiac activity in zebrafish embryos. Future studies employing larger sample sizes, a broader range of photoperiod regimes, and extended developmental periods may provide a more comprehensive understanding of the effects of photoperiod on developmental and physiological processes in zebrafish.

Institutional Review Board Statement

Under Directive 2010/63/EU, zebrafish (*Danio rerio*) are considered protected vertebrates used for scientific purposes from the stage at which larvae are capable of independent feeding, generally around 5 days post-fertilisation (120 hpf) under optimal conditions at approximately 28.5 °C. Accordingly, ethics committee approval was not required for the experimental procedures involving *Danio rerio* embryos used in the present study under the provisions of Directive 2010/63/EU.

References

Arambam, K., Singh, S. K., Biswas, P., Patel, A. B., Jena, A. K., & Pandey, P. K. (2020). Influence of light intensity and photoperiod on embryonic development, survival and growth of threatened catfish Ompok bimaculatus early larvae. *Journal of Fish Biology*, *97*(3), 740-752.

Bradshaw, W. E., & Holzapfel, C. M. (2010). Light, time, and the physiology of biotic response to rapid climate change in animals. *Annual Review of Physiology*, *72*(1), 147-166.

Chan, P. K., Lin, C. C., & Cheng, S. H. (2009). Noninvasive technique for measurement of heartbeat regularity in zebrafish (*Danio rerio*) embryos. *BMC Biotechnology*, *9*(1), 11.

European Commission. (2020). *Commission Implementing Decision (EU) 2020/569 of 16 April 2020 establishing a common format and information content for the submission of the information to be reported by Member States pursuant to Directive 2010/63/EU*. *Official Journal of the European Union, L 129*, 16–50.

Li, X., Xiao, Q., Liao, Q., Hu, C., Huang, J., Li, M., ... & Duan, P. (2025). Impairment of zebrafish (*Danio rerio*) oogenesis and F1 embryonic development by maternal methylparaben exposure: Insights from transcriptomic analysis. *Environmental Pollution*, 127610.

Ma, J., Diao, C., Zhang, Y., Kang, H., Feng, Y., Li, Y., & Li, X. (2025). Developmental effects of fenpropathrin on zebrafish (*Danio rerio*) embryo-larvae: toxic endpoints and potential mechanism. *Pesticide Biochemistry and Physiology*, *208*, 106262.

Pereira, F. B., Jablonski, C. A., Lima, M. H. L. D., Lautert-Dutra, W., Kist, L. W., Papaléo, R. M., & Bogo, M. R. (2026). PMMA Microplastics Induce Sublethal Cardiovascular and Developmental Effects During Early Development of Zebrafish (*Danio rerio*). *Microplastics*, *5*(3), 178.

Puligilla, R. D., Roos, N. J., Bolten, J. S., Hopf, N. B., Zurich, M. G., Barulin, N., & Huwyler, J. (2025). Zebrafish as a model to assess the neurotoxic potential of propylene glycol ethers. *Environmental Toxicology and Pharmacology*, *116*, 104678.

Ruchin, A. B. (2021). Effect of illumination on fish and amphibian: development, growth, physiological and biochemical processes. *Reviews in Aquaculture*, *13*(1), 567-600.

Sacksteder, R. E., & Kimmey, J. M. (2022). Immunity, infection, and the zebrafish clock. *Infection and Immunity*, *90*(9), e00588-21.

Santoso, F., Farhan, A., Castillo, A. L., Malhotra, N., Saputra, F., Kurnia, K. A., ... & Hsiao, C. D. (2020). An overview of methods for cardiac rhythm detection in zebrafish. *Biomedicines*, *8*(9), 329.

Santos-Villadangos, M., Sellés-Egea, A., Robles, V., & Valcarce, D. G. (2025). Temperature and photoperiod stress in zebrafish larvae: impacts on development, gene regulation and PGC migration. *Fish Physiology and Biochemistry*, *51*(5), 156.

Siddiqui, S., Siddiqui, H., Riguene, E., & Nomikos, M. (2025). Zebrafish: a versatile and powerful model for biomedical research. *BioEssays*, *47*(12), e70080.

Uddin, M. H., da Silva Junior, F. C., Ritu, J. R., Niyogi, S., & Chivers, D. P. (2026). Behavioural responses of fishes to abiotic stressors: A comparative synthesis of shared physiological mechanisms and ecological consequences. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, 110684.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

HATE SPEECH IN CROATIA: THE APPLICATION OF ARTICLE 325 OF THE CRIMINAL CODE AND THE BOUNDARIES OF FREEDOM OF EXPRESSION

Dijana GRACIN
Assoc. Prof. Dr., ORCID ID: 0000-0002-6732-2659, Dr. Franjo Tuđman Defense and Security University, Zagreb, Republic of Croatia

Abstract

Hate speech represents a complex legal and societal phenomenon, particularly in determining the boundary between freedom of expression and unlawful forms of expression, including public incitement to violence and hatred and the glorification of individuals responsible for serious international crimes. This paper examines the criminal-law aspects of hate speech using the Republic of Croatia as a case study, with the aim of assessing the challenges of criminal-law intervention and distinguishing protected expression from unlawful forms of expression. It analyses the relevant provisions of the Croatian Criminal Code, with particular emphasis on Article 325 concerning public incitement to violence and hatred. The Croatian legal framework is examined in the context of the constitutional protection of freedom of expression and relevant European and international human rights standards. The research adopts a qualitative legal-analytical approach, complemented by a descriptive analysis of data from the Croatian Bureau of Statistics on trends in relevant criminal offences for the 2021–2025 period. The analysis also draws on relevant judicial decisions, European and international legal instruments, institutional reports, and scholarly literature. Particular attention is given to the findings and recommendations of the European Commission against Racism and Intolerance (ECRI) concerning Croatia. Contemporary examples illustrate the difficulties of distinguishing protected expression from unlawful glorification and public incitement, including the public glorification of convicted war criminal Ratko Mladić and the display of his image accompanied by the message "Direction: Potočari" during a football match. The findings indicate that criminal-law intervention remains necessary in cases involving public incitement to violence or hatred, while its application requires careful assessment of the boundaries and proportionality of restrictions on freedom of expression. The paper highlights the need for a balanced approach that protects human dignity, equality, and public order while preserving freedom of expression in a democratic society.

Keywords: hate speech; freedom of expression; criminal law; public incitement to hatred; Croatia**.**

INTRODUCTION[1]

There is no single, universally accepted definition of *hate speech*. Nevertheless, the Council of Europe Recommendation No. R (97) 20 is commonly regarded as an important point of departure for conceptualizing the term. It defines hate speech as encompassing "all forms of expression which spread, incite, promote or justify racial hatred, xenophobia, anti-Semitism or other forms of hatred based on intolerance," including intolerance manifested through aggressive nationalism and ethnocentrism, as well as discrimination or hostility towards minorities, migrants, and persons of immigrant origin (Recommendation No. R 97/20, 1997).

Although the term *hate speech* linguistically refers to "speech," potentially suggesting verbal communication, the concept is understood more broadly and encompasses different forms of expression. It therefore extends beyond spoken or written language to include non-verbal forms of public expression, such as images, signs, symbols and gestures, where these are capable of conveying or disseminating messages of hatred, intolerance or hostility (Alaburić, 2003; Munivrana Vajda & Šurina Marton, 2016; Maršavelski, Munivrana & Sučić, 2024). Such an understanding is particularly relevant in the contemporary communication environment, in

[1] This research was conducted within the framework of the scientific research project (NPOO 581-990-1024) entitled "From Scandal to Normalization: A Theoretical and Empirical Study of Hate Speech in Contemporary Public Discourse."

which discriminatory, hateful or hostile messages may be disseminated through a wide range of public and digital communication channels.

From a criminal-law perspective, however, the qualification of forms of expression as unlawful hate speech raises complex questions concerning the boundaries between freedom of expression and the protection of individuals and groups from hatred, discrimination and violence. The issue is particularly sensitive in democratic societies, where freedom of expression constitutes a fundamental human right, while certain forms of expression may seriously undermine human dignity, equality, public order, and the rights of others. The criminal-law response must therefore be assessed within the broader framework of constitutional guarantees of freedom of expression and the applicable European and international human rights standards.

Against this background, this paper examines the criminal-law aspects of hate speech through the Republic of Croatia as a case study. Attention is devoted to the relevant provisions of the Croatian Criminal Code, especially Article 325, which criminalizes public incitement to violence and hatred and contains a specific provision concerning the public approval, denial or significant minimization of certain serious international crimes. The Croatian legal framework is examined in conjunction with the constitutional protection of freedom of expression and the relevant standards developed at the European and international levels. This research adopts a qualitative methodological approach based on the analysis of Croatian legislation, relevant judicial decisions, European and international legal instruments, institutional reports, statistical data, and relevant scholarly literature. In addition, the study analyses statistical trends in criminal offences related to hate speech, based on data published by the Croatian Bureau of Statistics for the most recent five-year period. The analysis is complemented by consideration of the findings and recommendations of the European Commission against Racism and Intolerance (ECRI) concerning Croatia, with reference to its fifth and sixth monitoring cycles, published in 2018 and 2025.

The paper also examines contemporary cases that illustrate the difficulties inherent in distinguishing constitutionally protected expression from unlawful incitement, glorification or other forms of prohibited expression. The analysis further examines the public glorification of convicted war criminal Ratko Mladić and the display of his image accompanied by the message “Direction: Potočari” during a football match. These examples illustrate the challenges of determining the limits of criminal-law intervention where expressions may contribute to the glorification of perpetrators of serious international crimes, while simultaneously raising questions concerning the scope of freedom of expression. By combining doctrinal legal analysis with an examination of statistical trends, institutional assessments and contemporary examples, the paper seeks to contribute to a more comprehensive understanding of the effectiveness and limitations of the Croatian criminal-law framework addressing hate speech.

REVIEW OF INTERNATIONAL AND NATIONAL LEGAL FRAMEWORK FOR FREEDOM OF EXPRESSION AND HATE SPEECH

Freedom of expression is a fundamental human right protected by international, European, and national legal instruments. Article 19 of the Universal Declaration of Human Rights (UDHR) guarantees the freedom to hold opinions and to seek, receive, and impart information and ideas through any media, regardless of frontiers (UN, 1948). At the European level, Article 10 of the European Convention on Human Rights (ECHR) likewise protects freedom of expression while permitting restrictions prescribed by law and necessary in a democratic society for, inter alia, national security, public safety, the prevention of disorder or crime, and the protection of the rights and reputation of others.

In Croatia, Article 38 of the Constitution guarantees freedom of thought and expression, including freedom of the press and other media, speech, public expression, and the establishment of institutions of public communication. Article 39 simultaneously prohibits and makes punishable any call for or incitement to war or violence and any form of incitement to national, racial, religious, or other intolerance. The constitutional framework therefore establishes both the protection of expression and the basis for restricting expression that exceeds legally permissible limits.

The scope of this protection must be interpreted in light of the case law of the European Court of Human Rights (ECtHR). In *Handyside v. the United Kingdom*, the Court established that Article 10 protects not only

expression that is favourably received or regarded as inoffensive, but also that which may offend, shock, or disturb. This principle defines the broad scope of protected expression while requiring careful assessment where expression may contribute to intolerance, hostility, or violence. In *Delfi AS v. Estonia*, the ECtHR addressed hate speech in the online environment and the liability of an Internet news portal for user-generated comments, illustrating the continuing need to balance freedom of expression with protection against unlawful forms of expression.

The digital environment has further complicated this balance. At EU level, the regulation of illegal online content initially developed under Directive 2000/31/EC of the European Parliament and of the Council on electronic commerce. Although the Directive established important principles concerning intermediary liability, the rapid expansion and misuse of social media exposed limitations in this framework and contributed to the development of a more comprehensive EU approach to online platforms. The protection of fundamental rights online is also reflected in UN Human Rights Council Resolution 20/8 of 29 June 2012, which affirmed that the same rights enjoyed offline must also be protected online.

Within Croatian criminal law, the Criminal Code, in force since 1 January 2013 and subsequently amended, introduced Article 325, *Public Incitement to Violence and Hatred*. According to the Government's explanatory memorandum, its introduction was, inter alia, intended to implement Council Framework Decision 2008/913/JHA of 28 November 2008 on combating certain forms and expressions of racism and xenophobia by means of criminal law. Article 325 expressly recognizes the Internet as a means through which the offence may be committed, thereby adapting criminal-law protection to contemporary forms of public communication. Article 325(1) criminalizes public incitement to violence or hatred directed against a group or a member of a group on grounds including race, religion, national or ethnic origin, language, descent, colour, gender, sexual orientation, gender identity, disability, or another characteristic, and provides for imprisonment of up to three years. Paragraph 2 establishes a more serious form of liability for organizing or leading a group of three or more persons for the purpose of committing the offence, punishable by imprisonment of six months to five years, while paragraph 3 provides for imprisonment of up to one year for participation in such an association. Paragraph 5 establishes liability for an attempt to commit the offences referred to in paragraphs 1 and 2.

Particularly relevant to the relationship between freedom of expression, hate speech, and the public treatment of international crimes is Article 325(4). It extends the punishment prescribed in paragraph 1 to public approval, denial, or gross trivialization of genocide, aggression, crimes against humanity, or war crimes directed against a protected group, where the conduct is carried out in a manner likely to incite violence or hatred against that group or its members. This provision is therefore particularly significant in assessing expressions involving the glorification or denial of international crimes, as its application requires not only the nature of the underlying statement but also its capacity, in context, to incite hatred or violence.

Taken together, these instruments establish a multilayered framework in which freedom of expression enjoys strong legal protection but is subject to restrictions where expression crosses the threshold into legally prohibited incitement to violence, hatred, or intolerance. The central legal challenge is therefore to maintain a proportionate balance between freedom of expression and the protection of individuals and groups from expression capable of undermining their rights, dignity, equality, or security. This challenge is particularly pronounced in the digital environment, where the speed, reach, and persistence of publicly disseminated content amplify both its potential impact and the difficulties of legal regulation.

HATE SPEECH IN CROATIA: TRENDS IN THE APPLICATION OF ARTICLE 325 OF THE CRIMINAL CODE (2021–2025)

Hate speech has attracted sustained academic, professional, and public attention in Croatia. Vesna Alaburić was among the first to systematically examine the theoretical and practical aspects of restricting hate speech (Alaburić, 2003), followed by scholarship addressing its constitutional (Gardašević, 2021), political (Cvijanović, 2016), sociological (Begić cited in Maršavelski, Munivrana & Sučić, 2024: 282), linguistic, and media dimensions (Poljak, Hadžić & Martinić, 2020). The issue has also been addressed in interdisciplinary publications and civil-society reports (Maršavelski, Munivrana & Sučić, 2024).

More recent research has focused on online hate speech, particularly its dynamics and regulation on social media (Roksandić Vidlička & Mamić, 2018), as well as its cross-border and regional dimensions (Maršavelski & Boras, 2024). Criminal-law scholarship has examined the constituent elements of public incitement to violence and hatred (Vukušić, 2023), comparative perspectives (Herceg Pakšić & Habrat, 2022), and the relevant case law of the European Court of Human Rights (Đurđević, 2011). Although some studies address Croatian judicial practice, the application of Article 325 of the Criminal Code has not been sufficiently examined through systematic analysis of recent empirical data.

The issue has also generated significant debate concerning misdemeanour-law regulation, particularly the use of the slogan *Za dom spremni* ("For the Homeland – Ready"), including following the 2021 statement of the High Misdemeanour Court. These developments illustrate the continuing difficulty of distinguishing protected expression from conduct warranting criminal or misdemeanour-law intervention.

A systematic examination of Croatian judicial practice was previously undertaken in the *Croatian Yearbook of Criminal Law and Practice*, based primarily on a qualitative analysis of final judgments concerning Article 325, with only limited reference to available misdemeanour judgments (Munivrana & Šurina, 2016). Since then, the legal, social, and technological environment has changed considerably, particularly with the expansion of digital communication and online public discourse.

Against this background, the present study addresses an identified empirical gap by analysing trends in the application of Article 325 in Croatia during 2021–2025. It examines available statistical data on reported offences, accused persons, indictments, and convictions to identify patterns in the criminal-law response to public incitement to violence and hatred. The study thus complements predominantly doctrinal, qualitative, and case-law-based research with a quantitative perspective on the contemporary enforcement of Article 325.

Table 1. Trends in the number of reported, accused and convicted persons in Croatia (2021–2025) Source: Croatian Bureau of Statistics. Data processing: Author.

	offence	reported	female	dismissed	accused	convicted	prison	suspend.	fine	note
2021	Art 325. Para 1	80	0	30	37	16	14	13	2	
2022	Art 325. Para 1	33	1	19	9	8	8	8	0	
2023	Art 325. Para 1	29	0	10	6	5	5	5	0	Para 4. 2
2024	Art 325. Para 1	32	0	17	8	8	5	3	0	Para 4. 2
2025	Art 325. Para 1	67	0	43	19	18	17	16	3	Para 4 . 2

The descriptive analysis (see Table 1) shows fluctuations in the number of reported persons during the observed period, while a substantial proportion of criminal complaints were dismissed. Approximately one third of reported persons were ultimately accused, whereas the majority of accused persons were convicted. A suspended sentence of imprisonment was the most frequently imposed sanction. All persons included in the analysis were reported for the basic form of the offence under Article 325(1) of the Criminal Code. These findings identify patterns in the criminal-law response but, given the descriptive nature of the data, do not permit reliable conclusions concerning their underlying causes or determinants.

The empirical findings must also be understood in light of the inherent difficulty of establishing and proving hate speech, particularly when distinguishing protected freedom of expression from criminally prohibited incitement to hatred and related forms of unlawful expression. Against this legal and empirical background, the analysis next considers the findings of the European Commission against Racism and Intolerance (ECRI) and examines two selected case studies, which illustrate the practical application of the relevant legal standards and the boundaries between protected expression and criminally punishable hate speech.

ECRI FINDINGS ON HATE SPEECH IN CROATIA

The European Commission against Racism and Intolerance (ECRI), in its reports on Croatia, has repeatedly drawn attention to shortcomings in the national legal framework for combating racism and hate speech. In its 2018 report, ECRI found that the Croatian Criminal Code was not yet fully aligned with its General Policy Recommendation No. 7 on national legislation to combat racism and racial discrimination. Although Articles 139, 147 and 149 of the Criminal Code criminalize threats, insult and defamation, respectively, ECRI identified gaps concerning the grounds of discrimination covered by the relevant criminal-law provisions. In particular, ECRI noted that the ground of citizenship was not expressly included. While the Croatian authorities argued that the relevant provisions should be read in conjunction with Article 87(21) of the Criminal Code, which provides for an aggravating circumstance where an offence is committed on account of the victim's race, colour, religion, national or ethnic origin, language, disability, gender, sexual orientation or gender identity, ECRI nevertheless considered that further alignment with GPR No. 7 was necessary. Accordingly, it recommended, inter alia, that the Criminal Code include citizenship among the relevant grounds, criminalize incitement to discrimination, prohibit the public expression, with a racist aim, of ideologies asserting the superiority of or denigrating groups on specified grounds, and criminalize the production and storage of written, pictorial or other material containing racist manifestations. The 2025 ECRI report indicates that these concerns remain relevant, noting that Croatian criminal legislation on hate speech was examined in detail in its previous report and that most of the earlier findings and recommendations continue to apply. Although Article 325(1) of the Criminal Code remains the principal provision concerning hate speech, ECRI observes that hate speech is also frequently addressed through misdemeanour law, including following legislative changes introduced in 2023 that increased the maximum fine for disturbing the peace through the use of symbols or salutes expressing or inciting hatred. More broadly, ECRI expresses serious concern about the widespread presence of hate speech in political discourse, public spaces and online environments in Croatia, identifying LGBTI persons, Roma and ethnic Serbs among the groups most frequently targeted by negative narratives. A substantial proportion of racist hate speech continues to be associated with the display of symbols and slogans of the fascist and ultranationalist "Ustaša regime", including the salute "Za dom spremni" (*engl. For the Homeland – Ready!")* particularly during public events and in connection with sporting competitions. ECRI also highlights the occurrence of such incidents among young people, including at school graduation events and trips, as well as the prevalence of hate speech in connection with football matches. In addition, the online environment represents a significant context for the dissemination of hate speech: according to a 2021 survey cited by ECRI, 62% of respondents, predominantly young people, reported encountering hate speech online during the preceding year, while research concerning the 2024 electoral campaign indicated that social media platforms were used by politicians and their supporters to disseminate polarising narratives, including anti-LGBTI and anti-migrant content (ECRI, 2025). Taken together, the 2018 and 2025 ECRI reports demonstrate both the persistence of structural shortcomings in the legal framework and the continuing prevalence of hate speech across political, public, sporting and digital contexts in Croatia.

ANALYSIS OF CONTEMPORARY CASES: CONTEXTUAL AND LEGAL ASSESSMENT

Case study 1 - Ratko Mladić – "Serbian Hero"– Contextual and Legal Assessment

The statement "Ratko Mladić – Serbian hero" cannot, in isolation, automatically be classified as the criminal offence of publicly inciting violence or hatred under Article 325(1) of the Croatian Criminal Code. The constituent elements of the offence require an assessment of whether the expression is directed against a group or a member of a group on account of a legally protected characteristic and whether, in substantive terms, it amounts to incitement to violence or hatred. Considered separately, the statement contains neither an explicit call for violence nor an express incitement to hatred against a protected group. It may nevertheless constitute the glorification of a person convicted of genocide and other international crimes, thereby carrying significant social and historical implications without necessarily reaching the criminal-law threshold for incitement.

The legal assessment may differ where the statement is accompanied by material that expressly or implicitly approves Mladić's crimes, portrays violence against a protected ethnic or national group as justified or necessary, or advocates similar conduct. Such circumstances may also engage Article 325(4), particularly where the glorification amounts to public approval, denial, or gross trivialization of genocide, aggression, crimes against humanity, or war crimes, provided that the other statutory requirements are satisfied. The decisive issue is therefore not merely whether a person convicted of international crimes is praised, but whether the expression approves or justifies the relevant criminal conduct in a manner capable of inciting hatred or violence against a protected group. Thus, "Ratko Mladić – Serbian hero" should be distinguished from a statement such as "Ratko Mladić was a hero because what he did in Srebrenica was necessary to defend the Serbian people", which expressly justifies conduct associated with an international crime and consequently provides a materially stronger basis for considering Article 325(4).

Any such assessment must also comply with Article 10 of the European Convention on Human Rights, which protects not only ideas that are favourably received or regarded as inoffensive, but also expression that may offend, shock, disturb, or provoke. Restrictions must have a legal basis, pursue a legitimate aim, and be necessary in a democratic society. The European Court of Human Rights accordingly applies a contextual approach, taking into account the content and wording of the expression, its context, purpose, manner of dissemination, potential impact, and other relevant circumstances. The fact that an expression is historically revisionist, offensive, or morally objectionable does not, without more, remove it from the protection of Article 10.

Accordingly, the legal assessment should consider whether a protected group is identifiable, whether the expression was public, its precise wording, the immediate and broader context, the speaker's purpose or intent insofar as legally relevant, and whether the expression was objectively capable of inciting violence or hatred. References to Mladić in connection with Srebrenica, explicit approval of the killing or expulsion of Bosniaks, denial of the established facts of genocide, or calls for similar conduct could materially alter that assessment.

Thus, "Ratko Mladić – Serbian hero", taken in isolation, should not automatically be classified as hate speech or as the criminal offence under Article 325 of the Croatian Criminal Code. Its criminal-law relevance depends on the broader communicative context and, in particular, on whether the glorification amounts to public approval of international crimes in a manner capable of inciting hatred or violence against a protected group. The legally relevant distinction is therefore not simply between a positive and negative attitude towards Ratko Mladić, but between protected, albeit provocative or historically revisionist, expression and expression which, having regard to its content and context, approves or glorifies international crimes in a manner capable of inciting hatred or violence. This approach is consistent with Article 325 of the Croatian Criminal Code and the contextual and proportionality-based requirements of Article 10 of the ECHR.

Case Study 2: Display of Ratko Mladić's Image with the Message "Direction: Potočari" at a Football Match – Contextual and Legal Assessment

This case concerns the display of a photograph of Ratko Mladić accompanied by the message "PRAVAC POTOČARI" ("Direction: Potočari") during the 180th Belgrade derby between Red Star and Partizan on 6 September 2026 at the Rajko Mitić Stadium in Belgrade. The display, reportedly accompanied by a minute of

silence in honour of Mladić, prompted reactions and complaints, including from the Srebrenica–Potočari Memorial Centre, which subsequently addressed the matter to the Football Association of Serbia (FSS), UEFA officials, and the FARE network (Softić, 2026).

According to the Memorial Centre, the FSS did not provide a substantive response or take adequate disciplinary action. The Centre therefore escalated the matter to Aleksander Čeferin, UEFA President; Theodore Theodoridis, UEFA Secretary General; Martin Kallen, UEFA Executive Director; and Piara Powar, Executive Director of FARE. FARE has cooperated with UEFA since 2001 in monitoring discriminatory and racist incidents in football and in collecting material potentially relevant to disciplinary proceedings (HINA, 2026). The Memorial Centre stated that it had received assurances that FARE would recommend the suspension of the FSS from UEFA competitions. However, such an alleged recommendation must be distinguished from any formally adopted UEFA disciplinary decision.

The Centre also referred to previous incidents involving the glorification of Mladić at football matches, including a banner stating "General, eternal glory and gratitude" displayed following a Red Star Belgrade–Viktoria Plzeň match and subsequently disseminated through the club's official communication channels. It argued that the recurrence of comparable displays indicates that previous sanctions have been insufficient. The Centre further invoked Article 29(4) of the UEFA Disciplinary Regulations, arguing that UEFA may intervene where a national association fails to prosecute a serious infringement of its statutory objectives or handles such a matter inappropriately (HINA, September 7, 2026; Softić, 2026).

From a legal perspective, the incident illustrates the difficulty of distinguishing between protected expression, glorification of persons convicted of international crimes, and conduct capable of engaging criminal or disciplinary liability. The slogan "Direction: Potočari" acquires particular significance when considered together with Mladić's image and the stadium context. Potočari is directly associated with the Srebrenica genocide, for which Mladić was convicted by the International Criminal Tribunal for the former Yugoslavia and whose convictions were upheld on appeal. Accordingly, the combination of the image, slogan, commemorative gesture, and circumstances of public dissemination may convey a substantially different message from an isolated expression praising Mladić.

Nevertheless, the factual occurrence of the display, the interpretation advanced by the complainant, and the legal qualification of the conduct must be distinguished. The presence of a particular image or slogan does not, in itself, establish either a criminal offence or a disciplinary violation. The legal assessment requires consideration of the precise content and combination of the displayed material, its historical and immediate context, the circumstances and manner of dissemination, the intended or objectively discernible message, and its potential to promote or incite hatred or violence against a protected group. The recurrence of similar incidents and the institutional context may additionally be relevant to determining the significance and foreseeable impact of the expression.

The case therefore demonstrates why the assessment of alleged hate speech or glorification cannot be based solely on the literal wording of a slogan. Where an expression combines the image of a person convicted of genocide with a reference strongly associated with the site of the crime, the contextual relationship between the elements may substantially strengthen its potential legal significance. At the same time, any criminal-law qualification must remain subject to the applicable statutory requirements, while disciplinary responsibility must be assessed independently under the relevant football regulations.

CONCLUSION

Taking into account the limitations of the research, the findings indicate that addressing hate speech in Croatia requires a comprehensive approach extending beyond the criminal-law framework of Article 325 of the Criminal Code. The empirical analysis for 2021–2025 identified fluctuations in reported persons, a substantial proportion of dismissed criminal complaints, approximately one third of reported persons ultimately being accused, and a high proportion of convictions among those accused, with suspended imprisonment being the most frequently imposed sanction. As the analysis is descriptive, these patterns should not be interpreted as establishing their underlying causes or determinants.

The selected contemporary case studies, including the public glorification of convicted war criminal Ratko Mladić and the display of his image accompanied by the message "Direction: Potočari" at a football match,

further demonstrate the difficulty of distinguishing protected expression from unlawful glorification, approval of international crimes, and incitement to hatred or violence. Such cases require a contextual and proportionate assessment of the content and wording of the expression, its purpose and circumstances, its potential impact, and the applicable criminal-law and misdemeanour provisions, while taking into account the protection afforded by freedom of expression.

Criminal-law intervention remains necessary where the statutory threshold for public incitement to violence or hatred is satisfied. At the same time, an effective response cannot rely exclusively on criminal sanctions. Preventive and institutional measures, including digital and media literacy, awareness-raising among young people, and strengthening the competencies of judicial and law-enforcement institutions, are also relevant. In this regard, Marsavelski et al. (2024) emphasize the need for systematic training of judges, prosecutors, and police officers concerning the specific characteristics of hate speech and the applicable legal framework. Such measures may contribute to greater consistency in the interpretation and application of relevant provisions and to a more effective and proportionate institutional response.

Overall, the findings support a balanced, context-sensitive, and multi-level approach to hate speech that combines appropriate legal intervention with prevention, education, and institutional capacity-building. Such an approach must protect individuals and groups from unlawful incitement and glorification of serious international crimes while preserving the fundamental role of freedom of expression in a democratic society.

REFERENCES

Alaburić V 2003. Ograničavanje „govora mržnje“ u demokratskom društvu – teorijski, zakonodavni i praktički aspekti - I. dio, II. dio, *Hrvatska pravna revija*, 3 (1 i 2): 1-18; 1-16.

Constitution of the Republic of Croatia, Official Gazette Nos. 56/90, 135/97, 8/98, 113/00, 124/00, 28/01, 41/01, 55/01, 76/10, 85/10, 5/14.

Convention for the Protection of Human Rights and Fundamental Freedoms.1950. adopted by the Council of Europe on 4 November 1950.

Criminal Code of the Republic of Croatia, Official Gazette Nos. 125/11, 44/12, 56/15, 61/15, 101/17, 118/18, 126/19, 84/21, 114/22, 114/23, 36/2024, 136/25

Croatian Bureau of Statistics (2021-2025 Reports). Available at: https://www.dzs.hr

Cvijanović H 2016. Govor kao verbalni i simbolički prostor slobode i političkog: američki poučak i govor mržnje u EU i Hrvatskoj, u: Kulenović E. (ur.), Govor mržnje u Hrvatskoj, Fakultet političkih znanosti, Zagreb, p. 61–121.

Đurđević Z 2011. Sloboda izražavanja: čl. 10 Europske konvencije za zaštitu ljudskih prava i temeljnih sloboda, u: Radačić I (ur.), Usklađenost hrvatskog zakonodavstva i prakse sa standardima Europske konvencije za zaštitu ljudskih prava i temeljnih sloboda, CMS, Zagreb, p. 152–189.

ECHR 1976. *Handyside v. the United Kingdom*, Application no. 5493/72, Judgment of 7 December 1976, Series A no. 24. Par. 49.

Gardašević Đ 2021. Pravna analiza govora mržnje, *Pravnik : časopis za pravna i društvena pitanja*, 55(107): 9–35.

Herceg Pakšić B, Habrat D 2022. Comparative Views on a Permanent Challenge: Hate Speech sanctioning in Poland and Croatia, ECLIC, pp. 289–314.

Hina 2026. Navijači u Srbiji izvjesili Mladićevu zapovijed. Odgovorile im Majke Srebrenice. Available at: https://www.index.hr/vijesti/clanak/navijaci-zvezde-i-partizana-slavili-ratka-mladica-stigla-reakcija-majki-srebrenice/2831698.aspx?index_ref 07.09.2026.

Index 2026. Available at: https://www.index.hr/vijesti/clanak/navijaci-zvezde-i-partizana-slavili-ratka-mladica-stigla-reakcija-majki-srebrenice/2831698.aspx?index_ref

Maršavelski A, Boras A 2024. Govor mržnje u Bosni i Hercegovini i regiji: Regulatorni izazovi i prijedlozi za reformu, u: Dvadeset godina reforme krivičnog zakonodavstva u Bosni i Hercegovini, OSCE, Sarajevo.

Maršavelski A, Munivrana M, Sučić I 2024. Izazovi u procesuiranju i sankcioniranju govora mržnje *Hrvatski ljetopis za kaznene znanosti i praksu* , 31(2): 279-306.

Munivrana Vajda M, Šurina Marton A 2016. Gdje prestaju granice slobode izražavanja, a počinje govor mržnje?... *Hrvatski ljetopis za kaznene znanosti i praksu*, 23(2): 435-467.

Poljak M, Hadžić J, Martinić M 2020. Govor mržnje u hrvatskom medijskom prostoru, *In Medias Res*, 9(17): 2709–2744.

Recommendation No. R 97/20 on "hate speech" adopted by the Committee of Ministers of the Council of Europe on 30 October 1997.

Roksandić Vidlička S, Mamić, K 2018. Zlouporaba društvenih mreža u javnom poticanju na nasilje i mržnju i širenju lažnih vijesti: Potreba transplantiranja njemačkog Zakona o jačanju provedbe zakona na društvenim mrežama, *Hrvatski ljetopis za kazneno pravo i praksu*, 25(2):329–357.

Softić I 2026. 'Direction Potocari': From Srebrenica genocide to a Belgrade football match Serbia's Red Star fans honoured convicted war criminal Ratko Mladic. Analysts say that's nothing new – and that's the problem. Al Jazeera, 7 Sep 2026. Available at: https://www.aljazeera.com/amp/features/2026/9/7/direction-potocari-from-srebrenica-genocide-to-a-belgrade-football-match?utm_source=

The European Commission against Racism and Intolerance (ECRI) 2018. ECRI REPORT ON CROATIA (fifth monitoring cycle). Available at: http://www.coe.int/ecri

The European Commission against Racism and Intolerance (ECRI) 2025. ECRI REPORT ON CROATIA (sixth monitoring cycle). Available at: http://www.coe.int/ecri

UN 1948. Universal Declaration of Human Rights, adopted and proclaimed by United Nations General Assembly Resolution 217 A (III) of 10 December 1948.

United Nations Human Rights Council. 2008. Council Framework Decision 2008/913/JHA of 28 November 2008.

Vukušić I 2023. Comparative and dogmatic issues of hate speech-traditional and modern acts of commission, *EU and Comparative Law Issues and Challenges Series (ECLIC)*, 7: 225–248.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

EUROPEAN UNION ENLARGEMENT TO THE EAST AND CHANGES IN THE MEDIATION LEGISLATION WITHIN THE REPUBLIC OF MOLDOVA

Corneliu Tuni
Mihai Susanu
Consortiul National al Institutiilor de Invatamant Academia de Studii Economice din Moldova si Universitatea de Studii Politice si Economice Europene "Constantin Stere"
Iasi, Romania
Consortiul National al Institutiilor de Invatamant Academia de Studii Economice din Moldova si Universitatea de Studii Politice si Economice Europene "Constantin Stere"
Iasi, Romania

Abstract

The accession process of the Republic of Moldova to the European Union entails the progressive approximation of national legislation to European standards, including access to justice and alternative dispute resolution. This paper examines how European Union enlargement to the East shapes the evolution of mediation legislation in Moldova, assessing the extent to which the legal framework, which evolved from Law No. 137/2015 to the new Law No. 9/2026 on mediation and the status of mediators, corresponds to Directive 2008/52/EC and to the European policy of promoting amicable settlement. Attention is devoted to the legal status of mediators, the enforceability of mediated settlement agreements, confidentiality guarantees, the relationship between mediation and judicial proceedings, and the institutional transition from the Mediation Council to the Union of Mediators.

Methodologically, the study combines doctrinal analysis of national and European legal instruments with a comparative examination of reforms in Central and Eastern European states during previous enlargement waves, identifying transferable practices and recurrent difficulties. The paper argues that accession-driven legislative reform has strengthened the normative foundations of mediation, enhanced procedural predictability, and created the conditions for a gradual decongestion of the courts. Nevertheless, persistent obstacles remain, including limited public awareness, insufficient financial incentives, uneven professional training, and the caution of legal practitioners towards extrajudicial settlement. The analysis further considers the potential of mediation in commercial, family, and cross-border disputes, supporting investor confidence and social cohesion under geopolitical pressure.

The study concludes that full convergence with European standards requires not only legislative refinement, such as stronger incentives and the careful calibration of the newly introduced mandatory elements, but also sustained institutional capacity-building and cultural acceptance of consensual dispute resolution. Mediation is presented as an indicator of Moldova's broader rule-of-law transformation and as a practical instrument for consolidating European integration and public trust in justice institutions.

Keywords: European Union enlargement; Republic of Moldova; mediation legislation; alternative dispute resolution; Directive 2008/52/EC; access to justice

INTRODUCTION

The accession process of the Republic of Moldova to the European Union has moved from an aspiration to a structured negotiation. Moldova was granted candidate status on 23 June 2022, the first intergovernmental conference took place on 25 June 2024, and the "Fundamentals" cluster – which includes Chapter 23 (Judiciary and fundamental rights) and Chapter 24 (Justice, freedom and security) – was opened on 15 June 2026, followed by the "Internal market" cluster, including Chapter 28 (Consumer and health protection), on 13

October 2026 (Council of the EU, 2026a; 2026b). Under the revised enlargement methodology, the "Fundamentals" cluster is the first to be opened and the last to be closed, which places the functioning of the justice system at the centre of the whole accession process.

Alternative dispute resolution is part of this agenda. The EU acquis in this field is relatively small in volume – Directive 2008/52/EC on certain aspects of mediation in civil and commercial matters, Directive 2013/11/EU on consumer alternative dispute resolution and the mediation-related provisions of family law instruments such as Regulation (EU) 2019/1111 – but it reflects a broader European policy, expressed since the Tampere European Council of 1999, of promoting amicable settlement as a component of access to justice and of an efficient internal market. For a candidate state, the alignment of mediation legislation is therefore both a legal obligation and an indicator of the quality and efficiency of its justice system.

Moldova offers a particularly instructive case. For a decade, mediation was governed by Law No. 137/2015 on mediation, a modern but largely voluntary framework that produced modest results. A judicial mediation stage introduced in the Code of Civil Procedure in 2017 failed and was abolished in 2022. Law No. 9/2026 on mediation and the status of mediators, published on 12 March 2026 and in force since 12 September 2026, replaced the Mediation Council with a self-governing Union of Mediators, introduced licensing and – most significantly – made participation in at least one mediation session mandatory before filing certain civil, family and labour claims. Moldova has thus moved from a model close to the Romanian one, in which mediation is purely voluntary, to a model close to the Italian, Greek or Lithuanian ones, in which a limited mandatory element is used to overcome what De Palo et al. (2014) called the "EU mediation paradox": the proven benefits of mediation contrasted with its use in less than 1% of civil and commercial disputes.

This paper examines how EU enlargement to the East shapes the evolution of mediation legislation in Moldova. It asks three questions: (i) to what extent the Moldovan framework corresponds to Directive 2008/52/EC and to the European standard derived from the case law of the Court of Justice of the EU; (ii) what lessons can be drawn from the reforms of Central and Eastern European (CEE) states during previous enlargement waves; and (iii) which obstacles still prevent mediation from becoming an effective instrument of access to justice.

MATERIALS AND METHODS

The study combines doctrinal and comparative legal analysis. The doctrinal component examines the EU instruments mentioned above, the case law of the Court of Justice of the EU on mandatory out-of-court procedures – Alassini (Joined Cases C-317/08 to C-320/08), Menini (Case C-75/16) and Investcapital (Case C-658/23) – and the relevant Council of Europe standards, in particular Recommendation R(98)1 on family mediation and the guidelines of the European Commission for the Efficiency of Justice (CEPEJ). On the national side, it analyses Law No. 137/2015, Law No. 9/2026, the Code of Civil Procedure, the Law on State Fee No. 1216/1992 and the Law on consumer protection No. 105/2003, as amended by Law No. 342/2023.

The comparative component covers Romania, Bulgaria, Croatia, Lithuania and the Czech Republic, states that joined the EU in the 2004, 2007 and 2013 waves and that adopted different solutions regarding the voluntary or mandatory character of mediation. The selection follows the "most similar systems" logic: all are post-socialist civil law jurisdictions that had to build mediation as a profession largely from scratch, under the pressure of EU accession and membership.The empirical component uses the activity report of the Mediation Council for 2025, the evaluation of judicial mediation conducted by the European Bank for Reconstruction and Development and the International Development Law Organization (EBRD and IDLO, 2023), and the opinions submitted during the legislative process by the People's Advocate, the American Chamber of Commerce in Moldova and the Expert-Grup think tank. To assess the degree of alignment, the authors apply a scorecard of six criteria derived from Directive 2008/52/EC, Directive 2013/11/EU and the Alassini–Menini case law, each scored from 0 to 2 at the formal (legislative) and operational (implementation) levels. The reference date for legislation and data is 31 October 2026.

RESULTS

From Law No. 137/2015 to Law No. 9/2026

Law No. 137/2015 introduced the main principles of Directive 2008/52/EC – voluntariness, confidentiality, neutrality and the possibility of rendering settlement agreements enforceable – and established the Mediation Council as the body responsible for the attestation and supervision of mediators. Its effectiveness depended, however, on corresponding amendments to the codes. Some of them were adopted in 2016, while others – such as the procedural consequences of a mediation clause or a coherent regime for executing settlement agreements – remained incomplete. Law No. 31/2017 added a judicial mediation stage to the Code of Civil Procedure, conducted by judges after the claim had been filed. Between 2018 and 2022, about 43,500 cases were referred to judicial mediation, but only around 2.6% were settled, and the mechanism was abolished in 2022 (EBRD and IDLO, 2023). In parallel, voluntary private mediation grew steadily, from 478 mediated cases in 2018 to 1,670 in 2022 (EBRD and IDLO, 2023) and 2,487 cases settled in 2025, of which 47.8% were civil and 45.4% commercial disputes, while family (23 cases) and labour (3 cases) disputes were almost absent (Mediation Council, 2026).

Law No. 9/2026 responds to most of the shortcomings identified in the doctrine (Chifa and Gavrilă, 2024; Dumitrașcu, 2025). It expressly suspends limitation periods during mediation (Art. 45), provides that the settlement agreement is binding, must be performed voluntarily within 20 days and may be rendered enforceable by a notary or confirmed by a court (Art. 52), and enshrines confidentiality and the prohibition of hearing the mediator as a witness (Arts. 5–6). Institutionally, licensing is entrusted to the Ministry of Justice and professional self-government to the Union of Mediators (Arts. 34–35), a solution inspired by the Romanian model of an autonomous professional body (Law No. 192/2006).

The mandatory session and its safeguards

The central innovation is the obligation to attend at least one mediation session before filing claims in certain civil disputes (Art. 55), family disputes concerning parental rights, the child's residence and maintenance (Art. 56), and certain individual labour disputes, such as reinstatement claims (Art. 57). Failure to prove attendance leads to the return of the statement of claim (Art. 47). The parties remain free to end the process after the first session, so the principle of voluntariness applies to the outcome, not to the attempt (Art. 4). The remuneration for the mandatory session is capped at one tenth of the minimum wage and is not charged in labour disputes (Art. 21(5)); the state fee is reduced by 25% if mediation preceded the claim. Divorce cases are excluded, and cases involving domestic violence cannot be mediated, in line with Article 48 of the Istanbul Convention. Claims of banks and utility providers for the recovery of debts, as well as cases involving public authorities, are also excluded, a compromise reached after the business community requested a regulatory impact assessment (AmCham Moldova, 2025). According to information published at adoption, the obligation applies in stages: after 12 months for family and labour disputes and after 24 months for civil disputes.

The compatibility of this design with EU law follows from Article 5(2) of Directive 2008/52/EC, which allows national legislation to make mediation compulsory provided that it does not prevent the parties from exercising their right of access to the judicial system. In Alassini, the Court of Justice held that a mandatory out-of-court procedure is compatible with the principle of effective judicial protection if it does not result in a binding decision, does not cause substantial delay, suspends limitation periods, does not give rise to significant costs and allows interim measures in urgent cases. Menini confirmed this test for consumer disputes and added that the consumer may not be required to be assisted by a lawyer or be penalised for withdrawing without a valid reason. In Investcapital, a reference from a Bucharest court, the Court confirmed that EU law does not preclude mandatory mediation, which Romanian scholarship has read as an invitation to reconsider the Constitutional Court's 2014 rejection of a mandatory information session (Călin, 2023).

Degree of alignment with the European standard

Table 1 presents the results of the scorecard. Formally, Law No. 9/2026 reaches 10 out of 12 points; operationally, 8 out of 12, for an overall score of 18/24 (75%).

Table 1. Alignment of Law No. 9/2026 with the European mediation standard (scores 0–2)

Criterion	Provisions of Law No. 9/2026	Formal	Operational	Justification of the operational score
C1. Quality of mediation	Licensing (Art. 16); Union of Mediators (Arts. 34–35)	2	1	Licensing and the Union became applicable only on 12.09.2026
C2. Enforceability	Notarial enforcement formula or court confirmation (Art. 52)	2	2	Notarial and judicial procedures functional
C3. Confidentiality	Arts. 5–6	2	2	Directly applicable rules
C4. Limitation periods	Suspension when mediation starts (Art. 45(1))	2	2	Directly applicable rule
C5. Access to court	Single session; capped fee (Art. 21(5)); exceptions (Arts. 44, 55–57)	1	1	Cost is not zero; no specific exemption for low-income parties
C6. Consumer protection	Consumer disputes included in the civil category (Art. 55)	1	0	Consumer ADR entities (Law No. 342/2023) not yet operational
Total		10/12	8/12	Overall score: 18/24 (75.0%)

Source: authors' assessment based on Directive 2008/52/EC, Directive 2013/11/EU, the Alassini and Menini judgments and Law No. 9/2026.

The weaker criteria concern access to court and consumer protection. Although the law limits the obligation to one session and caps its cost, there is no specific exemption for persons entitled to state-guaranteed legal aid, a concern raised by the People's Advocate, who considered that the obligation and its cost might unjustifiably restrict the right of access to justice guaranteed by Article 20 of the Constitution (People's Advocate, 2026). In consumer matters, Expert-Grup (2025) warned that subjecting consumer disputes to paid mediation, while the consumer ADR entities provided by Law No. 342/2023 are not yet functional, may weaken consumer protection – an issue that will be examined under Chapter 28, in light of Directive 2013/11/EU and its recent revision.

Lessons from Central and Eastern European states

The CEE experience shows a variety of solutions (Table 2). Romania adopted a modern law as early as 2006, amended it to transpose Directive 2008/52/EC, but the mandatory information session was invalidated by the Constitutional Court (Decision No. 266/2014) because non-attendance led to the inadmissibility of the claim; mediation remained voluntary and marginal. Bulgaria, after years of voluntary mediation, introduced from 1 July 2024 court-ordered mandatory mediation in pending cases concerning co-ownership, partition and certain corporate disputes. Croatia chose a financial rather than procedural sanction: failure to attempt mediation in certain disputes leads to the loss of the right to reimbursement of costs, while information sessions are free. Lithuania introduced, from 1 January 2020, mandatory pre-trial mediation in family disputes, with up to four hours of mediation provided free of charge through the state legal aid system (Kasiulaitė and Tvaronavičienė,

2023). The Czech Republic allows the court to order a first meeting with a mediator of up to three hours.

Table 2. Mandatory elements in the mediation legislation of selected CEE states and Moldova

State	Mandatory element	Sanction / incentive	Observation
Romania	Mandatory information session (2013–2014), invalidated	Inadmissibility of the claim (declared unconstitutional)	Mediation voluntary; debate reopened after Investcapital
Bulgaria	Court-ordered mediation in pending cases (since 1 July 2024)	Ordered by the court during proceedings	In-court model
Croatia	Attempt at mediation before certain claims	Loss of reimbursement of costs; free information sessions	Financial, not procedural, sanction
Lithuania	Pre-trial mediation in family disputes (since 2020)	Up to 4 hours free under state legal aid	Most relevant model for family mediation
Czech Republic	Court-ordered first meeting (up to 3 hours)	Ordered by the court	Low intensity
Moldova	One session before certain civil, family and labour claims (Law No. 9/2026)	Return of the claim; capped fee; 25% state fee reduction	Pre-trial model, phased application

Source: authors' compilation based on national legislation and the sources cited in the text.

Two lessons emerge. First, the location of the mandatory element matters more than its existence: the Moldovan experience of 2018–2022 shows that mediation conducted by judges after the claim has been filed does not produce settlements, whereas pre-trial sessions with professional mediators – the Italian, Lithuanian and now Moldovan model – have generated large volumes of mediations elsewhere (De Palo and Trevor, 2012). Second, the sanction must be proportionate: the Romanian case shows that inadmissibility combined with an unclear cost regime is vulnerable to constitutional review, while Croatia and Lithuania demonstrate that free or subsidised first sessions reduce this risk.

DISCUSSION

Accession as a driver of legislative reform

The Moldovan reform confirms the "external incentives" model of EU rule transfer: a credible membership perspective makes domestic actors accept reforms that had previously been postponed (Schimmelfennig and Sedelmeier, 2004). The recommendations of the EBRD–IDLO study, the screening process and the Growth Plan reform agenda converged towards a single legislative act, adopted in the same period as the analytical screening of the acquis (2025–2026). The reform has strengthened the normative foundations of mediation and increased procedural predictability: the effects of a mediation clause, the suspension of limitation periods, the enforceability of agreements and the status of mediators are now regulated at the level of law, not left to practice. In this sense, the hypothesis that accession-driven reform has contributed to legal certainty is confirmed at the normative level. Its contribution to the decongestion of courts remains, however, potential rather than demonstrated: in 2025, the 2,487 mediated settlements represented less than 1% of the more than 269,000 cases pending before the courts in 2023 (People's Advocate, 2026).

The implementation gap

The literature on previous enlargements warns that rapid transposition can coexist with weak application, producing what Falkner and Treib (2008) called a "world of dead letters", and that compliance may weaken

once conditionality is lifted (Sedelmeier, 2008). Mediation is particularly exposed to this risk because its success depends on behaviour rather than on rules. Several obstacles persist. Public awareness is limited, and Chifa and Gavrilă (2024) identify a low legal culture, legislative instability, financial pressure on mediators' offices and the lack of a united professional community as the main barriers. Financial incentives are modest: the 25% reduction of the state fee is unlikely to change the behaviour of parties with significant claims. Professional training is uneven, and all mediators certified more than two years earlier must undergo initial training to register under the new regime, while the Union of Mediators must build its organisational capacity from scratch. Legal practitioners remain cautious: lawyers may perceive mediation as a loss of fees, and judges may see the mandatory session as a formality rather than as a genuine opportunity for settlement.

An economic perspective clarifies what is at stake. The rational choice between trial and settlement depends on the expected costs and outcomes of each option, and alternative dispute resolution is efficient only if it reduces the cost of resolving disputes without weakening incentives to comply with the law (Shavell, 1995). Based on the average cost of a civil case for the courts reported by EBRD and IDLO (2023) – 4,203 lei in 2021 – and the capped fee for the mandatory session of about 630 lei in 2026, the authors estimate that the mandatory session produces net public savings only if the settlement rate exceeds roughly 15%. This threshold is far above the 2.6% achieved by judicial mediation, but well below the rates reported for voluntary mediation. The quality of the first session, rather than its existence, will therefore decide the outcome of the reform.

Commercial, family and cross-border disputes

The potential of mediation differs across categories of disputes. In commercial matters, mediation already accounts for almost half of the settlements and can support investor confidence, especially if combined with ratification of the Singapore Convention on Mediation, which provides for the cross-border enforcement of international mediated settlement agreements, and with the modernisation of arbitration legislation. In family matters, the mandatory session must be accompanied by safeguards: the screening of domestic violence, the involvement of guardianship authorities in matters concerning children, and attention to power imbalances between the parties, as required by Recommendation R(98)1. The critical literature reminds us that mediation should not become a substitute for adjudication where vulnerable parties need the protection of the courts or where public norms need to be clarified by judgments (Genn, 2010). In cross-border disputes, which are numerous given the size of the Moldovan diaspora, Law No. 9/2026 allows sessions to be held remotely and sets a longer notification period of 30 days, but the effectiveness of these rules depends on cooperation with the central authorities designated under EU and Hague instruments.

Mediation, rule of law and social cohesion

Mediation is thus an indicator of Moldova's broader rule-of-law transformation. A justice system in which parties can choose between a court judgment and a quality, affordable and enforceable consensual procedure is more accessible, more efficient and more trusted. In a society facing geopolitical pressure, polarisation and distrust in institutions, consensual dispute resolution can also contribute to social cohesion. The comparative literature emphasises, however, that the design of incentives, the role of courts and lawyers, the quality of mediators and the enforcement of agreements determine whether mediation is actually used (Alexander, 2009; Hopt and Steffek, 2013). These are precisely the elements that the accession negotiations on Chapters 23, 24 and 28 will monitor.

CONCLUSION

EU enlargement to the East has acted as a catalyst for the modernisation of mediation legislation in the Republic of Moldova. Law No. 9/2026 brings the national framework into formal alignment with Directive 2008/52/EC and with the case law of the Court of Justice, and goes further than several EU member states by introducing a limited mandatory element. The scorecard applied in this paper indicates a high level of formal alignment and a lower level of operational alignment (overall 75%), with the main gaps in access to court for low-income parties and in consumer protection.

Full convergence with European standards requires further legislative refinement and, above all, implementation. The authors recommend: (1) exempting beneficiaries of state-guaranteed legal aid from the fee for the mandatory session, following the Lithuanian model; (2) creating a single mediation information system, kept by the Union of Mediators and connected to the courts' case management system, to measure settlement rates and support an ex post impact assessment of the mandatory session 24 months after its full application; (3) operationalising the consumer ADR entities provided by Law No. 342/2023 before applying the mandatory session to consumer disputes; and (4) investing in mediator training, judicial and bar awareness, and public information. Under these conditions, mediation can become not only an element of the acquis, but a practical instrument for consolidating the European integration agenda and strengthening public trust in justice institutions.

REFERENCES

Alexander N 2009. International and comparative mediation: legal perspectives. Alphen aan den Rijn: Kluwer Law International.

AmCham Moldova 2025. Opinion No. 136 of 18.11.2025 on draft law No. 245 of 19.06.2025 on mediation and the status of mediators (second reading). Chișinău: American Chamber of Commerce in Moldova. Available at: https://amcham.md [31.10.26]

Chifa F, Gavrilă CA 2024. Barierele utilizării medierii în Republica Moldova. In: Integrare prin cercetare și inovare. Științe juridice și economice. Chișinău: CEP USM, pp. 503-509.

CJEU 2010. Judgment of 18 March 2010, Joined Cases C-317/08 to C-320/08, Rosalba Alassini and Others. ECLI:EU:C:2010:146.

CJEU 2017. Judgment of 14 June 2017, Case C-75/16, Livio Menini and Maria Antonia Rampanelli v Banco Popolare Società Cooperativa. ECLI:EU:C:2017:457.

CJEU 2024. Order of 3 September 2024, Case C-658/23, Investcapital Ltd v TK. Official Journal of the European Union, C/2024/6067.

Council of the EU 2026a. Enlargement: EU and Moldova reach a milestone in accession talks with opening of the first negotiation cluster. Press release, 15 June 2026. Available at: https://www.consilium.europa.eu/en/press/press-releases/2026/06/15/enlargement-eu-and-moldova-reach-a-milestone-in-accession-talks-with-opening-of-the-first-negotiation-cluster/ [31.10.26]

Council of the EU 2026b. Enlargement: EU and Moldova start negotiations on internal market, competitiveness and inclusive growth. Press release, 13 October 2026. Available at: https://www.consilium.europa.eu/en/press/press-releases/2026/10/13/enlargement-eu-and-moldova-start-negotiations-on-internal-market-competitiveness-and-inclusive-growth/ [31.10.26]

Călin D 2023. Refuzul Curții Constituționale a României de a accepta medierea obligatorie în analiza Curții de Justiție a Uniunii Europene. Cauza C-658/23, Investcapital. GEMME România. Available at: https://gemmeeurope.org/wp-content/uploads/2023/12/Refuzul-CCR-de-a-accepta-medierea-obligatorie-in-analiza-CJUE.pdf [31.10.26]

De Palo G, D'Urso L, Trevor M, Branon B, Canessa R, Cawyer B, Florence LR 2014. "Rebooting" the Mediation Directive: assessing the limited impact of its implementation and proposing measures to increase the number of mediations in the EU. Brussels: European Parliament, Directorate-General for Internal Policies.

De Palo G, Trevor MB (eds) 2012. EU mediation law and practice. Oxford: Oxford University Press.

Directive 2008/52/EC of the European Parliament and of the Council of 21 May 2008 on certain aspects of

mediation in civil and commercial matters. Official Journal of the European Union, L 136, 24.5.2008: 3-8.

Directive 2013/11/EU of the European Parliament and of the Council of 21 May 2013 on alternative dispute resolution for consumer disputes. Official Journal of the European Union, L 165, 18.6.2013: 63-79.

Dumitrașcu D 2025. Medierea obligatorie în cauzele civile: mijloc de eficientizare sau limitare a accesului liber la justiție? In: Integrare prin cercetare și inovare. Științe juridice și economice. Chișinău: CEP USM, pp. 492-499.

EBRD, IDLO 2023. The introduction of mandatory pre-litigation mediation for some categories of disputes in the Republic of Moldova. Chișinău: European Bank for Reconstruction and Development, International Development Law Organization.

Expert-Grup 2025. Medierea obligatorie poate îngrădi accesul consumatorilor la justiție. IPN News Agency, 8 December 2025. Available at: https://ipn.md [31.10.26]

Falkner G, Treib O 2008. Three worlds of compliance or four? The EU-15 compared to new member states. Journal of Common Market Studies, 46(2): 293-313.

Genn H 2010. Judging civil justice. Cambridge: Cambridge University Press.

Hopt KJ, Steffek F (eds) 2013. Mediation: principles and regulation in comparative perspective. Oxford: Oxford University Press.

Kasiulaitė I, Tvaronavičienė A 2023. The Lithuanian model of mandatory mediation in family disputes: an updated scheme for overcoming the mediation paradox. Kluwer Mediation Blog, 20 July 2023. Available at: https://legalblogs.wolterskluwer.com/mediation-blog/the-lithuanian-model-of-mandatory-mediation-in-family-disputes-an-updated-scheme-for-overcoming-the-mediation-paradox/ [31.10.26]

Law No. 137 of 3 July 2015 on mediation (Republic of Moldova). Monitorul Oficial al Republicii Moldova, 2015, No. 224-233, art. 445 (repealed).

Law No. 9/2026 on mediation and the status of mediators (Republic of Moldova). Monitorul Oficial al Republicii Moldova, 12.03.2026, No. 112-115, art. 89.

Mediation Council 2026. Activity report for 2025. Chișinău: Mediation Council. Available at: https://mediere.gov.md/sites/default/files/document/attachments/raport_2025.pdf [31.10.26]

People's Advocate 2026. Opinion on the Law on mediation and the status of mediators. Chișinău: Office of the People's Advocate (Ombudsman). Available at: https://ombudsman.md/wp-content/uploads/2026/04/opinie-la-legea-privind-medierea-si-statutul-mediatorului.pdf [31.10.26]

Schimmelfennig F, Sedelmeier U 2004. Governance by conditionality: EU rule transfer to the candidate countries of Central and Eastern Europe. Journal of European Public Policy, 11(4): 661-679.

Sedelmeier U 2008. After conditionality: post-accession compliance with EU law in East Central Europe. Journal of European Public Policy, 15(6): 806-825.

Shavell S 1995. Alternative dispute resolution: an economic analysis. Journal of Legal Studies, 24(1): 1-28.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

EUROPEAN UNION ENLARGEMENT TO THE EAST AND HOW LEGISLATIVE CHANGES WILL AFFECT THE ECONOMIC ENVIRONMENT OF THE REPUBLIC OF MOLDOVA

Mihai Susanu
Corneliu Tuni
Consortiul National al Institutiilor de Invatamant Academia de Studii Economice din Moldova si Universitatea de Studii Politice si Economice Europene "Constantin Stere"
Iasi, Romania
Consortiul National al Institutiilor de Invatamant Academia de Studii Economice din Moldova si Universitatea de Studii Politice si Economice Europene "Constantin Stere"
Iasi, Romania

Abstract

The European Union's eastern enlargement has entered a decisive phase following the opening of accession negotiations with the Republic of Moldova, a process that entails comprehensive alignment with the acquis communautaire. This paper examines how the resulting legislative changes are likely to reshape Moldova's economic environment, focusing on regulatory convergence in competition policy, state aid, public procurement, financial services and the protection of property rights. Moldova's trajectory is situated within previous enlargement waves, drawing on the experience of Central and Eastern European states to identify patterns of institutional adaptation and economic adjustment.

Methodologically, the research combines doctrinal legal analysis of the Association Agreement and the Deep and Comprehensive Free Trade Area (DCFTA) with a comparative assessment of macroeconomic indicators, including foreign direct investment, trade orientation and sectoral competitiveness. The paper argues that legislative harmonization is likely to enhance legal certainty, improve the investment climate and deepen Moldova's integration into European value chains, thereby supporting long-term growth. It also considers the short- and medium-term adjustment costs borne by small and medium-sized enterprises, agriculture and public administration, arising from compliance burdens, limited institutional capacity and stronger market competition. External vulnerabilities are addressed, notably energy dependence and the reorientation of trade away from eastern markets, together with the role of European financial and technical assistance in mitigating transitional costs and the implications of the unresolved Transnistrian conflict for the uniform application of EU-aligned legislation.

The paper concludes that the economic benefits of accession-driven reform depend primarily on effective implementation, administrative capacity and sustained political commitment, rather than on formal legal transposition alone, and offers policy recommendations for sequencing reforms so as to maximize economic gains while protecting vulnerable sectors.

Keywords: European Union enlargement; Republic of Moldova; legislative harmonization; acquis communautaire; DCFTA; economic convergence

INTRODUCTION

The eastern enlargement of the European Union has re-emerged as a central item on the European agenda after Russia's full-scale invasion of Ukraine in February 2022. The Republic of Moldova applied for membership on 3 March 2022, was granted candidate status by the European Council on 23 June 2022 and held the first intergovernmental conference on accession on 25 June 2024. After the analytical screening of the acquis was

completed in 2025, the process entered its decisive phase in 2026: the "Fundamentals" cluster was opened on 15 June 2026, the "External relations" cluster on 14 July 2026, and the "Internal market" and "Competitiveness and inclusive growth" clusters on 13 October 2026 (Council of the EU, 2026a; 2026b). The two economic clusters alone cover seventeen negotiating chapters, among them free movement of capital, company law, competition policy, financial services, taxation, enterprise and industrial policy, and the customs union. Moldova therefore faces, within a few years, the volume of legislative change that the Central and Eastern European (CEE) states absorbed over roughly a decade.

The domestic political mandate for this course was confirmed by the constitutional referendum of 20 October 2024, in which a narrow majority approved the inclusion of the objective of EU integration in the Constitution. At the same time, the economic base on which the reforms are being built is fragile. Real GDP grew by only 0.1% in 2024 and by 2.4% in 2025, the current account deficit has widened, and the country absorbed a severe energy shock at the beginning of 2025 (IMF, 2026; NBS, 2026b). The question of how legislative alignment will affect the economic environment is therefore not academic: it determines whether accession-driven reform will act as an engine of convergence or as an additional burden on an economy with limited adjustment capacity.

The literature on previous enlargements offers two broad expectations. The first, associated with the "external incentives" model, holds that a credible membership perspective makes domestic actors accept costly rule transfer and that the adoption of EU rules improves the quality of economic governance (Schimmelfennig and Sedelmeier, 2004; Grabbe, 2006). Econometric evidence is consistent with this view: Campos et al. (2019) estimate that, without EU membership, per capita incomes in the new member states would have been on average about 10% lower in the first ten years after accession. The second expectation is more cautious. It stresses that formal transposition can coexist with weak implementation, that compliance may deteriorate once conditionality ends, and that the benefits of the single market depend on state capacity built before and after accession (Dimitrova, 2002; Falkner and Treib, 2008; Sedelmeier, 2008; Bruszt and Vukov, 2017).

This paper applies these two lenses to the Republic of Moldova. Its objective is to examine how the legislative changes required by the pre-accession process are likely to reshape the economic environment, focusing on five areas with direct effects on market functioning: competition policy, state aid, public procurement, financial services and the protection of property rights. The paper asks three questions: (i) what has changed in Moldovan law under the Association Agreement and the accession process; (ii) what economic effects can be expected, in the light of indicators and of the experience of earlier enlargement waves; and (iii) which conditions and sequencing choices are likely to maximise the gains while protecting the most vulnerable sectors.

MATERIALS AND METHODS

The research combines doctrinal legal analysis with a comparative assessment of economic indicators. The doctrinal component examines the primary EU legal framework of enlargement (Article 49 of the Treaty on European Union and the Copenhagen criteria, see Hillion, 2004), the EU–Moldova Association Agreement (2014), signed on 27 June 2014 and fully in force since 1 July 2016, including its Deep and Comprehensive Free Trade Area (DCFTA), the decisions of the Association Committee in Trade configuration, Regulation (EU) 2025/535 establishing the Reform and Growth Facility for Moldova, and the relevant secondary legislation in the five areas studied. On the Moldovan side, the analysis covers Law no. 183/2012 on competition, Law no. 139/2012 on state aid, Law no. 131/2015 and the new Law no. 325/2025 on public procurement, Law no. 202/2017 on the activity of banks, Law no. 81/2004 on investments in entrepreneurial activity and Law no. 179/2016 on small and medium-sized enterprises, as well as the National Accession Programme for 2025–2029 updated by the Government on 29 December 2025.

The assessment of the degree of alignment relies primarily on the European Commission's 2025 Report on Moldova (European Commission, 2025), which uses a standardised five-level scale ranging from "early stage" to "well advanced", supplemented by Council conclusions and national implementation reports. The economic component uses official data from the National Bureau of Statistics (NBS), the National Bank of Moldova and the International Monetary Fund for 2024–2025, focusing on growth, trade orientation, foreign direct investment (FDI) and the use of EU financial assistance. Because the figures exclude the left bank of the Dniester, the Transnistrian region is treated separately on the basis of data from the Bureau for Reintegration Policies.

The comparative component is qualitative. It does not attempt to estimate a counterfactual for Moldova; rather, it uses the established findings of the literature on the 2004, 2007 and 2013 enlargements (Schimmelfennig and Sedelmeier, 2004; Sedelmeier, 2008; Epstein and Jacoby, 2014; Campos et al., 2019) to identify mechanisms – conditionality, administrative capacity, post-accession compliance, market integration – and to test whether the conditions under which these mechanisms produced economic gains are present in the Moldovan case. The cut-off date for legislative and statistical data is 31 October 2026.

RESULTS

The legal architecture of pre-accession alignment

Moldova enters accession negotiations with an unusually dense legal acquis already in place. The Association Agreement is not a classic trade agreement: its DCFTA requires the gradual approximation of Moldovan legislation to several hundred EU legal acts, with a mechanism by which market access is conditioned on regulatory convergence (Van der Loo, 2016; Emerson and Cenușa, 2018). Langbein and Wolczuk (2012) described this model as an attempt at "convergence without membership"; for Moldova, the opening of negotiations has transformed it into convergence with a membership perspective, which, according to the external incentives model, should increase both the speed and the domestic acceptance of reforms.

Three instruments now structure the process. The first is the revised enlargement methodology of 2020, which groups the 33 negotiating chapters into six clusters, makes the "Fundamentals" cluster the first to be opened and the last to be closed, and sets interim benchmarks that must be met before any chapter can be provisionally closed (Council of the EU, 2026a). The second is the National Accession Programme 2025–2029, which translates the screening results into a legislative calendar. The third, of novel design, is the Growth Plan: Regulation (EU) 2025/535 created a facility of up to EUR 1.9 billion for 2025–2027, composed mainly of concessional loans, disbursed only upon fulfilment of the reform steps in the Reform Agenda. By October 2026, EUR 661 million had been made available, the latest payment of EUR 157 million being released after Moldova completed 18 of the 20 reform steps due in the first half of 2026 (European Commission, 2026). Table 1 summarises the stage of alignment in the five areas studied.

Table 1. Stage of legislative alignment in selected economic areas

Area (chapter)	Main EU acquis	Moldovan framework and recent changes	Commission assessment (2025)
Competition policy (Ch. 8)	Art. 101–102 TFEU; Reg. 1/2003; Directive (EU) 2019/1 (ECN+)	Law 183/2012; merger and Competition Council regulations; 2026 draft raising fines to 10% of turnover	Some level of preparation; some progress
State aid (Ch. 8)	Art. 107–109 TFEU; de minimis rules	Law 139/2012; state aid registry; digital reporting incomplete	Some level of preparation; some progress

Area (chapter)	Main EU acquis	Moldovan framework and recent changes	Commission assessment (2025)
Public procurement (Ch. 5)	Directives 2014/23/EU, 2014/24/EU, 2014/25/EU; Remedies Directives	Law 131/2015 to be replaced by Law 325/2025 (applicable from 1 January 2027); concessions and PPP legislation; reformed remedies body	Some level of preparation; some progress
Financial services (Ch. 9) and capital (Ch. 4)	CRD/CRR; BRRD; DGSD; Solvency II; SEPA rules	Law 202/2017 (Basel III); partial Solvency II alignment; SEPA operational since 6 October 2025	Ch. 9: some level of preparation; Ch. 4: moderately prepared, good progress
Property rights and legal certainty (Ch. 23, economic criteria)	Charter, Art. 17; Copenhagen economic criteria	Civil Code modernised in 2018; Law 81/2004 on investments; justice and vetting reforms ongoing	Functioning market economy: some level of preparation; good progress

Source: authors' compilation based on European Commission (2025), Council of the EU (2026b) and Moldovan legislation.

Competition policy and state aid

Competition law was among the first areas approximated under the Association Agreement. Law no. 183/2012 reproduces the structure of Articles 101 and 102 TFEU and established the Competition Council as an autonomous authority, while Law no. 139/2012 introduced, for the first time, a general control of state aid, a domain in which, as in other post-socialist economies, subsidies had previously been granted without any ex ante scrutiny. The Commission notes that amendments to the competition law and regulations on the Competition Council and merger control were adopted, but that the powers of the authority and the level of fines still require alignment, and that all state aid, including de minimis aid, must be reported digitally in an up-to-date registry (European Commission, 2025). A draft package published in 2026 seeks to transpose the ECN+ Directive: it raises the ceiling of fines from 5% to 10% of total annual turnover, extends liability to parent companies, broadens inspection powers and removes the automatic suspensive effect of court appeals.

The economic significance of these changes lies less in the texts themselves than in their deterrent effect. In small markets dominated by a few incumbents – fuel distribution, pharmaceuticals, retail, construction materials – credible enforcement reduces rents, lowers entry barriers for SMEs and foreign investors, and disciplines state-owned enterprises. State aid control is equally relevant: once Moldova becomes a member, every support scheme, including those financed from the Growth Plan, will have to comply with EU rules, which makes early alignment a precondition for the predictability of public support.

Public procurement

Public procurement accounts for a significant share of public spending and is a major channel for both corruption risks and SME participation. The Commission considers Moldova to have "some level of preparation" and recorded progress through the adoption of concessions legislation and the amendment of the public–private partnership framework (European Commission, 2025). The decisive step is the new Law no. 325/2025 on public procurement, which repeals Law no. 131/2015 and is to apply from 1 January 2027, accompanied by a revised remedies system in which the National Agency for Dispute Resolution becomes a National Dispute Resolution Authority with randomly assigned review panels. Chapter 5 was opened as part of the "Fundamentals" cluster, which signals that the EU treats procurement as a rule-of-law issue and not merely as a market-access issue.

Financial services and the free movement of capital

The financial sector illustrates both the costs of weak rule enforcement and the benefits of alignment. After the banking fraud of 2014, Moldova rebuilt its prudential framework through Law no. 202/2017, which transposed the Basel III standards of the CRD/CRR package. Banks are now well capitalised, but financial intermediation remains low (European Commission, 2025). The most tangible result of alignment is Moldova's integration into the Single Euro Payments Area: the European Payments Council approved the application on 6 March 2025, and SEPA became operational on 6 October 2025. Outstanding issues include bank recovery and resolution, deposit guarantee schemes and central bank independence.

Property rights and legal certainty

Legal certainty is the channel through which legislative harmonisation most directly affects investment decisions. Property is protected by Article 46 of the Constitution, and the Civil Code was modernised in 2018 in line with European private law models. Nevertheless, the persistence of a large informal economy, slow reform of state-owned enterprises and the unfinished reform of the judiciary continue to weigh on the business environment (European Commission, 2025). For this reason, the conditions set for the "Fundamentals" cluster – judicial independence, the fight against corruption and asset recovery – have an economic dimension: they determine whether the substantive alignment achieved in the economic chapters can be enforced before the courts.

Trade, investment and macroeconomic indicators

The trade data confirm that the economic reorientation towards the EU is already largely completed. In 2025, the EU-27 absorbed 67.5% of Moldovan exports and supplied 54.1% of imports, while the share of the Commonwealth of Independent States fell to 5.9% of exports and 3.0% of imports (NBS, 2026a). The DCFTA has also been deepened: Decision No 1/2025 of the Association Committee in Trade configuration, adopted on 19 September 2025, further reduced and eliminated customs duties, with new access for Moldovan agricultural products conditioned on alignment with EU production standards and a review scheduled for 2027. Table 2 presents the main indicators.

Table 2. Selected economic indicators of the Republic of Moldova, 2024–2025

Indicator	2024	2025	Source
Real GDP growth (%)	0.1	2.4	NBS
Exports of goods (USD million)	3,555	3,783	NBS
Imports of goods (USD million)	9,064	10,922	NBS
EU-27 share of exports (%)	67.3	67.5	NBS
EU-27 share of imports (%)	50.2	54.1	NBS
FDI inflows (EUR million)	424	409	BIS/IA
EU Growth Plan disbursements, cumulative (EUR million)	–	313 (661 by Oct. 2026)	EC

Note: data exclude the left bank of the Dniester; 2024 trade values derived from 2025 values and NBS growth rates. Sources: NBS (2026a; 2026b); BIS/IA – study for the Investment Agency; European Commission (2026).

The combination of these indicators reveals the central paradox of Moldova's position. Market access is no longer the binding constraint: the EU is already the dominant partner, and most tariffs have been removed. The trade deficit, however, reached USD 7.1 billion in 2025, imports grew by 20.5% against 6.4% for exports, and

FDI inflows declined slightly in 2025. The Commission identifies skills shortages, low FDI, low innovation and a narrow export base as the main constraints on competitiveness (European Commission, 2025). In other words, further gains from integration must come from the supply side – investment, productivity and institutional quality – which is precisely the area where legislative alignment is expected to act.

DISCUSSION

Lessons from previous enlargement waves

The CEE experience suggests that the economic benefits of accession were driven by three factors: the credibility of the membership perspective, the anchoring of expectations of investors, and the build-up of state capacity to implement single market rules (Grabbe, 2006; Bruszt and Vukov, 2017; Campos et al., 2019). Where these factors were weaker – in Bulgaria and Romania, which joined under a Cooperation and Verification Mechanism – convergence was slower and rule-of-law concerns persisted for years after accession. The literature on compliance adds that new member states transposed directives quickly but often implemented them poorly, forming what Falkner and Treib (2008) called a "world of dead letters", and that the end of conditionality tends to reduce the pressure for compliance (Sedelmeier, 2008; Toshkov, 2008). Moldova, which combines a strong formal commitment with low administrative capacity – the civil service vacancy rate stood at 19.5% according to the Commission – is exposed to the same risk. The revised methodology, with interim benchmarks and the reversibility of progress, is the EU's institutional response to this lesson, and it shifts the emphasis from transposition to track record.

Adjustment costs: SMEs, agriculture and public administration

The benefits of harmonisation will be unequally distributed. For SMEs, which account for the overwhelming majority of Moldovan enterprises, alignment brings compliance costs – technical standards, food safety and sanitary rules, environmental requirements, data protection, late payment rules – that are largely fixed and therefore weigh more heavily on small firms. Agriculture is the most exposed sector: the Commission places Chapter 11 between "an early stage" and "some level of preparation", and the integrated administration and control system needed to manage future Common Agricultural Policy payments is still under construction. The DCFTA review shows how these tensions are already being managed: the EU opened new tariff quotas for Moldovan products in exchange for alignment with EU pesticide standards, while Moldova granted additional access for EU pork, poultry, milk and butter, protected by bilateral safeguards. For public administration, the cost is primarily one of capacity: the same limited pool of civil servants must draft legislation, negotiate, implement the Reform Agenda and absorb EU funds. An IPRE assessment of the first year of the Growth Plan found that key coordinating positions were only partially filled and that the national monitoring mechanism had not yet been adopted (Bolocan, 2026).

External vulnerabilities: energy and trade reorientation

Energy dependence has been the most serious external vulnerability. The end of Russian gas transit through Ukraine on 1 January 2025 left the Transnistrian region without gas supplies, halted most of its industry and disrupted the thermal power plant that had supplied a large part of the electricity consumed on the right bank. The crisis accelerated Moldova's integration into EU energy markets: the Commission now assesses Chapter 15 between "a moderate and a good level of preparation", notes full alignment with the Electricity Integration Package and anticipates market coupling with the EU in 2027 (European Commission, 2025). From the perspective of the external governance literature, this case confirms that interdependence with Russia constrained EU rule transfer in the eastern neighbourhood (Dimitrova and Dragneva, 2009), but also that the breakdown of that interdependence can remove obstacles to alignment. The trade reorientation towards the EU, likewise, reduces exposure to politically motivated embargoes from the east but increases dependence on EU demand and on the competitiveness of Moldovan producers in the single market.

The role of EU financial and technical assistance

Unlike the CEE states, which benefited from the PHARE, ISPA and SAPARD pre-accession instruments, Moldova receives a significant part of its support in the form of loans linked to reform conditions. This design strengthens the link between money and reform, but it also raises the cost of unmet targets: missing a key milestone can freeze an entire tranche. Assistance is therefore most effective when it targets the binding constraints identified above – administrative capacity, infrastructure, SME finance and the agricultural paying agency – rather than when it is spread across too many objectives. Twinning and technical assistance for the Competition Council, the procurement remedies authority and the National Bank will determine whether the new laws are actually enforced.

The Transnistrian dimension

The unresolved Transnistrian conflict makes uniform application of EU-aligned legislation across the national territory impossible for the time being. However, economic integration has advanced faster than political settlement. The DCFTA has applied to the entire territory of Moldova since 2016, and Transnistrian companies registered in Chișinău sent 70.48% of their exports to the EU in 2023 (IPN, 2024). Since 1 January 2024, under the new Customs Code, they pay customs duties into the national budget on the same footing as companies on the right bank. These measures show that legislative alignment can serve as an instrument of gradual economic reintegration. They also show its limits: without control over the region's institutions, Chișinău cannot guarantee the enforcement of competition, state aid or procurement rules there, an issue that will have to be addressed explicitly in the accession treaty, possibly through transitional arrangements comparable to those applied in the case of Cyprus.

CONCLUSION

The legislative changes required by accession are likely to improve Moldova's economic environment by strengthening legal certainty, opening markets to competition, making public spending more transparent and anchoring the financial system in EU standards. The first effects are already measurable – the reorientation of trade towards the EU, SEPA membership, the integration of energy markets – but the main gains, related to investment and productivity, have not yet materialised. The comparison with previous enlargement waves shows that these gains depend less on formal transposition than on effective implementation, administrative capacity and sustained political commitment, which confirms the central hypothesis of the paper.

Four policy recommendations follow from the analysis. First, reforms should be sequenced so that the institutions that enforce the rules – courts, the Competition Council, the procurement remedies authority and the agricultural paying agency – are strengthened before the most costly obligations become applicable. Second, the burden on SMEs and farmers should be reduced through transitional periods negotiated in the economic chapters, targeted compliance support financed from the Growth Plan and a systematic "SME test" in regulatory impact assessments. Third, Moldova should prioritise reforms that directly raise investment – judicial independence, competition enforcement, energy interconnections and market coupling – since market access is no longer the main constraint. Fourth, the Transnistrian region should be integrated gradually into the national legal and fiscal space, building on the DCFTA and customs experience, while transitional arrangements for the territory are prepared for the accession treaty. Further research should test these conclusions empirically once the first effects of the new competition and procurement laws can be observed after 2027.

REFERENCES

Association Agreement 2014. Association Agreement between the European Union and the European Atomic Energy Community and their Member States, of the one part, and the Republic of Moldova, of the other part. Official Journal of the European Union, L 260, 30.8.2014: 4-738.

Bolocan E 2026. One year into the Growth Plan: between reform ambition and absorption capacity. IPRE Policy Brief, Chișinău: Institute for European Policies and Reforms. Available at: https://ipre.md/2026/04/14/nota-analitica-ipre-un-an-de-planul-de-crestere-ue-pentru-moldova-intre-ambitia-reformelor-si-capacitate-de-absorbtie/?lang=en [31.10.26]

Bruszt L, Vukov V 2017. Making states for the single market: European integration and the reshaping of economic states in the Southern and Eastern peripheries of Europe. West European Politics, 40(4): 663-687.

Campos NF, Coricelli F, Moretti L 2019. Institutional integration and economic growth in Europe. Journal of Monetary Economics, 103: 88-104.

Council of the EU 2026a. Enlargement: EU and Moldova reach a milestone in accession talks with opening of the first negotiation cluster. Press release, 15 June 2026. Available at: https://www.consilium.europa.eu/en/press/press-releases/2026/06/15/enlargement-eu-and-moldova-reach-a-milestone-in-accession-talks-with-opening-of-the-first-negotiation-cluster/ [31.10.26]

Council of the EU 2026b. Enlargement: EU and Moldova start negotiations on internal market, competitiveness and inclusive growth. Press release, 13 October 2026. Available at: https://www.consilium.europa.eu/en/press/press-releases/2026/10/13/enlargement-eu-and-moldova-start-negotiations-on-internal-market-competitiveness-and-inclusive-growth/ [31.10.26]

Decision No 1/2025 of the EU-Moldova Association Committee in Trade configuration of 19 September 2025 on the reduction and elimination of customs duties under Article 147(4) of the EU-Moldova Association Agreement. Official Journal of the European Union, L series, 2025/1961.

Dimitrova A 2002. Enlargement, institution-building and the EU's administrative capacity requirement. West European Politics, 25(4): 171-190.

Dimitrova A, Dragneva R 2009. Constraining external governance: interdependence with Russia and the CIS as limits to the EU's rule transfer in the Ukraine. Journal of European Public Policy, 16(6): 853-872.

Emerson M, Cenușa D (eds) 2018. Deepening EU-Moldovan relations: what, why and how? 2nd edn. Brussels: CEPS; Chișinău: Expert-Grup; London: Rowman & Littlefield International.

Epstein RA, Jacoby W 2014. Eastern enlargement ten years on: transcending the East-West divide? Journal of Common Market Studies, 52(1): 1-16.

European Commission 2025. Republic of Moldova 2025 Report. Commission Staff Working Document SWD(2025) 758 final, Brussels, 4 November 2025.

European Commission 2026. Commission pays EUR 157 million to Moldova under the Growth Plan. Press release IP/26/2054, 5 October 2026. Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_26_2054 [31.10.26]

Falkner G, Treib O 2008. Three worlds of compliance or four? The EU-15 compared to new member states. Journal of Common Market Studies, 46(2): 293-313.

Grabbe H 2006. The EU's transformative power: Europeanization through conditionality in Central and Eastern Europe. Basingstoke: Palgrave Macmillan.

Hillion C 2004. The Copenhagen criteria and their progeny. In: Hillion C (ed), EU enlargement: a legal approach. Oxford: Hart Publishing, pp. 1-22.

IMF 2026. Republic of Moldova: IMF Executive Board concludes 2025 Article IV consultation. Press Release No. 26/67, 27 February 2026. Available at: https://www.imf.org/en/news/articles/2026/02/27/pr-26067-moldova-imf-executive-board-concludes-2025-article-iv-consultation [31.10.26]

IPN 2024. Over 70% of Transnistrian entrepreneurs' exports in 2023 went to EU. IPN News Agency, Chișinău. Available at: https://www.old.ipn.md/en/over-70-of-transnistrian-entrepreneurs-exports-in-2023-went-to-7966_1102212.html [31.10.26]

Langbein J, Wolczuk K 2012. Convergence without membership? The impact of the European Union in the neighbourhood: evidence from Ukraine. Journal of European Public Policy, 19(6): 863-881.

NBM 2025. Today the Republic of Moldova is connected to SEPA. National Bank of Moldova, press release, 6 October 2025. Available at: https://bnm.md/en/content/today-republic-moldova-connected-sepa-fast-secure-and-low-cost-euro-payments-just-european [31.10.26]

NBS 2026a. International trade of goods of the Republic of Moldova in December 2025 and in year 2025. Chișinău: National Bureau of Statistics. Available at: https://statistica.gov.md/en/international-trade-of-goods-of-the-republic-of-moldova-in-december-2025-and-in---9539_62323.html [31.10.26]

NBS 2026b. Gross Domestic Product in the fourth quarter and in 2025. Chișinău: National Bureau of Statistics. Available at: https://statistica.gov.md/en/gross-domestic-product-in-the-fourth-quarter-and-in-2025--9497_62357.html [31.10.26]

Regulation (EU) 2025/535 of the European Parliament and of the Council of 18 March 2025 establishing the Reform and Growth Facility for the Republic of Moldova. Official Journal of the European Union, L series, 2025/535.

Schimmelfennig F, Sedelmeier U 2004. Governance by conditionality: EU rule transfer to the candidate countries of Central and Eastern Europe. Journal of European Public Policy, 11(4): 661-679.

Sedelmeier U 2008. After conditionality: post-accession compliance with EU law in East Central Europe. Journal of European Public Policy, 15(6): 806-825.

Toshkov D 2008. Embracing European law: compliance with EU directives in Central and Eastern Europe. European Union Politics, 9(3): 379-402.

Van der Loo G 2016. The EU-Ukraine Association Agreement and Deep and Comprehensive Free Trade Area: a new legal instrument for EU integration without membership. Leiden: Brill Nijhoff.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

THE ROLE OF THE CLIMATIC ENVIRONMENT IN THE GLOBAL DISTINCTION OF THE JORDANIAN NICOLAUS DATE DURING THE BYZANTINE ERA: A HISTORICAL AND GEOGRAPHICAL/AGRICULTURAL STUDY

Mohammed Waheeb
Prof., Hashemite University –Queen Rania Faculty of Cultural Heritage & Tourism
Amman –Jordan

Abstract

This study investigates the relationship between the climatic, hydrological, and agricultural environment of the Jordan Valley and the Dead Sea basin, and the renown of dates described in classical sources specifically the Nicolaus date during Late Antiquity and the Byzantine period. The study employs a critical reading of ancient texts, primarily Pliny the Elder and Strabo, alongside visual and archaeological evidence, including the Madaba Mosaic Map, as well as recent research in archaeobotany and paleoclimatology. Textual analysis demonstrates that classical sources establish the fame of the date palm in Jericho and adjacent valleys, with Pliny explicitly describing the Nicolaus date by its exceptionally large size. However, textual evidence alone is insufficient to prove that this cultivar was produced exclusively in the Eastern Jordan Valley within modern Jordanian borders, nor that it was regularly exported to Constantinople or Gaul. Consequently, this study proposes a multi-factorial explanatory model linking low-altitude warm conditions with water availability, arable soil, human expertise, and preservation and transport techniques, considering the causal link between climate and cultivar traits as a testable hypothesis rather than an established fact. The study recommends an archaeobotanical research program incorporating geographic surveying, flotation sampling, morphometric seed analysis, sediment and soil testing, radiocarbon dating, and potential genetic analysis where preservation permits.

Keywords: Nicolaus Date; *Nicolaus*; Byzantine Period; Jordan Valley; Dead Sea; Paleoclimate; Archaeobotany; Madaba Map; Historical Agriculture; Mediterranean Trade.

1. Introduction

Date palm cultivation occupied a crucial economic and cultural position in the oases of the Southern Levant, where relatively high temperatures in low-lying depressions combined with springs, rivers, and irrigable lands enabled specialized agricultural date production. Greek and Roman sources describe the Jericho plain and its palm groves as prominent agricultural landscapes and link the region's value to high-value crops. However, these descriptions do not imply that every cultivar mentioned in texts was grown uniformly across all parts of the valley, nor do they allow for defining modern production boundaries without supplementary evidence.

This study utilizes the Nicolaus date as a case study to examine how the natural environment interacted with agricultural knowledge and commercial reputation to shape a luxury commodity. Pliny the Elder includes this cultivar among date varieties, describing it as remarkably large. Textual traditions transmit an explanation attributing its name to Nicolaus of Damascus, who reportedly presented dates to Emperor Augustus. Nevertheless, this tradition neither proves that Nicolaus bred the cultivar, nor that it was tied exclusively to a single locality, nor that it is genetically identical to any modern cultivar.

This issue gains added significance when evaluating the fourth through seventh centuries AD a period marked by geopolitical, economic, and climatic shifts in the Southern Levant. Recent paleoclimatic studies indicate fluctuations in precipitation and the potential overlap of economic pressures with drought episodes, cautioning

against treating the Byzantine climate as a static condition across four centuries. Thus, asserting that the region was warm is insufficient on its own to prove consistent production or uniform crop quality over time.

2. Research Problem, Questions, and Objectives

The research problem stems from the disparity between the fame of dates recorded in classical sources and the scarcity of direct evidence linking the Nicolaus cultivar specifically to a particular production site on the eastern bank of the Jordan Valley during the Byzantine era. While available sources focus on Jericho and broader areas of the Southern Levant, attributing this cultivar to modern Jordanian sites such as Tell er-Rameh, Al-Kafrein, or other localities requires more precise geographical and historical evidence.

The study poses several primary questions: What do classical sources actually state regarding the Nicolaus date? What climatic, topographic, and hydrological characteristics made the Jordan Valley a suitable environment for date palms? What evidence connects date palm cultivation to the eastern bank of the valley during the Byzantine era? To what extent can commercial quality be explained by climate alone, compared to the influence of genetic factors, grove management, harvesting, and post-harvest storage?

The study aims to critically analyze classical texts, delineate key insights from the region's agricultural geography, integrate archaeological and visual evidence into an explanatory model, and propose an actionable research framework for Jordanian sites that may retain agricultural or plant remains dating to the Late Roman and Byzantine periods.

3. Methodology and Scope

The study adopts a critical historical method to compare ancient texts, a geographical-environmental framework to assess the suitability of the Jordan Valley for date palms, and an archaeobotanical approach to identify evidence confirming palm cultivation and management within dated contexts. Literary texts are not treated as precise agricultural records in the modern sense, as ancient descriptions often incorporated rhetorical exaggeration or commercial classifications that do not align with modern botanical cultivar concepts.

The chronological scope focuses on the fourth to seventh centuries AD, drawing on earlier sources to contextualize the origin of the cultivar's fame and on modern research to explain climate and agricultural geography. The geographic scope encompasses the Jordan Valley and Dead Sea basin on both banks, with specific emphasis on the eastern side as the subject of investigation rather than an established origin site. Modern climatic data are utilized to illustrate spatial environmental variations without being automatically projected onto the Byzantine era without independent paleoclimatic evidence.

4. The Term "Nicolaus" in Classical Sources

In Book XIII of *Natural History*, Pliny the Elder lists several date varieties, classifying *caryotae* among the famous cultivars of Judea, with references to Jericho and surrounding areas such as Archelais, Phasaelis, and Livias. He subsequently mentions the Nicolaus date, describing it as less juicy but exceptionally large. This testimony provides key evidence that the name was recognized in ancient date taxonomy and associated with a prominent physical trait size though it lacks sufficient diagnostic botanical description to establish a genetic identity under modern classifications (Pliny, NH 13.44).

Traditional commentary in certain editions of Pliny cites Athenaeus, who links the name to Nicolaus of Damascus, the philosopher and historian who visited Rome with Herod and presented premium dates to Augustus. This account should be framed as an ancient folk etymology rather than an established fact regarding the cultivar's origin or agricultural selection. Furthermore, the ancient term *caryotae* must not be confused with the modern botanical genus *Caryota*, which

denotes a completely different genus of palms; hence, using "Nicolaus date" is preferable to avoid implying inaccurate botanical equivalence (Pliny, NH 13.44; Athenaeus, Deipnosophistae 14.652).

Strabo describes the banks of the Jordan River as harboring palm groves and flowing waters, highlighting the economic value of date palms and other crops. This account helps explain the relationship between water resources and the agrarian economy; however, it pertains primarily to the Jordan River and its immediate surroundings, without independently proving the presence of the Nicolaus cultivar across all areas of the Eastern Jordan Valley. Nevertheless, transitioning from the general renown of dates in the valley to demonstrating the production of a specific cultivar on the eastern bank remains plausible in light of the international acclaim of the Nicolaus date located on the eastern side of the river (Strabo, 16.2.41).

According to pilgrims and travelers' descriptions, pilgrims crossed the Jordan River to the eastern bank to obtain the Nicolaus date from its place of origin, as this date was characterized by its large size and delicious taste (Arculf, 1895).

5. Geographical and Topographic Framework of the Jordan Valley

The Jordan Valley forms part of the Syrian African Rift System, characterized by its extreme elevation below sea level and marked topographic contrast between the valley floor and surrounding highlands. This configuration fosters localized thermal conditions distinct from adjacent uplands, while wadis descending from the eastern plateau serve as conduits for seasonal runoff and sediment transport to the low plain. However, environmental conditions across the valley are non-uniform; temperature, precipitation, soil characteristics, and water resources vary significantly between the northern, central, and southern sectors, as well as the Dead Sea basin (FAO, 2006; FAO, 2017).

In Jordan, the valley transitions from relatively higher rainfall in the north to hyper-arid conditions in the south, with agricultural potential dictated by the stability of surface and groundwater supplies. Modern agro-ecological classifications confirm that low-lying, high-temperature areas hold high agricultural value when coupled with reliable irrigation. Nevertheless, these data do not define the specific structure of Byzantine irrigation networks or spring discharge rates during that era both of which require direct empirical study of ancient aqueducts, water installations, and dated sediment deposits (FAO, 2006; FAO, 2017).

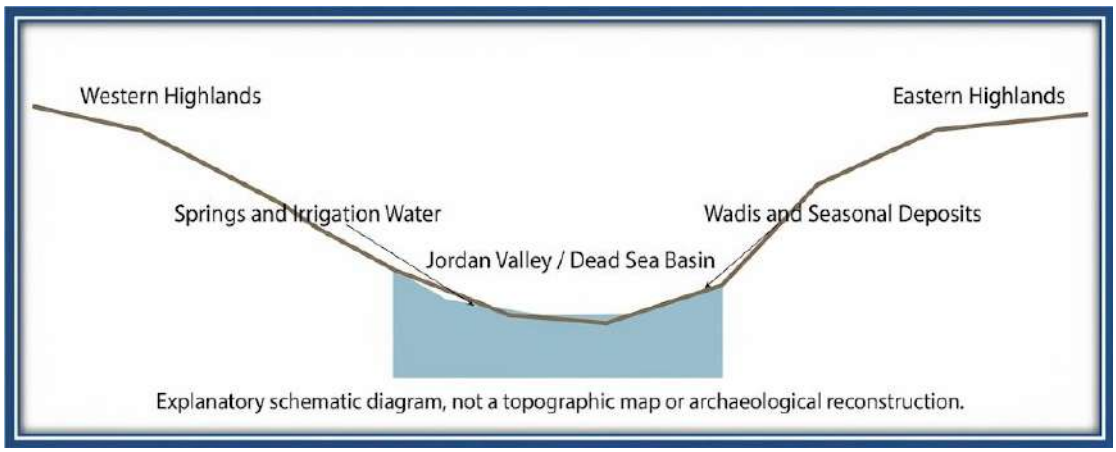


Figure 1. A simplified explanatory geographical cross-section illustrating the relationship between highlands, wadis, the low plain, and water sources. The drawing is a schematic diagram, not a survey map or an archaeological reconstruction.

6. Microclimate and Environmental Requirements of Date Palms

Temperature is a primary factor in the growth of date palms and the ripening of their fruit; the crop requires a long, warm season, and the low probability of frost in low-lying environments helps mitigate the risk of plant tissue damage. The Jordan Valley provides relatively suitable thermal conditions compared to the highlands. However, determining accumulated heat units or average temperatures in the 6th century AD requires independent paleoclimatic reconstruction, and modern measurements should not be presented as Byzantine parameters (FAO, 2006; Fuks et al., 2017).

Temperature alone is insufficient to explain fruit quality or the distinctiveness of a particular cultivar. Fruit size, sugar content, and texture are influenced by genetic factors, pollination, crop load, irrigation, water and soil salinity, harvest stage, and processing methods. Therefore, asserting that the eastern microclimate of the Valley automatically produced larger or sweeter dates remains a hypothesis requiring comparative evidence, rather than a conclusion derived from climate alone (FAO, 2006; Pliny, NH 13.44).

As for atmospheric humidity, it can affect the rate of fruit drying as well as the risk of fungal infestation and post-harvest spoilage. However, preservation is not solely tied to low humidity; it is also influenced by internal fruit moisture, skin integrity, ripeness level, ventilation, and packaging and storage conditions. Consequently, the transportability of dates should be interpreted as the potential result of an interaction between the cultivar, post-harvest technologies, and the environment, rather than a proven direct effect of the Byzantine Jordan Valley climate (FAO, 2006; Pliny, NH 13.44).

7. Water, Soil, and Irrigation Networks

Cultivating date palms in a relatively arid environment requires regular access to water, even if palms are more drought-tolerant than other crops. Springs, wadi courses, and seasonal floodwaters provided opportunities to establish oasis orchards in parts of the Jordan Valley. Strabo's description of the irrigated plain of Jericho underscores the importance of the relationship between water and orchards, while archaeological studies of irrigation networks in Dead Sea oases contribute to understanding water management in ancient arid environments (Strabo, 16.2.41; FAO, 2006).

The deposits of the low plain consist of materials transported via wadis and floods, and certain soils may be suitable for agriculture given adequate drainage and irrigation. However, describing the soil of a specific area as rich in potassium and magnesium requires published geochemical analyses, and high salinity can act as a stress factor rather than an agricultural advantage. Therefore, it is inaccurate to directly link the flavor of the *Nicolaus* date to specific mineral salts without analyzing soil and water samples and comparing them with other sites (FAO, 2006; FAO, 2017).

Water management likely combined small channels, catchment basins, seasonal diversions from wadi streams, and local rights to regulate distribution. Nevertheless, the presence of these elements at a specific Jordanian site during the Byzantine period must be field proven through survey, documentation, and dating, rather than merely generalizing known irrigation systems from other regions. This highlights the importance of studying water installations in the Jordanian Ghor and correlating them with archaeological strata and settlement context (Smith et al., 2013; FAO, 2006).

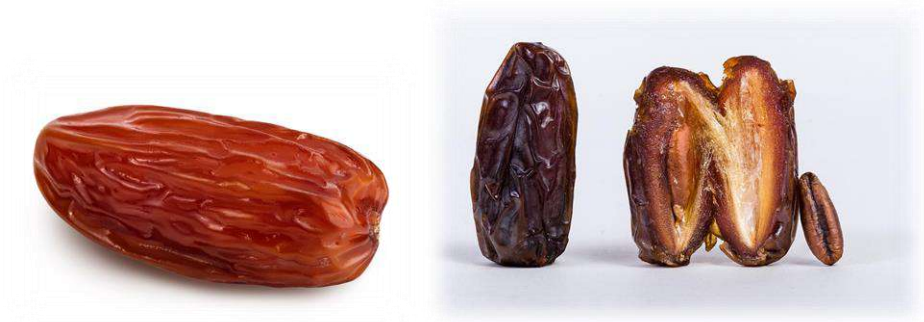


Figure (1) shows pictures of the Nicolaus date from the inside and outside.

8. Archaeological and Visual Evidence

The Madaba Mosaic Map, dated to the 6th century AD, provides an important visual witness to the presence of date palms in the geographical landscape of the southern Levant. Studies analyzing its botanical elements show that date palms are depicted around several sites located in the vicinity of the Jordan Valley and the Dead Sea, including Jericho and other sites on both sides of the river. While these depictions indicate that date palms were a significant element in geographical representation, they do not specify cultivar names, nor do they measure orchard areas or production volumes (Hepper & Taylor, 2004).

Furthermore, the study of archaeobotanical remains at Bir Madhkur, in the hinterland of Petra and Wadi Araba, demonstrates the utility of plant remains in understanding the timing and scale of agriculture during the Late Roman and Byzantine periods. The study underscores the value of dated botanical evidence in reconstructing agricultural economies, while cautioning against directly extrapolating findings from Bir Madhkur to the Jordan Valley; each region possesses its own specific agro-environmental and historical context (Smith et al., 2013).

However, the depiction of a palm tree in a mosaic or the discovery of an isolated date seed is insufficient to confirm the identity of the *Nicolaus* cultivar. Identifying a plant species differs significantly from pinpointing a specific agricultural cultivar; doing so typically requires morphometric analysis of seeds, a clear stratigraphic context, absolute dating, and comparison with reference collections. Moreover, extracting ancient DNA from degraded plant material is not guaranteed, as it depends heavily on preservation status, contamination, and laboratory conditions. Therefore, the primary objective should be establishing the presence and utilization of date palms before attempting to verify specific cultivars (Smith et al., 2013; Langgut, 2024).

Figure (2) illustrates date palm farms in the Jordan Valley region.

9. Economic Value and Exchange Chains

The renown of certain date varieties in ancient texts points to commercial differentiation among agricultural products, as not all fruits were equal in value or reputation. Pliny's description of the large-sized *Nicolaus* date serves as an example of how physical attributes formed part of the definition of a luxury product in Roman literature. However, the fame of a cultivar does not automatically imply the existence of regular trade to every province of the Empire, nor does a reference to a crop's value suffice to establish specific shipping routes (Pliny, NH 13.44; Strabo, 16.2.41).

It is likely that date marketing relied on a combination of local consumption, regional exchange, and possibly long-distance transport when storage conditions and demand permitted. Nevertheless, identifying the ports through which dates were exported, or proving that the *Nicolaus* date reached Constantinople and Gaul, requires additional evidence such as explicit commercial texts, tax records, archaeological cargo remains, or archaeobotanical finds in distant consumption contexts that can be dated and linked to a specific geographical origin. Therefore, these trade routes are presented as research prospects rather than definitive facts (Pliny, NH 13; Fuks et al., 2017).

Value Chain Link	Potential Factors	Required Evidence for Verification
Production	Temperature, water, soil, cultivar, and orchard management	Dated archaeobotanical remains, irrigation structures, and soil/water analyses
Harvesting & Sorting	Ripening stage, fruit selection, and agricultural expertise	Agricultural contexts, tools, and textual comparisons
Preservation & Storage	Drying, fruit moisture, packaging, and ventilation	Storage facilities, containers, and comparative preservation experiments

Transport & Exchange	Overland routes, ports, market demand, and taxation	Commercial texts, archaeological cargo/shipments, and consumption contexts
Reputation & Value	Size, taste, rarity, and association with elites	Cross-referenced literary sources and independent economic evidence

Table (1): A Value Chain Model, Factors, and Data Required for Verifying the Nicolaus Date in the Byzantine Era

10. Interpretive Model of the Relationship Between Environment and Distinctiveness

The working hypothesis can be formulated as follows: the warm, low-lying conditions of the Jordan Valley when combined with suitable water sources, arable soil, and human expertise in orchard management provided a favorable environment for producing high-value dates. As for the fame of the *Nicolaus* date, it appears in literary texts as a renown linked to a distinctive physical characteristic, namely its large size, within the broader range of dates known in the region. However, available evidence does not prove that climate alone was the sole reason for the cultivar's distinctiveness, nor that the Jordanian environment was the exclusive site of its production (Pliny, NH 13.44; Strabo, 16.2.41; FAO, 2006).

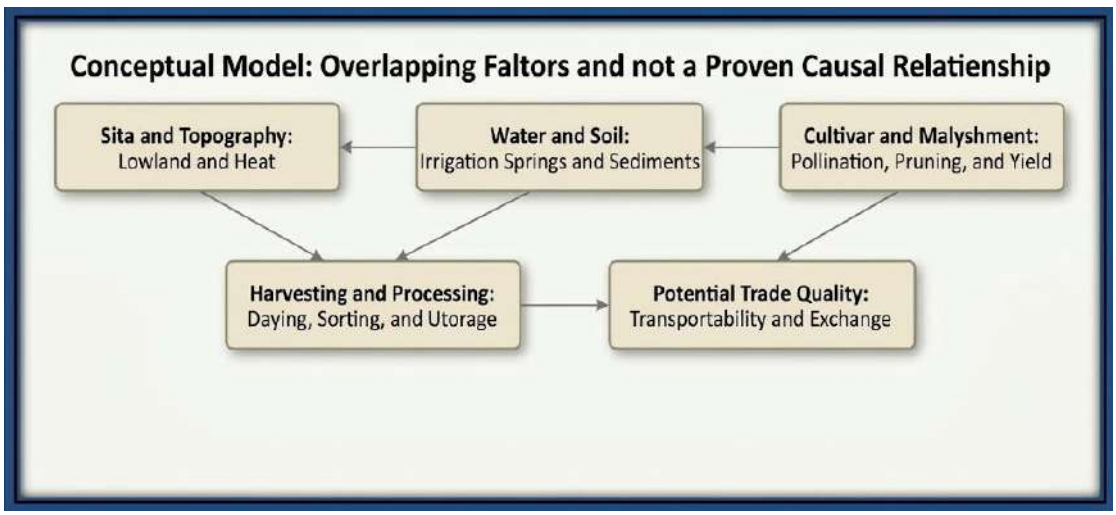


Figure 2. Analytical model of factors overlapping in the production of agricultural and commercial quality; arrows represent hypothesized relationships requiring testing rather than proven empirical results.

This approach helps avoid environmental determinism that is, explaining agricultural quality and prosperity solely through climate. Climate defines the range of possibilities and constraints, whereas human management influences site selection, water delivery, pollination, pruning, harvesting, and storage. Likewise, socio-economic networks impact the transport of saplings and expertise, as well as the formation of a commercial reputation. Thus, the environment serves as an important facilitating condition, but it is not a sufficient standalone explanation for the history of a luxury crop cultivar (Langgut, 2024; Fuks et al., 2017).

11. Critical Discussion of Hypotheses

- **First, the hypothesis of a specific origin for the *Nicolaus* date in Ghor al-Rama and Al-Kafrein in eastern Jordan requires careful scrutiny.** Available classical sources focus on Jericho and parts of the southern Levant, without explicitly identifying modern Jordanian sites as the cultivar's origin. While the presence of date palms on both sides of the Valley is geographically plausible, it does not constitute direct evidence of the cultivar's identity. Consequently, this origin should be formulated as a testable geographical hypothesis (Pliny, NH 13.44; Hepper & Taylor, 2004).
- **Second, the hypothesis that low humidity during the ripening stage rendered the *Nicolaus* date exportable assumes a mechanism that requires testing.** Atmospheric conditions may affect drying, but fruit sugar and moisture levels are also influenced by genetic traits, ripening stage, and processing methods. Chemical measurements for the *Nicolaus* date are absent from the text sources used; thus, descriptions such as "firm sugary pulp" or "skin adhering to the pulp" should not be presented as established historical traits unless an explicit source or comparative study is found (Pliny, NH 13.44; FAO, 2006).
- **Third, the hypothesis of the product reaching Constantinople and Gaul requires independent documentation of transport routes.** The existence of maritime routes connecting Eastern Mediterranean ports with imperial centers makes the transport of agricultural goods plausible in principle, but it does not prove that *Nicolaus* dates were regularly traded goods to these destinations. Explicit texts should be included, or the statement should be modified to "the potential for exchange within Mediterranean trade networks" (Pliny, NH 13; Fuks et al., 2017).
- **Fourth, modern climate cannot be projected onto the Byzantine era without qualification.** Paleoclimatic studies indicate rainfall fluctuations and significant climatic events in the southern Levant during Late Antiquity. This implies that agricultural production may have experienced temporal variability, and that irrigation systems, water storage capacity, and drought management might have been decisive factors alongside average temperature (Fuks et al., 2017).

12. Research Program for Testing the Hypothesis

The study recommends beginning with an archaeo-geographical survey of sites located on the eastern side of the Jordan Valley, prioritizing areas exhibiting water installations or Late Roman and Byzantine settlement strata. The survey should record installation sites, their association with wadis and springs, and their relationship with ancient fields, using reusable digital documentation. Selecting comparative sites from Jericho, the Dead Sea Basin, and other Jordanian areas is preferable to avoid drawing conclusions from a single site (FAO, 2006; Smith et al., 2013).

In terms of excavation, systematic sediment sampling for water flotation and archaeobotanical extraction should follow protocols that preserve context, while recording stratum, context, and dating. Morphometric measurements of date seeds can be conducted and compared with published modern and ancient reference collections, noting that morphology alone may not distinguish a specific cultivar. If suitable material is available, ancient DNA (aDNA) analysis can be explored, though its success should not be guaranteed in advance (Smith et al., 2013; Langgut, 2024).

From an environmental standpoint, analyzing soil, sediments, and water sources is proposed to determine salinity and mineral composition, alongside the study of pollen and charcoal when a suitable stratigraphic sequence is available. A distinction must be made between date palm pollen which may indicate local or regional presence and seeds, which are directly tied to consumption or processing. Finally, results must be correlated with absolute dating whenever possible, as the presence of palms in a region does not prove their continuity throughout the entire Byzantine period (Langgut, 2024; Fuks et al., 2017).

Work Phase	Procedure / Action	Expected Output
1. Survey	Identification of wadis, springs, water installations, and potential fields	GIS database and preliminary site map
2. Sampling	Water flotation, sediment sampling, and stratigraphic documentation	Archaeobotanical remains linked to archaeological contexts
3. Botanical Identification	Seed/pit morphometrics and comparison with modern and ancient reference collections	Probabilistic identification of plant species and range of variation
4. Environmental Analysis	Analyses of soil, water, sediments, and pollen	Reconstruction of agricultural conditions and resources
5. Dating	Radiocarbon (^{14}C) dating when suitable material is available	Comparable chronological sequence
6. Integration	Synthesis and comparison of results with literary sources and the Madaba Map	Evaluation of the strength of the local agriculture hypothesis

Table (2): Applied Methodology and Proposed Work Phases for Studying and Analyzing the Nicolaus Date

Results

The study concludes that classical sources demonstrate the renown of dates in Jericho and the southern Levant, and that Pliny describes the *Nicolaus* date as being large in size. This testimony underscores the importance of distinguishing between date cultivars in ancient agricultural culture, but it does not provide a modern botanical definition, nor does it single-handedly prove the origin of the cultivar within the borders of modern-day Jordan (Pliny, NH 13.44; Strabo, 16.2.41).

The physical geography of the Jordan Valley indicates relatively favorable conditions for date palm cultivation in warm, low-lying areas, particularly where fresh water and irrigation opportunities are available. However, variations among different parts of the Valley, climatic fluctuations during the Byzantine period, and the significance of agricultural management preclude reducing agricultural success to a single climatic factor (FAO, 2006; Fuks et al., 2017).

Furthermore, the Madaba Map and regional archaeobotanical evidence serve as important sources for reconstructing the agricultural landscape, but they do not allow for the specific identification of the *Nicolaus* cultivar without additional evidence. The research emphasizes that linking a historical cultivar to a modern archaeological site requires an accumulation of textual, archaeological, and environmental evidence, rather than a mere general geographical alignment (Hepper & Taylor, 2004; Smith et al., 2013).

Finally, the hypothesis that the local microclimate contributed to the distinctiveness of the product is plausible in principle, but it remains an explanatory hypothesis rather than an empirically proven result. Testing it necessitates studying the interactions among cultivar, irrigation, soil, agricultural management, and preservation techniques, alongside searching for independent evidence of long-distance trade (FAO, 2006; Pliny, NH 13.44).

Recommendations

The study recommends conducting a specialized archaeobotanical project at selected sites in the eastern Jordan Valley, integrating geographical surveying, sediment analysis, and absolute dating, rather than merely referencing sites without documented sampling. It also recommends establishing a shared database for ancient plant remains in Jordan and Palestine to enable comparative analysis across different agricultural basins (Smith et al., 2013; Langgut, 2024).

It further recommends re-examining the textual evidence related to the name *Nicolaus* and tracing the transmission of the narrative from classical texts to modern commentaries, distinguishing between ancient testimony and subsequent interpretation. Any specific claim regarding export to Constantinople or Gaul should be removed unless supported by a direct source or otherwise presented as a possibility within Mediterranean exchange networks (Pliny, NH 13.44; Athenaeus, Deipnosophistae 14.652).

Additionally, the study suggests documenting the historical agricultural heritage of the Jordan Valley and connecting it to environmental awareness and cultural tourism. As for enrolling the region in the Globally Important Agricultural Heritage Systems (GIAHS) programs of the FAO, this should not be presented as an automatic entitlement; it requires a dossier demonstrating the continuity of the agricultural system and its heritage, social, and environmental value according to established criteria (FAO, 2006).

Conclusion

The study of the *Nicolaus* date demonstrates that the renown of historical crops cannot be explained by the natural environment alone, nor by literary narratives in isolation. Ancient texts provide crucial testimony to the reputation of certain date cultivars, agricultural geography reveals suitable environmental potential in the Jordan Valley, and mosaic maps alongside plant remains offer independent avenues for testing the extent of date palm distribution and management. However, pinpointing the origin of the *Nicolaus* date to a specific site in Jordan or proving its export to distant destinations requires direct evidence that the sources available here have not yet settled (Pliny, NH 13.44; Hepper & Taylor, 2004; Smith et al., 2013).

Accordingly, the most significant scientific contribution is transforming the concept from a deterministic narrative of "climatic superiority" into a testable framework connecting texts with topography, water resources, archaeobotany, and trade. Studying date palms in Jordan can contribute to understanding the history of agriculture and ecological economics in the southern Levant, while maintaining a clear distinction between what is proven, what is probable, and what requires further field research (Langgut, 2024; Fuks et al., 2017).

References

1. Athenaeus. Deipnosophistae, Book XIV, section 652.
2. FAO. 2006. Irrigation in the Near East Region in Figures. Rome: Food and Agriculture Organization of the United Nations.
3. FAO. 2017. Agro-Ecological Zones of Jordan. Food and Agriculture Organization of the United Nations / Jordan country materials.
4. Fuks, D., Ackermann, O., Ayalon, A., Bar-Matthews, M., Bar-Oz, G., Levi, Y., Maeir, A. M., Weiss, E., Zilberman, T., & Safrai, Z. 2017. “Dust clouds, climate change and coins: consiliences of palaeoclimate and economy in the Late Antique southern Levant.” Levant 49(2): 205–223. https://doi.org/10.1080/00758914.2017.1379181

5. Hepper, N. F., & Taylor, J. E. 2004. "Date Palms and Opobalsam in the Madaba Mosaic Map." Palestine Exploration Quarterly 136(1): 35/44. https://doi.org/10.1179/003103204225014193
6. Langgut, D. 2024. "The core area of fruit-tree cultivation: central Jordan Valley (Levant), ca. 7000 BP." Palynology 48(4), Article 2347905. https://doi.org/10.1080/01916122.2024.2347905
7. Pliny the Elder. Natural History, Book XIII, sections 44/46.
8. Smith, A. M., et al. 2013. "Desert agriculture at Bir Madhkur: The first archaeobotanical evidence to support the timing and scale of agriculture during the Late Roman/Byzantine period in the hinterland of Petra." Journal of Arid Environments 99: 51–63. https://doi.org/10.1016/j.jaridenv.2013.09.005
9. Strabo. Geography, Book XVI, chapter 2, section 41.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

TYPES OF DIVINE RETRIBUTION ASSOCIATED WITH CLIMATIC AND GEOLOGICAL PHENOMENA IN THE NOBLE QURAN: AN INTERDISCIPLINARY ANALYTICAL STUDY BETWEEN MODERN CLIMATIC STUDIES AND THE QURANIC TEXT

Mohammed Waheeb
Prof., Hashemite University –Queen Rania Faculty of Cultural Heritage & Tourism
Amman –Jordan
ENSAR FIRAT
Mohammed V University in Rabat- Morocco
PHD Candidate in "Contemporary İslamic Thought" program. Researcher in the field of Quranic Archaeology

Abstract

This study examines the Quranic descriptions of natural phenomena associated with the destruction of certain past nations, such as violent winds, the Deluge (flood), torrential floods, thunderbolts, tremors (earthquakes), the blasting cry (*al-Saiha*), the punishment of the Day of the Shadow, and the rain of stones. It aims to analyze these descriptions within their Quranic and exegetical contexts while discussing potential comparative perspectives with the fields of paleoclimatology, hydrology, geology, and environmental archaeology. The study adopts an inductive approach to the texts, exegetical analysis, and interdisciplinary comparison, maintaining a clear distinction between religious significance and empirically testable material evidence. The findings indicate that while drought, floods, and environmental disruptions undoubtedly impacted ancient societies, they alone do not account for all civilizational transformations. Furthermore, the study emphasizes that a structural resemblance between a Quranic description and a natural phenomenon does not historically establish their strict equivalence without independent, radiometrically dated evidence. It recommends fostering collaborative research between scriptural studies, natural sciences, and environmental archaeology, alongside employing Quranic narratives in environmental awareness within a disciplined scientific framework.

Keywords: The Noble Quran; Climatic Phenomena; Paleoclimatology; Environmental Archaeology; Drought; Floods; Earthquakes; Civilizational Transformations.

1. Introduction

The history of human societies has been profoundly shaped by their surrounding environments; agriculture, urban settlement, and trade were closely tied to water availability, soil fertility, and climatic stability. Conversely, droughts, floods, earthquakes, and landslides frequently disrupted production and altered settlement patterns. Archaeological and geological studies indicate that these factors did not always operate in isolation; rather, they interacted dynamically with political, economic, and technological conditions, as well as the adaptive capacities of these societies.

The Noble Quran recounts the stories of past nations within a religious and ethical framework, occasionally describing the mechanisms of their retribution, such as the howling wind (*al-Rih al-Sarsar*), the Deluge, the destructive flood of *al-Arim*, the thunderbolt (*al-Saa'iqah*), the tremor (*al-Rajfah*), the blasting cry (*al-Saiha*), the punishment of the Day of the Shadow, and the rain of stones. These texts raise critical questions concerning the limits of comparison between them and the natural phenomena investigated by modern sciences, without reducing Quranic significance to a purely material interpretation or treating scientific hypotheses as definitive proofs of a specific historical event.

1.1 Problem Statement and Research Questions

The core problem of this study lies in how to analyze the Quranic descriptions of retribution associated with natural phenomena in light of paleoclimatology, geology, and environmental archaeology, while strictly maintaining the distinction between religious exegesis and scientific verification. The study addresses the following questions: What are the prominent phenomena mentioned in the texts? How have traditional sources interpreted their terminology? What are the viable avenues for scientific comparison? And what types of empirical evidence are required to test hypotheses regarding ancient environments?

2. Conceptual Framework and Methodology

The expression "retribution associated with natural phenomena" is employed here as an analytical framework broader than the term "climatic punishment." Winds, temperature, and precipitation pertain to climatology and meteorology; floods relate to hydrological sciences; whereas earthquakes and landslides fall within the domain of geology. This classification does not imply that Quranic terminology consists of modern technical terms, nor that every phenomenon can be reduced to a single physical mechanism.

Environmental archaeology investigates the relationship between humans and their environment through empirical evidence such as pollen, plant and animal remains, sediments, soils, charcoal, and traces of agriculture and irrigation. Meanwhile, paleoclimatology reconstructs past environmental conditions using natural archives, including lake and marine sediments, speleothems (stalactites and stalagmites), and biological and chemical proxies. The strength of any scientific conclusion increases when independent lines of evidence converge across both space and time; a single isolated indicator is insufficient to prove the cause of an abandoned settlement or a collapsed society.

This study relies on four methodological pathways: the induction of relevant verses, the analysis of terminology and contexts through classical and modern exegesis, the comparison of descriptions with modern scientific knowledge, and the evaluation of the limitations inherent in archaeological and geological evidence. Table 1 outlines these pathways and their respective objectives.

Methodological Pathway	Scientific and Functional Procedure	Research Objective
1. Textual Induction	Enumerating and classifying the Quranic verses denoting climatic and geological phenomena (winds, the Deluge, torrential floods, thunderbolts, tremors, the blasting cry, the shadow, and the rain of stones).	Constructing the textual database of the phenomena under study.
2. Exegetical and Semantic Analysis	Examining lexical semantics as well as the historical and linguistic context across authoritative works of exegesis (*tafsir*) and Quranic lexicography.	Determining the precise intended meaning of the phenomenon while avoiding forced interpretations (*takalluf*).
3. Interdisciplinary Scientific Comparison	Aligning Quranic descriptions with physical concepts and mechanisms in climatology, meteorology, hydrology, and geology.	Exploring points of intersection between the scriptural text and the natural sciences.
4. Archaeological and Geological Evaluation	Examining material and stratigraphical field evidence, while defining the limits of scientific verification and distinguishing hypotheses from definitive facts.	Ensuring methodological rigor and avoiding dogmatic or premature conclusions.

Table 1. Methodological Pathways Adopted in the Study

3. Divine Laws (Sunan) and Natural Phenomena in the Quranic Text

The Noble Quran views the universe as subordinate to the power and governance of God; as stated in the verse: "And to Allah belong the soldiers of the heavens and the earth, and Allah is ever Exalted in Might and Wise" (Quran 48:7). Within the narratives of past nations, natural phenomena are presented within a religious and ethical context rather than as an independent paleoclimatic record detached from the text's overarching

objectives. Consequently, analytical inquiry must originate from the lexical and exegetical meanings of the verses before establishing scientific comparability, avoiding any assumption of strict equivalence between Quranic descriptions and modern taxonomies (al-Tabari, n.d.).

4. Types of Retribution Associated with Natural Phenomena

4.1 The Howling Wind (al-Rih al-Sarsar): The People of 'Ad

The Quran states: "So We sent upon them a screaming wind in days of ill omen" (Quran 41:16), and: "Which He imposed upon them for seven nights and eight days in succession, so you would see the people therein fallen as if they were hollow trunks of palm trees" (Quran 69:7). In classical exegesis, the term sarsar is associated with violent, freezing winds, whereas husuman denotes uninterrupted continuity across various scholarly interpretations.

This description can be comparatively analyzed alongside the impacts of extreme wind events, such as soil erosion, aeolian sand transport, uprooting of vegetation, and structural degradation. In Islamic tradition, 'Ad is historically localized in the al-Ahqaf region of southern Arabia a region that has undergone cycles of humidity and aridity throughout historical epochs. However, such context neither proves a specific catastrophic storm that destroyed 'Ad nor permits its automatic classification as a tropical cyclone or sandstorm under modern meteorological nomenclature (Ibn Kathir, n.d.; al-Tabari, n.d.).

4.2 The Deluge and the Flood of al-Arim: The People of Noah and Sheba

Regarding the narrative of Noah, the text states: "So We opened the gates of the sky with rain pouring down. And We caused the earth to burst forth with springs, so the waters met for a matter already decreed" (Quran 54:11–12). The passage describes the dual action of torrential precipitation and groundwater discharge. Hydrologically, flooding can result from heavy precipitation, soil saturation, riverine overflow, or water accumulation in low-lying basins. Yet, these physical mechanisms alone do not demarcate the spatial extent or chronology of the Deluge, nor do they settle debate over its nature (Douglas et al., 2016).

Conversely, the flood of al-Arim is mentioned in: "But they turned away [refusing], so We sent upon them the flood of the dam (Sail al-'Arim)" (Quran 34:16). Archaeological remains in Marib offer empirical evidence of advanced Sabaean hydraulic engineering, including dams, sluices, and canal networks, underscoring the importance of water management for agricultural stability in a semi-arid environment. While these physical remains enable the study of flash flood hazards, sediment aggradation, and infrastructure collapse, they do not independently confirm the specific historical event narrated in the verse.

While flooding can destroy crops, collapse dwellings, alter river courses, and disrupt transportation frequently driving migration or land-use reorganization not all flood events are purely destructive; some deposit fertile sediments that renew soil fertility. The net impact depends on flood magnitude, timing, frequency, geomorphology, structural resilience, and societal adaptive capacity (UNESCO World Heritage Centre, n.d.).

4.3 The Thunderbolt (al-Saa'iqah): The People of Thamud

The Quran records: "And as for Thamud, we guided them, but they preferred blindness over guidance, so the thunderbolt (saa'iqah) of humiliating punishment seized them for what they used to earn" (Quran 41:17). Al-Saa'iqah appears in the context of divine retribution; classical commentators have analyzed it within descriptions of severe punishment, occasionally linking it with the blasting cry (al-Saiha) or the earthquake tremor (al-Rajfah). In modern science, an atmospheric lightning strike is an electrical discharge associated with cumulonimbus clouds, capable of causing fatalities, igniting fires, and inflicting direct damage. However, the textual description lacks sufficient parameters to isolate a single physical mechanism, rendering it scientifically unviable to assert that the Quranic saa'iqah is strictly identical to a specific meteorological phenomenon in all its parameters (Ibn Kathir, n.d., 1999).

4.4 The Punishment of the Day of the Shadow: The Companions of the Wood (Ashaab al-Aykah)

The text states: "But they denied him, so the punishment of the day of the shadow (Yawm al-Zhullah) seized them. Indeed, it was the punishment of a terrible day" (Quran 26:189). Exegetical literature provides accounts regarding the shadow, dense clouds, intense heat, and associated afflictions. While heat stress, prolonged drought, and severe atmospheric anomalies offer comparative points of inquiry, empirical evidence remains insufficient to classify this event as a heatwave storm, volcanic plume, or pyroclastic cloud. Exegetical narratives must remain within their historical-hermeneutical framework rather than being transformed into modern meteorological measurements (Quran, Surah al-Shu'ara; al-Qurtubi, n.d.).

4.5 The People of Lot: Inversion of Place and the Rain of Stones

The Quran records: "So We made the highest part [of the city] its lowest and rained upon them stones of layered hard clay (sijjeel)" (Quran 15:74). The verse combines structural inversion with the precipitation of stone-like projectiles. The Dead Sea basin is characterized by active tectonics along the Dead Sea Transform (DST) fault line, where earthquakes and land subsidence can leave distinct signatures on structures and stratigraphic layers. However, localized seismic history does not validate a specific earthquake as the event referenced in the text, nor does the presence of localized stone deposits definitively prove a volcanic eruption (Trifonov, 2007).

Geological hypotheses regarding the destruction of ancient Bronze Age settlements in the region can be evaluated through sedimentological, archaeoseismic, and radiometric analyses, alongside competing explanations such as faulting, flooding, or slope failures. Although various studies have discussed the interplay between regional traditions and Dead Sea geology, they do not provide conclusive proof that the Quranic verse describes a specific volcanic eruption (Emery & Neev, 1995).

4.6 The Earthquake Tremor (al-Rajfah) and the Blasting Cry (al-Saiha): Thamud and the People of Shu'ayb

Regarding Thamud, the text states: "So the earthquake (al-rajfah) seized them, and they became within their homes fallen prone" (Quran 7:78). Regarding Midian, it states: "And the awful cry (al-saiha) seized those who had wronged, and they became within their homes fallen prone" (Quran 11:94). Methodological precision requires distinguishing between these passages: al-rajfah pertains to Thamud, whereas al-saiha targets the people of Shu'ayb in Midian.

Al-rajfah can be compared to seismic ground shaking, which causes structural wall cracking, roof collapses, hydrological disruptions, or secondary landslides. Archaeoseismology investigates structural damage patterns in ancient built environments, distinguishing them from war damage, conflagrations, or gradual abandonment.

Nevertheless, the term al-rajfah does not specify a magnitude on modern seismic scales, nor does al-saiha provide physical parameters to model a destructive acoustic shockwave. Secondary agricultural and urban decline could also arise indirectly if population collapse halted the maintenance of vital irrigation networks a hypothesis requiring independent empirical validation in each case (Trifonov, 2007).

4.7 The Inundation (al-Tufan) in the Narrative of Pharaoh

The Quran states: "So We sent upon them the flood (al-tufan), locusts, lice, frogs, and blood as distinct signs" (Quran 7:133). Inundation appears within a series of signs in the Pharaonic narrative. While hydrological hazards, multi-year droughts, or Nile failure significantly disrupted ancient Egyptian agriculture and political stability, equating a specific historical Nile event with the Quranic inundation requires independent, synchronized evidence. Studies on the (~4.2 ka BP)aridification event highlight the vulnerability of ancient Egypt to hydrological shifts, yet they do not establish a direct causal linkage to the Pharaonic narrative of the Quran (Younes & Bakry, 2022).

5. Comparative Analytical Table of Quranic Phenomena and Natural Sciences

Table 2 summarizes the nations, associated phenomena, Quranic verses, potential domains of scientific comparison, and prospective physical/archaeological evidence. The referenced empirical lines of evidence represent research hypotheses requiring field verification, rather than a priori proofs of exact equivalence between natural phenomena and Quranic events.

Nation / People	Quranic Phenomenon	Quranic Reference	Scientific Comparative Domain	Prospective Field / Empirical Evidence
People of 'Ad	Severe howling wind (al-Rih al-Sarsar)	Fussilat: 16 Al-Haqqah: 6–8	Aerodynamics, wind velocity, and soil erosion	Sand dune deposits (*aeolian sediments*) and historical erosion features
People of Noah	Comprehensive Deluge (sky precipitation &groundwater springs)	Al-Qamar: 11–12 Hud: 40–44	Hydrology, surface runoff, and aqueous sedimentation	Alluvial stratification and ancient river channel dynamics (*paleochannels*)
People of Sheba (*Saba'*)	The Flood of the Dam (Sail al-'Arim)	Saba': 15–17	Hydraulic engineering, water management, and wadi flooding	Structural remains of ancient dams/canals and flash flood deposits
People of Thamud	Thunderbolt (*Saa'iqah*), Earthquake Tremor (*Rajfah*), Blasting Cry (*Saiha*)	Fussilat: 17 Al-A'raf: 78	Atmospheric electrical discharge and seismic ground motion	Radiometrically dated fault lines and structural collapse patterns (*archaeoseismology*)

Companions of the Wood (*Ashaab al-Aykah*)	Punishment of the Day of the Shadow (*Yawm al-Zhullah*)	Al-Shu'ara: 189	Severe thermal stress and extreme atmospheric anomalies	Paleoclimatic proxy records (where available)
People of Lot	Urban inversion and rain of stones	Al-Hijr: 74	Tectonic geology, slope failure, and rockfalls	Tectonically induced lithological or volcanic strata
People of Shu'ayb	The Blasting Cry (*al-Saiha*)	Hud: 94	Acoustic phenomena and catastrophic shockwave impacts	Independent mechanical or archaeological evidence (if identifiable)
People of Pharaoh	Inundation (*al-Tufan*) (among the Plagues)	Al-A'raf: 133	Nile Delta hydrology and paleoclimatology	Sedimentary records associated with historical Nile water level fluctuations
Nations In General	Ecological degradation / Mischief (*Fasad*) on land and sea	Al-Rum: 41	Ecological economics, land degradation, and environmental deterioration	Palynological analysis (pollen cores), soil salinization, and sediment dynamics

6. Climate Change and Civilizational Transformations

6.1 Methodological Guidelines for Comparing Scriptural Texts with Empirical Evidence

Scientific comparison requires clearly defining the nature of the claim to be tested prior to evidence collection. A fundamental distinction exists between stating that a known natural phenomenon resembles a description in the text and asserting that this phenomenon constitutes the direct historical cause of the Quranic event. The former represents a descriptive comparative exercise that can generate useful research questions; the latter, however, demands precise spatial and chronological demarcation, independent empirical evidence, and a synchronized timeline between the event and the archaeological or sedimentological strata under examination. Furthermore, alternative explanations must be rigorously evaluated; structural collapse may result from earthquakes, warfare, fires, or protracted structural deterioration, just as a sedimentary layer can originate from flooding, human activities, or recurring natural processes.

A critical methodological imperative is avoiding selection bias namely, cherry-picking evidence that supports a single hypothesis while disregarding contradictory indicators and refraining from superimposing modern scientific terminology onto ancient scriptural expressions without adequate linguistic and exegetical justification. Equally crucial is distinguishing the history of a natural phenomenon from the history of human settlement; a region may have experienced paleoclimatic shifts without empirical proof that such shifts led to its abandonment or that a specific community inhabited the area during that precise interval. Consequently, findings should be articulated using nuanced and open formulations such as "aligns with," "allows for comparative analysis," or "warrants further empirical testing" rather than definitive assertions unsupported by absolute proof.

Recent research indicates that while droughts, floods, and environmental shifts exacerbate agricultural and economic stress, they do not singularly account for the collapse of civilizations. For instance, civilizational transformations in the Eastern Mediterranean during the Late Bronze Age were driven by complex, interconnected climatic, political, commercial, and socio-economic dynamics (Kaniewski et al., 2015). Similarly, the study by Douglas et al. (2016) highlights the role of drought in the collapse of the Maya civilization while emphasizing that societal collapse cannot be reduced to a single climatic variable.

Paleoclimatic investigations in Southern Arabia demonstrate that the region experienced alternating humid and arid phases that shaped water availability, vegetation cover, and human settlement patterns (The Stalagmite Record of Southern Arabia, 2021). While these findings reconstruct the environmental context of ancient societies, they neither prove that drought was the sole cause for settlement abandonment nor automatically link these climatic episodes to a specific Quranic event. Explaining civilizational transformations necessitates the integrated synthesis of paleoclimatic, archaeological, and historical evidence.

The ancient hydraulic system of Marib serves as an exemplar of the adaptive capacity of past societies in engineering sophisticated water management solutions within hyper-arid environments. This case underscores the vital necessity of infrastructure maintenance, equitable water distribution, and flood hazard management, illustrating that the impact of natural phenomena is intrinsically conditioned by a society's adaptive capacity and resilience (UNESCO World Heritage Centre, n.d.).

The Quran explicitly connects environmental and ethical degradation on land and sea to human actions, stating: "Corruption has appeared throughout the land and sea by [reason of] what the hands of people have earned so He may let them taste part of [the consequence of] what they have done that perhaps they will return" (Quran 30:41). This verse offers a normative ethical framework for reflecting on human environmental stewardship. In contrast, contemporary climate change is empirically investigated through the measurement of surface temperatures, precipitation dynamics, greenhouse gas concentrations, and related physical proxies. Value-based ethical frameworks and empirical scientific research can complement one another without one subsuming the other or reducing complex climatic drivers to a single factor.

6.2 Limitations of the Study and Future Research Directions

This study is limited to textual analysis and theoretical comparison with published literature in paleoclimatology, geology, and environmental archaeology. It does not claim to present new empirical fieldwork or perform radiometric dating on archaeological strata associated with the narrated events. Furthermore, geographically pinpointing the precise historical settlements of specific ancient nations, or definitively attributing their demise to a single geological catastrophe, remains subject to ongoing scholarly debate requiring independent empirical verification. Data availability varies significantly across geographical regions, and natural archives do not preserve all historical events with equal fidelity; successive geomorphic processes frequently overlap, confounding attempts to attribute sedimentological signatures to a single event (Trifonov, 2007; Emery & Neev, 1995).

Future research avenues include conducting targeted case studies focused on specific geographic regions with robust, well-documented archaeological and geological records. The spatial-temporal and material data from these sites can then be evaluated against proposed hypotheses without predetermining outcomes. Such empirical investigations could incorporate flood sediment analyses, palynological datasets (pollen cores), pedological transformations, and structural failure patterns in built environments, integrated with a systematic review of relevant historical and exegetical sources. This approach moves the academic discourse beyond generalized structural resemblances toward the empirical testing of specific hypotheses, while preserving religious and hermeneutical inquiries within their proper framework (Kaniewski et al., 2015; Jahan & Quamar, 2024).

6.3 Applied Significance and Environmental Awareness

The significance of this topic extends beyond comparative analysis between Quranic descriptions and natural phenomena; it offers valuable applications for environmental education. Narratives of ancient civilizations provide a platform for examining societal vulnerability when critical resources face disruption, underscoring the imperative of sustainable water management, soil conservation, infrastructure maintenance, and disaster preparedness. These concepts can be integrated into educational frameworks that bridge scriptural texts with

empirical scientific data, provided that a clear distinction is maintained between moral exhortation and empirical evidence.

Furthermore, educational materials should incorporate well-documented modern examples of droughts, floods, and earthquakes, highlighting their physical mechanisms and mitigation strategies, rather than presenting them as literal repetitions of ancient historical events. Consequently, this interdisciplinary inquiry serves as a bridge for dialogue between religious heritage and modern science, rather than a mechanism for imposing unverified scientific conclusions.

7. Findings

1. Quranic descriptions of divine retribution encompass diverse phenomena including violent winds, the Deluge, torrential floods, thunderbolts, seismic tremors (*al-rajfah*), the blasting cry (*al-saiha*), the Day of the Shadow, and the rain of stones each requiring rigorous analysis within its specific linguistic and exegetical context.
2. The disciplines of paleoclimatology, hydrology, geology, and environmental archaeology offer constructive comparative perspectives; however, they do not independently establish strict historical equivalence between a Quranic narrative and a modern scientific phenomenon.
3. Establishing the historical occurrence of a specific disaster at a given site requires independent, radiometrically dated empirical evidence such as alluvial deposits, archaeological stratigraphy, fault lines, and paleoclimatic proxies alongside a rigorous evaluation of alternative hypotheses.
4. While droughts and catastrophic floods can trigger societal instability, major civilizational transformations typically result from multi-causal interactions among environmental, economic, political, and socio-cultural drivers.
5. The ancient Sabaean irrigation system of Marib provides a primary archaeological model demonstrating the critical role of hydraulic infrastructure in sustaining agricultural stability within hyper-arid environments.
6. Quranic narratives can be effectively leveraged to enhance modern environmental ethics and human stewardship, provided a clear distinction is maintained between religious significance and empirical scientific findings.

8. Recommendations:

1. Encourage collaborative interdisciplinary research involving scholars of Quranic exegesis (*tafsir*), climatologists, geologists, and environmental archaeologists.
2. Develop comprehensive databases documenting ancient environmental phenomena, complete with sampling locations, analytical methodologies, and radiometric chronologies.
3. Establish a rigorous taxonomy classifying scientific outcomes into confirmed empirical data, probable inferences, and testable hypotheses, explicitly avoiding assertions of direct causality without independent empirical evidence.
4. Incorporate Quranic narratives into environmental awareness initiatives using evidence-based educational materials and documented imagery, while ensuring illustrative diagrams or artistic renderings are not misrepresented as definitive historical records.

9. Conclusion

This study concludes that the natural phenomena cited within the narratives of past nations provide a viable matrix for interdisciplinary convergence between Quranic exegesis, paleoclimatology, geology, and environmental archaeology. Modern scientific inquiry enhances our understanding of how droughts, floods, and earthquakes impacted ancient ecosystems and human societies; nevertheless, it does not automatically establish that a specific physical phenomenon constitutes the direct historical explanation for a given Quranic

event. The validity of any scientific conclusion remains contingent upon the availability of independent, radiometrically dated physical evidence and a clear distinction between exegetical hermeneutics and scientific hypotheses. Ultimately, the most rigorous approach is one that synthesizes reverence for the Quranic text, analytical precision in presenting scientific data, and the application of scriptural ethical insights to foster contemporary environmental consciousness.

References:

1. القرآن الكريم، سورة الفتح، الآية 7؛ سورة فصلت، الآيتان 16–17؛ سورة الحاقة، الآيات 6–8؛ سورة القمر، الآيات 11–12؛ سورة سبأ، الآيات 15–17؛ سورة الشعراء، الآية 189؛ سورة الحجر، الآية 74؛ سورة الأعراف، الآيتان 78 و133؛ سورة هود، الآية 94؛ سورة الروم، الآية 41.
2. الطبري، محمد بن جرير. جامع البيان عن تأويل آي القرآن. ويمكن الرجوع إلى تفسير الآية السابعة من سورة الحاقة عبر المكتبة القرآنية بجامعة الملك سعود.
3. ابن كثير، إسماعيل بن عمر. تفسير القرآن العظيم. تفسير سورة فصلت، الآية 17. النص الإلكتروني.
4. القرطبي، محمد بن أحمد الأنصاري. الجامع لأحكام القرآن. تفسير سورة الشعراء، الآية 189. النص الإلكتروني.

5. Douglas, P. M. J., Demarest, A. A., Brenner, M., & Canuto, M. (2016). Impacts of Climate Change on the Collapse of Lowland Maya Civilization. Annual Review of Earth and Planetary Sciences, 44, 613–645. https://doi.org/ 10.1146/annurev-earth-060115-012512.
6. Kaniewski, D., et al. (2015). Drought and societal collapse 3200 years ago in the Eastern Mediterranean: a review. WIREs Climate Change, 6, 369–382. https://doi.org/ 10.1002/wcc.345.
7. Jahan, T., & Quamar, M. F. (2024). The '4.2 ka drought event' and the fall of the Harappan Civilization: A critical review. Review of Palaeobotany and Palynology, 331, 105187.
8. Younes, M. A., & Bakry, A. (2022). The 4.2 ka BP Climate Event in Egypt: Integration of Archaeological, Geoarchaeological, and Bioarchaeological Evidence. African Archaeological Review, 39, 315
9. The Stalagmite Record of Southern Arabia: Climatic Extremes, Human Evolution and Societal Development. (2021). Frontiers in Earth Science
10. Trifonov, V. G. (2007). The Bible and geology: destruction of Sodom and Gomorrah. In L. Piccardi & W. B. Masse (Eds.), Myth and Geology. Geological Society, London, Special Publications, 273. https://doi.org/ 10.1144/GSL.SP.2007.273
11. Recognition of earthquake-related damage in archaeological sites: Examples from the Dead Sea fault zone.
12. Emery, K. O., & Neev, D. (1995). The Destruction of Sodom, Gomorrah, and Jericho: Geological, Climatological, and Archaeological Background. Oxford University Press.
13. UNESCO World Heritage Centre. Landmarks of the Ancient Kingdom of Saba, Marib. https://whc.unesco.org/en/list/ 1700.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

TRANSLATING CULTURE OR MEDIATING CULTURE? THE REPRESENTATION OF ALBANIAN CULTURAL CONCEPTS FOR INTERNATIONAL AUDIENCES

Xhiljola Abdihoxha
PhD in Linguistics, Lecturer at European University of Tirana, Rruga Xhanfize Keko, Tiranë 1000
ORCID: *0009-0004-1012-7395*

Abstract

This article examines how culturally specific Albanian concepts, including *besa*, the Kanun, *mikpritja*, and iso-polyphony, are represented for international, English-speaking audiences, and asks whether this process is better understood as linguistic translation or as cultural mediation. The relevance of the study lies in the growing international visibility of Albania since the country's post-1990 opening and its subsequent European Union candidacy, developments that have multiplied the contexts in which such concepts now circulate beyond specialist and diaspora audiences. The purpose of the article is to establish a theoretical foundation for analysing this circulation through a critical synthesis of literature from Translation Studies, cultural mediation, intercultural communication, recontextualization theory, and studies of Balkan and Albanian cultural representation. The review draws on peer-reviewed sources selected for their direct relevance to culture-specific translation and to Albanian and Balkan identity, combining foundational theoretical works with scholarship published within the last five years. The discussion shows that although each of these bodies of literature offers well-developed tools for analysing how culturally embedded meanings are rendered across languages and genres, none has so far been applied systematically to Albanian cultural concepts, and the mediation of such concepts on digital platforms remains almost entirely unstudied. The article's main contribution is to integrate these separate theoretical strands into a single coherent analytical framework and to identify precisely where empirical research on the international representation of Albanian culture is currently lacking. Its practical value lies in offering translators, cultural mediators, heritage institutions, and researchers in Albanian and Balkan studies a structured basis for examining how such concepts are, and could more carefully be, represented to international audiences.

Keywords: *cultural mediation; translation studies; culture-specific items; recontextualization; Albanian cultural identity; intercultural communication.*

INTRODUCTION

Since Albania's opening after 1990 and, more markedly, since its 2009 application for European Union membership, the country's cultural life has become visible to international audiences in ways it was not during the preceding decades of isolation. Concepts that circulated primarily within Albanian-language and diaspora contexts, such as *besa*, an oath-bound code of honour; the Kanun, a body of customary law; *mikpritja*, a practice of hospitality; and iso-polyphony, a form of traditional vocal music, now appear regularly in English-language journalism, tourism promotion, academic writing, official heritage documentation, and digital media. This growing circulation raises a question that is conceptually prior to any specific case: whether rendering such concepts for an international audience is best understood as an act of linguistic translation, in the narrow sense of finding equivalent words, or as an act of cultural mediation, in the broader sense of constructing intelligibility for an audience whose frames of reference differ from those of the source culture.

Recent scholarship across several adjacent fields suggest that this distinction is far from settled. Work on cultural mediation in tourism translation has shown how culture-specific items are systematically adapted, rather than simply translated, when a destination markets itself to international visitors (Alangari, 2022). Studies of media paratexts and of crisis communication have likewise documented translators and interpreters actively reshaping meaning for new audiences well beyond the wording of the source text (Yuan, 2023; Zhang, Zhuang, & Chang, 2023). At the same time, research on untranslatable words continues to demonstrate how

easily culturally dense concepts slide into a popularising, listicle-like treatment once they leave specialist discourse (Piazzoli, Corderi Novoa, & Hogan, 2024), while the latest edition of the standard reference on cultural mediation in translator and interpreter training reaffirms the need to treat mediation as an operation distinct from, though related to, linguistic transfer (Katan & Taibi, 2021). On the Albanian side specifically, recent work in paremiology has begun to trace how *besa* circulates in English-language sources through comparison with existing English idioms of honour (Shijaku, 2025), extending an older but still valuable line of Albanian-focused scholarship (Tarifa, 2008; Schwandner-Sievers, 2008).

Despite this activity across adjacent fields, no existing study brings these strands together to examine Albanian cultural concepts specifically through the lens of translation and mediation theory. The purpose of this article is to address that gap at the theoretical level: to synthesise the relevant literature on translation and cultural difference, cultural mediation, intercultural communication, recontextualization, and Balkan and Albanian representation, and to show precisely where these bodies of scholarship converge, where they remain in tension, and where Albanian material is genuinely absent rather than merely under-cited. The novelty of the article lies not in proposing a new theory but in the systematic cross-disciplinary synthesis itself, which has not previously been undertaken for this case.

The discussion below is organized into four sections addressing, in turn, six interconnected strands of literature: translation and the limits of linguistic equivalence; cultural mediation as an extension of translation; intercultural communication together with recontextualization theory; and cultural identity together with digital discourse in the representation of Albanian culture. Sources were identified through targeted searches of the relevant literatures, prioritising foundational works that remain the standard reference points in their fields alongside scholarship published within the past five years where such work exists, with particular attention paid to locating Albanian and Balkan material specifically rather than assuming it to be sparse. Where the search confirmed that a given strand of theory has not yet been applied to Albanian material, this is reported as a finding of the review rather than left unaddressed.

LITERATURE REVIEW

1. Translation and Culture: The Limits of Linguistic Equivalence

The dominant early paradigm in Translation Studies treated the discipline as a problem of equivalence: finding target-language forms capable of reproducing the meaning carried by a source text. Nida and Taber's (1969) distinction between formal and dynamic equivalence, the former preserving source-text form and the latter prioritising an equivalent effect on the target reader, still underpins much of the field. By the 1980s and 1990s, however, a cultural turn associated above all with Bassnett and Lefevere (1990) had begun to reframe translation as a culturally and ideologically embedded act rather than a straightforward exercise in linguistic transcoding. Meaning is no longer treated as a stable, portable unit that survives transfer intact, but as something reconstructed within a new set of cultural expectations and reception norms.

Two contributions within this tradition matter directly here. Aixelá's (1996) notion of culture-specific items (elements bound up with source-culture history or practice that have no ready target-culture equivalent) offers a workable taxonomy of translation procedures, from conservation strategies such as repetition and gloss to substitution strategies such as universalization, naturalization, and deletion, well suited to describing how terms such as *besa* or *mikpritja* are handled in English-language texts. Venuti's (1995) distinction between domestication, which assimilates a foreign text to target-culture norms, and foreignization, which retains the source culture's strangeness, reframes this as an ethical and political choice rather than a purely stylistic one. A recent application of this framework to tourism translation, examining how Saudi Arabian culture-specific items are rendered for international visitors, confirms that such choices remain analytically productive well beyond literary translation, the context in which Venuti's model was originally developed (Alangari, 2022). What neither Aixelá nor Venuti addresses directly, however, is why a given strategy is chosen or what its ideological consequences are. These questions are taken up below through cultural mediation and recontextualization theory. A further point worth noting is that neither framework was developed with non-literary, multi-genre material in mind: extending a taxonomy built for literary culture-specific items to tourism

copy, heritage documentation, or social media captions is a legitimate move, supported by Alangari's (2022) tourism-focused application, but it is an extension rather than a direct transfer, and should be treated as such in any study that adopts it.

2. Cultural Mediation: Definitions and Divergence from Translation

Within Translation Studies specifically, Katan and Taibi's (2021) *Translating Cultures* remains the central reference for cultural mediation. Katan positions the translator or interpreter not as a code-switcher but as a mediator who manages the implicit, culture-bound frames that differ between source and target audiences, deciding what must be made explicit, what can be omitted as obvious, and what needs to be reframed. This is where the distinction the present review builds on can be anchored: translation, even under the cultural-turn paradigm, still orients around a text and an act of transfer, whereas cultural mediation reframes the mediator as someone who actively constructs intelligibility for an audience. Recent empirical work supports treating mediation as a distinct operation rather than a synonym for good translation: studies of crisis communication (Zhang, Zhuang, & Chang, 2023) and of film paratexts (Yuan, 2023) both document mediators reshaping tone, framing, and emphasis well beyond what lexical substitution alone would require. What remains unresolved in the literature is how sharp the boundary between translation and mediation actually is; the position adopted here, consistent with this recent work, is that the two sit on a continuum of intervention rather than occupying categorically separate territory.

This distinction matters because it has direct consequences for how a text can be read. A passage may retain an Albanian term and supply an accurate gloss, a conservative move in translation-strategy terms, while still mediating the concept into a simplified or moralized frame at the level of the surrounding discourse. Recognising this possibility requires treating lexical strategy and discursive framing as related but separable questions, which is precisely why cultural mediation theory needs to be paired with the recontextualization framework discussed in Section 3 rather than substituted for it.

3. Intercultural Communication, Meaning Negotiation, and Recontextualization

Two positions dominate the literature on intercultural communication. The older position, associated with cultural-dimensions and high or low-context models, treats national or ethnic culture as a relatively stable variable that predicts communicative behaviour. The now-dominant academic position is explicitly anti-essentialist: Holliday's (1999) concept of small cultures locates culture at the level of cohesive behaviour within any social grouping rather than in a fixed national essence, and Dervin and Machart (2015) extend this critique, arguing that the field continues to rely on culture as an explanatory variable even while rejecting essentialism in principle. Essentialist, nation-as-culture models nonetheless persist in popular discourse, including tourism marketing, journalism, and some heritage institutions, even where academic theory has largely moved past them. This gap between scholarly consensus and popular practice is directly relevant here, since English-language representations of *besa* or *mikpritja* are precisely the kind of popular discourse that tends to essentialize Albanian identity.

A genuine methodological tension follows from this, and it is worth naming rather than resolving away: analysing Albanian cultural concepts as a category risks reproducing the very essentialism that anti-essentialist theory sets out to critique. The most defensible response in the literature is not to abandon the category but to treat it as historically and discursively constructed rather than as a timeless expression of national character, a position consistent with Holliday's (1999) own insistence that culture is best studied as an emergent, interpretive construct. It is also worth noting that direct engagement between intercultural communication theory and Balkan or Albanian material remains thin: Holliday's and Dervin and Machart's (2015) illustrative material is drawn overwhelmingly from East Asian, Western European, or generically international contexts, with the Balkans largely absent from this literature.

A related question concerns not whether cultural categories are essentialized but how meaning itself changes as a concept moves from one discursive setting into another, which is where recontextualization theory becomes directly relevant. Bauman and Briggs (1990) introduced entextualization, the process by which a stretch of discourse is rendered extractable as a bounded text detachable from its original interactional setting,

together with the paired processes of decontextualization and recontextualization, arguing that this movement is never neutral but shaped by differential access and authority. Blommaert (2010) extends this into a framework of scales, in which linguistic and cultural resources shift in function and authority as they move from local to global, or from vernacular to institutional, settings. This fits well with tracking how *besa* moves from oral proverb and Kanun clause, a local and vernacular scale, to shorthand for a wartime rescue narrative in international journalism, a global and moralized scale, to a single line in official heritage documentation, an institutional scale. Entextualization and recontextualization are by now standard tools for describing exactly this kind of movement across genres, though no existing study applies them specifically to Albanian cultural concepts or to Balkan heritage discourse.

Blommaert's scale framework has itself drawn criticism, notably for describing hierarchy among discursive scales without always interrogating where that hierarchy originates, and for relying on a spatial metaphor that risks becoming explanatory in its own right rather than remaining a descriptive heuristic. This is a reasonable caution to carry into any application of the framework: moving up a scale is best used to describe observable shifts in genre, authority, and audience, not treated as a mechanism that explains those shifts by itself. With that caveat noted, the framework's core claim, that recontextualization is never a neutral transfer of content, remains the most directly applicable theoretical tool currently available for tracking how a single Albanian concept accrues different meanings as it moves between academic, journalistic, institutional, and digital settings.

4. Cultural Identity and Digital Discourse in the Representation of Albanian Culture

This is where Albanian-specific scholarship is genuinely available. On the theoretical side, Hall's (1997) account of representation as a signifying practice, including his discussion of the spectacle of the Other, applies directly to how touristic and journalistic texts stage Albanian hospitality or honour codes for an outside audience. On the specifically Balkan register of the same problem, Todorova's (1997) concept of Balkanism describes how the Balkans function in Western discourse as Europe's internal, semi-familiar other, while Goldsworthy (1998) traces how British and American fiction constructed a durable, largely invented Balkan imaginary that continues to shape Western expectations of the region.

Three strands of Albania-specific scholarship extend this into the present case. Schwandner-Sievers (2008) documents how Albanian violence has been alternately romanticized and demonized with reference to Kanun tradition, in both outsider and Albanian self-representations. Tarifa (2008) gives an academically grounded account of *besa*'s centrality to Kanun-based customary law and its semantic range (oath, faith, trust, protection, truce) that serves as a source-culture anchor against which international renderings can be measured. Shijaku (2025) examines *besa* through Albanian proverb collections and stages an explicit comparison with the English idiom “an Englishman's word is his bond,” directly documenting *besa*'s circulation in English-language media and in the work of both Albanian and English-language writers on Albania. Taken together, this literature confirms that Balkanism-style critique of Western representation is mature and well evidenced, and that good-quality Albanian-specific scholarship on *besa* and the Kanun exists, even though none of it is framed through translation or cultural-mediation theory specifically. This is the clearest indicator of where the present synthesis contributes something not yet available in the literature.

How cleanly the Balkanism framework transfers to Albania specifically is a further question worth flagging rather than assuming settled. Todorova (1997) and Goldsworthy (1998) work primarily with material concerning the former Yugoslav space and the wider Balkan peninsula, and Albania's international image has followed a somewhat different trajectory: decades of isolationist communist rule, a later and more compressed post-1990 opening, and a wartime rescue narrative around *besa* that is unusually positively coded compared with much Balkanist discourse elsewhere. Balkanism is therefore best treated in this context as an enabling framework rather than as a claim that Albania is a straightforward instance of a general Balkan pattern.

A substantial and growing literature on digital storytelling and heritage or tourism branding confirms that digital platforms are reshaping how cultural heritage is packaged for international audiences, with genre conventions such as short captions, visual-first storytelling, and algorithmic discoverability that differ from print journalism or academic writing. It also confirms that UNESCO-listed intangible heritage generally, a

category that includes Albanian iso-polyphony, inscribed in 2008, is a recognized object of this kind of scholarship. What could not be located, however, is any substantial peer-reviewed literature examining digital-platform mediation of Albanian cultural concepts specifically; the available material in this domain is largely non-scholarly.

This does not mean the digital dimension should be set aside; it means the opposite conclusion should be drawn carefully. Digital platforms are, by the general literature's own account, where genre conventions differ most sharply from print and institutional discourse, which makes their neglect in Albania-specific scholarship a substantive gap rather than a peripheral one. At the same time, the absence of prior work in this area means that any claim about how Albanian cultural concepts circulate on social media or video platforms currently rests on general trends observed elsewhere, not on evidence specific to the Albanian case, and should be presented with that limitation made explicit.

METHODOLOGY

This study adopts a qualitative, narrative literature-review approach based on a critical synthesis of scholarship relevant to the representation of Albanian cultural concepts for international audiences. The material comprises peer-reviewed literature from Translation Studies, cultural mediation, intercultural communication, recontextualization theory, and Balkan and Albanian cultural representation, combining foundational theoretical works with recent scholarship, particularly where Albanian or Balkan material is available. Sources were identified through targeted searches and selected for their direct relevance to culture-specific translation, cultural mediation, and Albanian and Balkan identity. The analysis is guided by an integrated theoretical framework drawing primarily on culture-specific items, cultural mediation, anti-essentialist intercultural communication, recontextualization, and theories of cultural representation.

RESULTS

The review demonstrates that the representation of Albanian cultural concepts cannot be adequately understood through linguistic translation alone, as translation and cultural mediation operate as related points on a continuum of intervention. The literature shows that recontextualization provides a useful framework for examining how meanings shift as concepts move across genres, audiences, and discursive scales, while intercultural communication scholarship highlights the risk of essentializing cultural identity in international representations. Albanian-specific scholarship provides substantial documentation of concepts such as *besa* and the Kanun, but has not systematically connected this material with translation and mediation theory. The review also identifies a pronounced lack of peer-reviewed research on the digital-platform mediation of Albanian cultural concepts, establishing a specific empirical gap for future research.

CONCLUSIONS

This review has brought together six interconnected strands of literature that are rarely considered jointly: Translation Studies' account of culture-specific items, cultural mediation theory, anti-essentialist intercultural communication scholarship, recontextualization theory, and Balkan and Albanian representation and digital-discourse studies. Each offers a well-developed set of analytical tools; none has previously been applied, in combination, to the way Albanian cultural concepts circulate internationally. The central conclusion is that rendering concepts such as *besa*, the Kanun, *mikpritja*, and iso-polyphony for English-speaking audiences cannot be adequately described as either translation or mediation alone, since the literature reviewed here shows these operating as points on a continuum rather than as alternatives, and that existing Albanian-specific scholarship, though of good quality, has so far documented this circulation through folklore, anthropology, and paremiology rather than through translation or mediation theory.

The main academic contribution of this article lies in this cross-disciplinary synthesis itself and in the precision with which it identifies where the resulting gap actually sits: not in a general absence of scholarship on Albanian culture, but in the specific absence of studies that track how translation and mediation strategies

shape international representations of that culture across genres. This distinction matters in practice: it means that future research in this area does not need to build a case for Albanian cultural studies from first principles, but can instead bring an already well-developed, cross-disciplinary analytical toolkit to bear on a case that toolkit has not yet been asked to address. For translators, interpreters, and cultural mediators working between Albanian and English, as well as for heritage institutions and tourism bodies engaged in international promotion, the review offers a clearer vocabulary for recognising when a rendering of a cultural concept moves from conservative gloss toward essentializing or promotional reframing, a distinction with practical consequences for how such institutions represent Albanian culture abroad.

This synthesis has clear limitations. As a literature review, it establishes a theoretical framework rather than empirical findings, and its conclusions about how Albanian concepts are actually rendered in practice remain hypotheses to be tested rather than demonstrated results. Its account of digital-platform mediation is limited by the genuine scarcity of peer-reviewed scholarship in that specific domain, and the review draws primarily on English-language sources, which may itself shape which strands of Albanian and Balkan scholarship it was able to draw on. A further limitation follows from the selectivity inherent in any narrative synthesis of this kind: the strands examined here were chosen because they converge most directly on the article's guiding question, but adjacent literatures, on heritage tourism management, diaspora studies, or language policy in EU accession contexts, for instance, could extend the picture in ways this review does not attempt to cover. Future research should apply the integrated framework developed here to a purpose-built corpus of English-language texts about Albanian cultural concepts, spanning academic, journalistic, institutional, and digital genres, in order to establish empirically how far the patterns anticipated by this review actually hold, and to determine whether the strategies identified for *besa*, the Kanun, *mikpritja*, and iso-polyphony generalize to other Albanian cultural concepts not examined here.

Synthesis: What the Literature Establishes and What Remains Open

Several claims hold up across the literature reviewed here. Translation is not a neutral search for equivalence, and culture-specific items constitute a well-theorized problem (Aixelá, 1996; Venuti, 1995). Cultural mediation is a recognized extension of translation theory, supported by recent empirical work outside the Albanian context (Katan & Taibi, 2021; Zhang, Zhuang, & Chang, 2023). Essentialist models of national culture persist in popular discourse even where intercultural communication theory has largely set them aside (Holliday, 1999; Dervin & Machart, 2015), and recontextualization theory offers a robust toolkit for tracking how meaning changes across genres and scales (Bauman & Briggs, 1990; Blommaert, 2010). Other questions remain genuinely open: where translation ends and mediation begins; whether Balkanism as a framework transfers cleanly to Albania's distinct historical trajectory; and how a study can analyse Albanian cultural concepts as a category without reproducing the essentialism its own framework sets out to critique. What is missing altogether is a systematic application of this combined toolkit to Albanian material across the genres in which it circulates: academic, journalistic, institutional, and digital.

It is worth being precise about what kind of gap this is, since the term is used loosely in much academic writing. It is not a gap in theory: the analytical tools reviewed here are mature and, in several cases, have already been applied productively to comparable cases in other national contexts, such as tourism translation in Saudi Arabia (Alangari, 2022) or crisis-driven cultural mediation in China (Zhang, Zhuang, & Chang, 2023). Nor is it a gap in source-culture documentation, given the quality of existing Albanian folkloristic and anthropological scholarship (Tarifa, 2008; Schwandner-Sievers, 2008; Shijaku, 2025). It is, specifically, a gap in the application of the first kind of literature to the second: no study has yet used a translation-mediation framework to read the corpus of English-language texts in which Albanian cultural concepts already circulate.

ACKNOWLEDGMENTS

I gratefully acknowledge the scholars whose research provided the theoretical foundations for this study.

REFERENCES

Aixelá JF 1996. Culture-specific items in translation. In: Álvarez R, Vidal MC-Á (eds), Translation, power, subversion. Clevedon, England: Multilingual Matters, pp. 52-78.

Alangari E 2022. Cultural mediation in tourism translation: Saudi Arabia as a case study. Arab World English Journal for Translation & Literary Studies, 6(3): 82-98.

Bassnett S, Lefevere A (eds) 1990. Translation, history and culture. London, England: Pinter.

Bauman R, Briggs CL 1990. Poetics and performance as critical perspectives on language and social life. Annual Review of Anthropology, 19: 59-88.

Blommaert J 2010. The sociolinguistics of globalization. Cambridge, England: Cambridge University Press.

Dervin F, Machart R (eds) 2015. Cultural essentialism in intercultural relations. Basingstoke, England: Palgrave Macmillan.

Goldsworthy V 1998. Inventing Ruritania: The imperialism of the imagination. New Haven, CT: Yale University Press.

Hall S (ed) 1997. Representation: Cultural representations and signifying practices. London, England: Sage.

Holliday A 1999. Small cultures. Applied Linguistics, 20(2): 237-264.

Katan D, Taibi M 2021. Translating cultures: An introduction for translators, interpreters and mediators. 3rd ed. Abingdon, England: Routledge.

Nida EA, Taber CR 1969. The theory and practice of translation. Leiden, Netherlands: E. J. Brill.

Piazzoli E, Corderi Novoa M, Hogan Z 2024. Performing Yuánfèn: An exploration of untranslatable words in the Lacunae project. Arts, 13(1): 2.

Schwandner-Sievers S 2008. Albanians, Albanianism and the strategic subversion of stereotypes. Anthropological Notebooks, 14(2): 47-64.

Shijaku F 2025. Is an Albanian man's besa his bond? A paremiological dimension of besa. Proverbium, 42(1): 200-227.

Tarifa F 2008. Of time, honor, and memory: Oral law in Albania. Oral Tradition, 23(1): 3-14.

Todorova M 1997. Imagining the Balkans. New York, NY: Oxford University Press.

Venuti L 1995. The translator's invisibility: A history of translation. London, England: Routledge.

Yuan M 2023. Translation and cultural mediation in the media paratexts of Green Book: Localizing racism and friendship for a Chinese audience. Translation Studies, 16(3): 331-345.

Zhang S, Zhuang Y, Chang L 2023. Cultural mediation in crisis translation: A snapshot of the citizen translator in China's Greater Bay Area during the COVID-19 pandemic. Translation and Interpreting Studies, 18(2): 301-324.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FROM ARCHIVES TO DATA: RENEWING THE WRITING OF SENEGAL'S CULTURAL HISTORY

Aliou SENE
Lecturer and researcher, Department of History and Geography, Faculty of Sciences and Educational and Training Technologies (FASTEF), Memories, Professions and Laboratory Territories (M2TA),
Cheikh Anta Diop University of Dakar

Abstract

The historiography of Senegal has long privileged political and socio-economic narratives, relying primarily on internal critiques of colonial textual archives. The emergence of the digital humanities and the global historiographical shift now offer an opportunity to rethink the production of historical knowledge. This article examines how the transition from traditional archival collections to massive and heterogeneous digital data is reinventing Senegalese cultural history. By combining the digitization of colonial sources, the integration of oral corpora, and the creation of relational databases, contemporary research is crossing the boundaries of classical analysis. We demonstrate that this digital transformation is not simply a technical mutation, but a genuine methodological and epistemological shift. It allows us to decenter the colonial gaze, to bring to light subaltern cultural figures, and to map the circulation of Senegalese aesthetic, musical, and literary practices from a transnational perspective.

Keywords: Cultural history, Senegal, Digital archives, Digital humanities, African historiography, Research data.

Introduction

The writing of Senegalese history in the 20th century took shape around key moments, ranging from colonial chronicles to the major works of the Dakar School, spearheaded by leading figures from Cheikh Anta Diop University. While this historiography has deconstructed the imperial narrative and restored narrative sovereignty to African societies, it has remained persistently marked by a predominance of political and institutional history. Cultural history, for its part, has often been confined to the study of intellectual elites or major poetic and philosophical movements such as Negritude.

Today, the world of historical research is undergoing a profound transformation linked to the digitization of heritage collections and the use of quantitative and computational methods. This shift from material "archives" to usable "data" subjects the discipline to a major epistemological renewal.

How does the transformation of traditional sources into digital data change the practice of cultural history in Senegal? To what extent do digital tools allow us to overcome the biases of the colonial archive to bring about new representations of local and popular cultural dynamics?

The aim of this study is to demonstrate that the shift to digital is not solely about facilitating the preservation of documents, but also about creating new historical objects. It involves analyzing how the use of large corpora (old newspapers, sound recordings, photographs, civil registration records) allows us to renew the scales of analysis and offer a more inclusive historical narrative.

Our approach is based on a historiographical and critical methodology that combines cultural history and *digital humanities*. We analyze diverse documentary corpora held primarily at the National Archives of Senegal (ANS), the Fundamental Institute of Black Africa (IFAN), and the audiovisual archives of the Senegalese Radio and Television Broadcasting Corporation (RTS). The method combines computer-assisted textual analysis, historical mapping of cultural networks, and semantic indexing of oral archives.

This article is organized into three balanced parts:

The constitution of the Senegalese cultural archive and its traditional limits : a critical analysis of printed and oral sources from the 19th to the 20th century.

From document to data: digital tools and new historiographical practices : an examination of the processes of digitization, data modeling and visualizations applied to the Senegalese field.

Towards a new history of Senegalese cultural practices : illustrating theoretical contributions through the study of musical circuits, printed culture and popular memories.

1. The constitution of the Senegalese cultural archive and its traditional limits

The writing of cultural history in Senegal has long been hampered by the nature of the available sources. The hegemony of the colonial administrative archive, centralized in Dakar in what would become the General Government of French West Africa (AOF), imposed an interpretive framework centered on the concerns of the occupying power (Mbaye, 1990). Administrative reports, police records, and official bulletins viewed local cultural practices through the lens of maintaining order or the civilizing mission. Festivals, religious ceremonies, and artistic expressions were frequently categorized as disturbances to be regulated or folklore to be cataloged (Coquery-Vidrovitch , 1999).

This state-centric approach has left significant gaps in the documentation. Popular cultures, indigenous knowledge, and the dynamics of daily life outside the urban centers of the Four Communes (Saint-Louis, Gorée, Dakar, Rufisque) have been seldom recorded in writing. To address these shortcomings, Senegalese historiography has relied on oral sources since the 1960s. Pioneering work conducted at IFAN (the French Institute of Black Africa) enabled the collection of oral traditions from griots and other keepers of memory (Vansina , 1985). However, traditional oral history collection has remained limited by the constraints of physical recording on magnetic tape and by difficulties of access for researchers located far from the centers of preservation.

Structure of the Classical Historical Archive	
Colonial Funds (AOF)	Oral Archives (IFAN / Stories)
Administrative documents	Tales of griots / Epics
State/colonial filter	Fragile oral transmission
Institutional biases	Physical access restricted

Another obstacle lies in the fragmentation of the collections. Senegal's cultural memory is scattered across several continents. A significant portion of the written and iconographic sources from the 19th and early 20th centuries is held in France (National Overseas Archives in Aix-en-Provence, National Library of France), while local productions sometimes suffer from precarious conditions of physical preservation (Thiam, 2004). This geographical dispersion has long hampered attempts to create comprehensive corpora, restricting cultural history to sectoral monographic studies.

Finally, the analytical categories used in traditional inventories have often obscured translocal exchanges. The history of ideas in Senegal has often been reduced to a binary confrontation between African tradition and Western modernity (Diagne, 2007). Documents attesting to trans-Saharan intellectual exchanges, to literary networks in Arabic or Wolof (Wolof written in Arabic script), remained on the margins of official archival institutions for a long period, limiting the overall understanding of the Senegalese cultural landscape.

2. From document to data: digital tools and new historiographical practices

The transition to digital humanities is reinventing the ways in which Senegalese historical documentation is processed. Converting a heritage document into "data" is not simply a matter of producing an image file via a scanner. This process involves structuring information, metadata creation , and the application of natural language processing and computer vision (Bulla, 2018). In the Senegalese context, recent digitization programs conducted at the National Archives and the UCAD Library are paving the way for the algorithmic exploration of large corpora that were previously inaccessible in their entirety.

One of the major contributions of this transformation lies in the modeling of relational data. By converting old press records (such as *Le Petit Sénégalais* or *L'Afrique Occidentale Française*) into searchable textual databases, researchers can perform textometric analyses and map lexical co-occurrences (Sinnief , 2021). These approaches reveal the evolution of political and cultural vocabulary, the emergence of new concepts in the Senegalese public sphere between the two world wars, and the frequency with which cultural figures marginalized by official historiography appear.

Data Processing Chain
1. Digitization & OCR (Press, Manuscript , Printed Materials)
2. Enrichment & Metadata (TEI / Dublin Core Formats)
3. Computational Analysis (Textometry , Network Graphs)

The creation of digitized sound and visual archives is also redefining the processing of oral sources. Semantic indexing and text-to-sound alignment make it possible to explore hundreds of hours of audio recordings of historical narratives or radio programs without requiring exhaustive manual transcription (Fall & Ndiaye, 2020). The use of geospatial databases (GIS) allows for a spatial reinterpretation of cultural history, for example, by mapping the location of cinemas, dance halls, or cultural associations in Dakar and Saint-Louis from the 1930s to independence.

Nevertheless, the production of historical data subjects historians to new critical responsibilities. Algorithms are not neutral: the quality of digitization and the asymmetry of technological resources between the Global North and the Global South risk reproducing new forms of epistemic dependence (Mbembe, 2016). Algorithmic biases and omissions in metadata entry necessitate the development of a "critique of data" just as rigorous as the traditional diplomatic criticism developed by 19th-century historians.

3. Towards a new history of Senegalese cultural practices

The use of data as source material allows for a fresh perspective on several areas of Senegalese cultural history. The first concerns the history of music and urban social spaces. Combining business license records, radio programs, and digitized record catalogs makes it possible to reconstruct the circuits of the Senegalese music movement from the 1950s to the 1970s (Seck, 2012). Network analysis applied to this data highlights how Senegalese musicians blended Afro-Cuban influences with local rhythms (such as sabar), while also revealing the maritime and air routes used by records and artists in the Atlantic world.

Scope of application	**Traditional sources**	**Data-driven approach**	**Historiographical contribution**
Musical History	Testimonies, isolated articles	Discography catalogues, GIS of performance venues	Mapping of diffusion and crossbreeding circuits

Scope of application	Traditional sources	Data-driven approach	Historiographical contribution
Printed culture	Books by leading authors	Textometry on the press, digitized Wolofal corpus	Reconstitution of networks of subordinate readers
Islamic knowledge	Rare manuscripts in the library	Databases of Tivaouane/Touba manuscripts	Measuring the trans-Saharan circulation of texts

A second area enriched by the computational approach is the study of popular print culture and intellectual production in national languages. For a long time, literary history focused on works written in French and published in Paris. The digitization of local press corpora and Wolofal manuscripts preserved in religious brotherhoods (notably Mouride and Tijani) reveals a widespread writing and reading activity that escaped institutional channels (Ngom, 2016). Modeling this data demonstrates the existence of a public sphere literate in Arabic script as early as the late 19th century, challenging the idea of a colonial monopoly on writing.

Finally, the history of photography and visual culture directly benefits from advances in digital image processing. Serial analysis of thousands of studio photographs taken by Senegalese photographers (such as Mama Casset or Salla Casset) documents the transformations in dress codes, personal grooming, and self-presentation in mid-20th-century urban society (Nagar, 2015). The image is no longer treated as a mere passive illustration of historical text, but as a set of visual data revealing expressions of identity and popular modernity in Senegal.

Conclusion

The shift from archives to data represents a significant epistemological turning point for the cultural history of Senegal. Far from being a mere technical gimmick, the integration of computational methods offers the means to overcome the scarcity, fragmentation, and ideological bias of colonial sources. By converting printed materials, voices, images, and manuscripts into modelable data, historians can shift their focus, move from micro-narratives to serial analyses, and bring to light the memories of traditionally invisible social actors.

This shift, however, requires constant critical vigilance. Researchers must ensure that metrics do not replace interpretation and that sovereignty over Senegalese historical data remains firmly rooted in African institutions. Under these conditions, the cultural history of Senegal will continue to renew its methods, offering a more complex, inclusive narrative that is open to global exchanges.

Bibliography

- Bulla, D. (2018). *Digital Humanities and African History : Challenges and Opportunities* . Journal of African Digital History , 2(1), 12-34.
- Coquery-Vidrovitch , C. (1999). *Reflections on the cultural history of Black Africa* . Annales. Histoire, Sciences Sociales, 54(4), 911-925.
- Diagne, SB (2007). *The ink of scholars: Reflections on philosophy in Africa* . Présence Africaine.

- Fall, M., & Ndiaye, A. (2020). *Safeguarding and promoting sound heritage in Senegal: The experience of the RTS archives* . Revue Sénégalaise d'Histoire, 15, 78-95.
- Mbaye, S. (1990). *The archives of Senegal and French West Africa* . Gazette des archives, 149(1), 85-98.
- Mbembe, A. (2016). *Politics of invisibility and digital archives in Africa* . Présence Francophone, 86, 101-118.
- Nagar, A. (2015). *Visual Archives and Urban Identity: Photography in Mid -Century Dakar* . African Arts, 48(2), 34-49.
- Ngom, F. (2016). *Muslims Beyond the Arab World: The Multiliteracy of Ajami Sociolinguistics in West Africa* . Oxford University Press .
- Seck, A. (2012). *Music as archive: Reconstructing the memory of salsa in Dakar* . Cahiers d'Études Africaines, 52(206), 415-438.
- Sinnief , R. (2021). *Text Mining Colonial Archives: New Approaches to West African Press History* . Digital Studies in History , 9(3), 204-222.
- Thiam, I. (2004). *The memory of Senegal: Challenges of archival preservation in West Africa.* Ethiopiques, 72, 45-62.
- Vansina, J. (1985). *Oral Tradition as History*. University of Wisconsin Press.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

REFERENCES THAT THE MAE KAMPONG MODEL COULD PROVIDE FOR THE VILLAGE OF TAHTAKUŞLAR AS AN EXAMPLE OF COLLECTIVE SUSTAINABILITY

Safiye İrem Dizdar
ORCID. 0009-0007-7416-3215, Yeni Yüzyıl University Architectural Department İstanbul- Turkiye

Abstract

Rapid changes in global cycles today have led us to frequently use concepts such as sustainability, a livable environment, the use of active green spaces, per capita active green space, and the effective use of resources. In addition to these concepts, cultural change and degeneration are also among the threats we face.
The focus of this study is to examine the "collective sustainability" approach—which we can define as a step beyond the concept of sustainability that encompasses the protection of both the natural environment and cultural values amidst all these threats. This study begins with a detailed analysis of the Mae Kampong example, which implements the concept of collective sustainability along with all its sub-components, to define the model's functionality and sustainability. The second step of the study involves determining what kind of references this examined model could provide for Tahtakuşlar Village, which possesses considerable natural and cultural capacity but faces sustainability challenges. In this step, Tahtakuşlar Village's natural and cultural capacity was identified, and reflections and discussions regarding the reasons for its lack of sustainability were presented.
Answers to these reflections and discussions were sought by examining Mae Kampong, which can be evaluated as a positive example of collective sustainability.
The study's methodology consists of on-site assessments and observations, combined with a literature review.

Keywords: Collective Sustainability, Livable Environment, Cultural Heritage, Mae Kampong, Tahtakuşlar Village.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

HEALING SPACE, GENDERED PLACE: A TOPOANALYTICAL READING OF THE HOSPITAL IN TURKISH LITERATURE

Yasemin Hekimoğlu
Elif Özgen Aydın
0000-0001-8830-3724, Bolu Abant Izzet Baysal University, Faculty of Architecture, Department of Architecture, Bolu, Turkey.
0000-0002-8081-2097, Bolu Abant Izzet Baysal University, Faculty of Architecture, Department of Architecture, Bolu, Turkey.

Abstract

Hospitals are conventionally understood as clinical apparatuses geared solely towards medical intervention. Yet this paper proposes a different reading: the hospital as a site of bodily and psychological transformation, saturated with cultural and social meaning that far exceeds its ostensibly functional remit. Rather than examining the architecture of care through built form or design intent, this study is concerned with representation, that is, with how the hospital's relationship to the female occupant is constructed within literary narrative. Positioned within the broader category of "healing spaces," the hospital is here approached through Gaston Bachelard's topoanalysis, a phenomenological method attentive to the emotional residue and imaginative resonance that space leaves upon the subject. The hospital's transformative bearing on the female character is thus traced not through its material fabric but through the affective and psychological imprint it leaves in the text.

The paper further considers how the hospital, as a cultural institution, is textually figured in its encounter with the female user: how she is first and foremost cast as "patient", a designation that momentarily eclipses her other social identities. Turkish literature, and the novels of Suat Derviş in particular, furnish the case material. Where the street, the domestic interior and the gazino are shown to be sharply stratified along lines of social status in Derviş's fiction, the hospital emerges, remarkably, as an exception, a site of transformation and topophilia largely indifferent to class. Confined deliberately to topoanalysis alone, the paper's findings are situated, in closing, within the wider question of women's presence in public space as it is rendered in literary representation.

Keywords: Hospital, literary representation, topoanalysis, public space, healing space, women.

Introduction

Women's experience has long occupied an uneasy place in knowledge production. Feminist scholarship has shown that the supposedly universal subject of social theory was in practice a male one. Oakley's (1972) separation of sex from gender made it possible to ask how femininity is assigned rather than merely observed. Walby (2016) later theorized patriarchy as a system of interlocking structures rather than a single form of oppression. Sancar (2013) showed for Turkey that male domination operates at once within the family, the market, and the street. These accounts converge on a point that matters for everything that follows: women's lives are shaped by arrangements that are social in origin yet felt as intimately personal. The argument gains particular force when applied to space. Massey (1994) contended that place and gender constitute one another, and that women's mobility is curtailed by mechanisms ranging from the threat of violence to symbolic exclusion. McDowell (1999) turned this insight into a methodological caution, since the researcher's position, no less than that of the subject, conditions what can be known. Wolff's (1985) "invisible flâneuse" gives the problem its most memorable form, because the anonymous stroller of urban modernity was by definition a man. Turkey offers an instructive variation. Republican reforms placed women in public life as emblems of national modernization, yet Kandiyoti (2016) observed that they were admitted as bearers of a state project

more than as autonomous subjects. Tuncer (2014) found that women in Ankara still negotiated public space through restrictions on hours, routes, and companionship decades after legal equality had been granted. The question deserves attention because legal entitlement and lived access are different things, and the distance between them becomes visible only when everyday experience is examined closely. The neutral "user" presupposed by most spatial research erases precisely those differences of gender, status, and body that decide whether a street feels like freedom or like threat. Taking women's spatial experience seriously is therefore less an addition to existing scholarship than a correction of its starting point.

Architecture and literature are usually taught as separate pursuits, yet each records how a society lives, and each carries an implicit theory of the relation between the individual and the place that individual inhabits. Architecture does so through material form: thresholds, orientations, and proportions that anticipate particular bodies and habits. Phenomenologists such as Merleau-Ponty (2017) and Pallasmaa (2006) insist that space is apprehended through the body before the intellect interprets it. Norberg-Schulz (1971) likewise treated architecture as the concretization of an "existential space" through which a person orients herself in the world. Literature produces space through language. It names streets, furnishes rooms, and, more importantly, registers what those places feel like to a specific consciousness. Read together, the two disciplines yield evidence that neither supplies alone. Spurr (2012) describes them as interlocking responses to modernity's crisis of meaning. Szpakowska-Loranc (2019) demonstrates that quotation, metaphor, and point of view operate in architectural and literary composition alike. Topolovská (2022) reads the textual turn in architectural theory and the spatial turn in literary studies as parallel developments, which licenses treating a novel as a legitimate source of spatial knowledge. Pocock (1981) had argued from geography that imaginative literature does not merely mirror places but circulates and shapes them. Serin Güner and Gökmen (2020) confirm that this intersection is attracting growing interest in Turkey. However, their survey of dissertations also shows how seldom gender has been used as an analytical variable. Here, the woman–space relationship becomes legible. A plan can show where a door stands, but not who hesitates before it, at what hour, or accompanied by whom. A novel can. Because narrative follows a character through a day or a lifetime, it records the conditions under which space is entered, the status that grants or withholds permission, and the emotional residue left once the place has been abandoned. Literary space thus works as a document of lived experience. It captures the dimensions of social role, class position, and bodily vulnerability that Rendell et al. (2003) show to be erased whenever analysis assumes a generic occupant, and it supplies the narrative texture that sociological findings such as Mills's (2007) account of gendered neighborhood space in Istanbul can only describe from outside. The woman in the text is no longer a neutral body crossing a neutral setting. She is a subject whose access to space is negotiated, and the novel records that negotiation.

This study treats literary space as something felt before it is mapped. It begins with the sensory dimension of place: the textures, sounds, smells, and temperatures through which a character first registers a setting, and which stay with her long after she has left it. Bachelard's (2014) topoanalysis captures this residue. It reads space through the images it leaves in the imagination rather than through its measurable properties. Tuan's (1990) paired notions of topophilia and topophobia give those images a vocabulary, sorting them into attachment and dread. A sensory reading of this kind, however, describes a place at a single moment. It cannot explain why a setting that once frightened a character later shelters her. Bakhtin's (1981) chronotope addresses this limitation by treating time and space as one inseparable unit, so a place acquires meaning at particular points in the plot. Because the study follows how spaces transform across several novels, it examined both methods together and adopted neither in its original form. Bachelard's examples are predominantly domestic, and his subject is gender neutral. Bakhtin's account of the novel pays little attention to the social position of the person who moves through its chronotopes. The approach proposed here therefore recombines selected concepts from each around the female subject, with gender and status as explicit analytical variables. A space is first read for its sensory and affective charge and classified as topophilic, topophobic, or paradoxical. Its transformation is then traced through narrative knots, moments when time condenses, and a character's relation to the place is reversed or confirmed. Document analysis and a case study design give this procedure its structure (Yıldırım & Şimşek, 2021). The aim is to test whether a reading attuned to sensation and to temporal turning points can explain how women experience public space, and to leave behind a procedure that other

researchers can carry to different authors, cities, and periods. The contribution to the literature is threefold. The study positions fiction as a source of architectural spatial knowledge, and it restores gender and status to an analytical field that has long treated the user as neutral (Rendell et al., 2003). It also gives Turkish architectural scholarship a transferable method where none has existed.

Across the ten novels by Suat Derviş examined under the heading of women and public space, the hospital stands out as a prominent setting, consistently linked to imagery of transformation. It also plays an important role in how women use public space in these texts. This finding is mentioned here only in outline, because the novels and analyses that substantiate it appear in a separate section. At this stage, what matters is what the finding shows about the approach itself. The combined topoanalytic and chronotopic reading made the hospital's position legible by asking how a space is sensed, when it acts upon the character, and how it changes across the narrative. It did not begin from assumptions about which spaces count as significant. The categories on which the method relies are independent of any particular plot. They are the affective quality of a space, its place in narrative time, its transformation, and the gender and status of the woman who encounters it. A text can therefore be read through them even when its content is unfamiliar. A reader who has not met a given novel can still follow how its spaces are classified, how they shift, and where they fall within a woman's trajectory. The study's contribution should be understood in this light. It adds to the limited body of research on women and space in Turkish architectural literature. It offers a repeatable procedure through which the female subject's presence in public space becomes visible. In this respect, it answers the concern voiced by Massey (1994) and McDowell (1999) that spatial knowledge is shaped by whose experience is treated as the norm. The following sections set out the method in full, apply it to the selected novels, and discuss the results.

Materials and Methods

This study sets aside the hospital's curative function and asks what else the institution signifies when women encounter it in literary narrative. The inquiry is qualitative, combining an interpretive paradigm with a critical orientation that treats gender and status as analytical variables rather than as background. Document analysis frames the novels as spatial records, while a case study design confines the investigation to a single author and a single city.

The corpus comprises ten novels by Suat Derviş, published between 1930 and 1963: Emine, Çamur, İstanbul'un Bir Gecesi, Sınır, Çılgın Gibi, İki Kadın İki Aşk, Kendine Tapan Kadın, Fosforlu Cevriye, Büyük Ateş, and Şoför Mustafa. They were chosen from the author's wider output because they are set in Istanbul's public spaces, their narratives center on female characters, and their socially realist register renders contemporary conditions with documentary precision. I read the novels at two levels. A distant reading first cataloged each protagonist's status, gender roles, and the public spaces she uses, grouping the spaces into working, transport, dining, entertainment, accommodation, open-air, and health categories. A close reading then examined the passages in which these spaces act upon the character.

The analytical procedure draws selectively on two reference methods. From topoanalysis, it retains the focus on sensory and emotional traces, and it classifies each space as topophilic, topophobic, paradoxical, or intermediate, the last designating neutral, transitional settings that evoke neither attachment nor dread. From the chronotope, it retains the inseparability of time and space and the notion of the knot, a point at which spatial and temporal strands converge and the character's condition shifts. Hospital passages were coded for the manner of entry, whether alone or accompanied, the woman's status, the affective charge of the space, and any reversal of her relation to it as the plot advances. The codes were then compared across novels and status groups to establish whether the hospital's effect varies with class. This analysis excludes the material fabric of hospitals, focusing only on their textual construction.

Hospitals as Healing Spaces

Conventional hospital design tends to focus on meeting regulatory requirements and accessibility criteria, while keeping essential services running without interruption. Each country anchors this process in its own guidance. In Türkiye, the Minimum Design Standards for Health Facilities, 2010 Guidebook (T.C. Sağlık Bakanlığı, 2010) sets hospital standards. In the United States, the Facility Guidelines Institute (FGI, 2022)

shapes health facility planning through its guidelines. These guidelines define mandatory design criteria for a broad spectrum of building types, from hospitals and outpatient centers to long-term care facilities, and they provide the national benchmarks that individual states adopt. In England, the National Health Service takes a different route. Its Health Building Note series offers a holistic, evidence-informed approach to planning health buildings. The NHS also has a strong research tradition of examining how clinical processes and environmental arrangements affect one another, drawing on long-term user data. That accumulated knowledge has been distilled into comprehensive standards that guide design decisions.

In contemporary healthcare thinking, however, the standards for a comprehensive facility such as a hospital cannot be treated as a mere product of physical capability. They should evolve continuously in response to research and critical evaluation of design approaches and their outcomes. Healing architecture responds to this need. It pursues functional efficiency, but it is also built on the World Health Organization's definition of health as a state of "complete well-being" (WHO, 1984), and it aims to sustain holistic well-being over time (WHO, 2025). Conceptually, healing architecture is defined directly and structurally through the relationship between Evidence-Based Design (EBD) and the therapeutic environment. This relationship requires that the planning and design of health facilities rest on scientific research and empirical evidence.

The idea that the built environment can aid recovery has a long history. In 1860, Florence Nightingale argued that visual connections with nature, such as views of natural scenes through a window, helped patients recover. She was the first to set out the therapeutic effects of nature in writing (McDonald, 2020). EBD is the principle of grounding health facility design in scientific findings (Harris et al., 2024). The hypothesis-testing logic underlying its conceptual framework traces back to the Evidence-Based Design Framework associated with Ulrich and colleagues (Ulrich, 1984).

Evidence-based design strategies aim to move hospitals beyond being places where disease is treated. They aim to make hospitals environments that support a more integrated model of care and prioritize patients' well-being, comfort, and recovery (Zhu et al., 2025). Healing design, which includes nature integration and daylight exposure strategies, rests on a substantial body of evidence indicating that it improves recovery and well-being. This evidence shows that access to nature reduces stress and improves health outcomes. Health facility spaces are therefore deliberately used to strengthen the physical, psychological, and social contributions that healthcare makes to people.

NHS guidance is particularly significant in this context because its understanding of the healing environment rests on a systematic methodology. It treats policy, care processes, and spatial design as one integrated whole. This creates a comparable foundation for research across countries. The standards England has developed for health buildings have also served as a reference for guidelines in many other countries. Reading current views on hospitals and their standards through these documents is therefore a sound way to analyze the topic and to show why it remains relevant.

The belief that health facilities should be designed as places that actively support recovery is confirmed by extensive research on the effect of the architectural environment on patient outcomes. In general terms, the role of the physical environment in hospital design is examined under the heading "the role of the physical environment in the 21st-century hospital" (NHS, 2014). The central premise of the sources on health building design is that buildings should do more than deliver medical services. They should function as therapeutic environments that directly support patients' recovery and general well-being. This principle rests on literature reviews of evidence-based healthcare design that look specifically at the physical environment's role in the 21st-century hospital (NHS, 2015).

This philosophy requires the hospital to provide environmental quality holistically. Its scope extends beyond clinical areas to the public and support spaces used by patients, their relatives, and staff (NHS, 2013a; NHS, 2013b). Design aims to maximize the positive effects on treatment outcomes. For example, it draws on research suggesting that a view from a window can influence post-operative recovery (NHS, 2015). Design decisions also include features that promote recovery in vulnerable patient groups. For people with dementia, the

relationship between behavior and environmental quality is examined. To help with orientation, distinctive decoration on care home doors and corridors is recommended (NHS, 2015).

Standard hospital designs often risk becoming "copy-paste" projects because of inadequate preliminary planning. This can produce suboptimal solutions, such as oversizing. It also causes operational problems, including longer travel distances, slower service delivery, and wasted resources (T.C. Sağlık Bakanlığı, 2010). Healing design, by contrast, treats architecture as an art of healing to achieve the widest possible inclusiveness and equity. This calls for design professionals to understand users' needs in depth, going beyond legal obligations (Day, 2004). The approach treats social sustainability as a core macro-domain of hospital design. That domain includes criteria such as humanization, well-being, and health promotion (Zhu et al., 2025). The design process therefore goes beyond placing medical equipment. It develops strategies that maximize the mental and physical well-being of both patients and staff.

Women, Public Space and Literary Representation: Suat Derviş's Istanbul

The Republican reforms that followed 1923 redefined women's legal presence in public life. The 1926 Civil Code secured rights to divorce, custody, and inheritance; the 1930s brought the franchise and eligibility for office, and access to education and employment widened considerably. The state, in turn, treated women's visible presence in public space as a sign of national modernization. Yet, as Kandiyoti (2016) observed, women entered this space as bearers of a state project rather than as autonomous subjects. The transformation was neither simultaneous, linear, nor uniform. Class, education, and geography determined whether legal equality acquired any experiential counterpart. Tuncer's (2014) finding that women still negotiated public space through restrictions on hours, routes, and companionship points to the same distance between entitlement and lived access. Sociological and planning studies can document this distance from the outside, showing how women's relation to public space varies with their status. As in sociological studies, literary narratives can also analyze the relationship between women and public space, and the status that shapes it.

Suat Derviş is an especially suitable author for this task. Her output of more than fifty works spans the 1920s to the 1970s and covers the period in which women's public spatial practices were most visibly reshaped. Derviş's suitability rests on more than chronology. As a journalist, she edited a women's page in İkdam in 1926 and reported on international conferences. In the 1930s, she interviewed people living on the city's margins. She later co-edited Yeni Edebiyat (1940–1941), an early organ of socialist-realist literature in Turkey and took part in the 1935 International Women's Congress in Istanbul. This trajectory produced a realism that treats the novel as a social document. Her female characters function less as bearers of individual stories than as figures in whom status and gender roles intersect. Because the settings of her novels are largely Istanbul's public spaces, the city where the reforms were most intensely felt and urban tension was most visible, a coherent case emerges.

From this broader output, ten novels were selected: Emine, Çamur, İstanbul'un Bir Gecesi, Sınır, Çılgın Gibi, İki Kadın İki Aşk, Kendine Tapan Kadın, Fosforlu Cevriye, Büyük Ateş, and Şoför Mustafa. They meet four criteria: an Istanbul public-space setting, a central female character, composition between the early 1930s and 1963, and a socially realist register. A distant reading cataloged each protagonist's status, gender roles, and the spaces she uses, grouped into working, transport, dining, entertainment, accommodation, open-air, and health categories. The protagonists cover a wide social range. Emine (1931) and Zeliha (İstanbul'un Bir Gecesi, 1939) are poor. Mehlika (Çamur, 1938), Ayla (Sınır, 1943), Celile (Çılgın Gibi, 1945), Macide (İki Kadın İki Aşk, 1946), and Fazilet (Büyük Ateş, 1950) are well-off, and most are defined chiefly as wives. Leyla works in a tailor's workshop, and Sârâ (Kendine Tapan Kadın, 1947) moves from low to high status. Cevriye (Fosforlu Cevriye, 1948) and Zerrin and Melek (Şoför Mustafa, 1963) are sex workers. Although hospitals are not among the public spaces most frequently used in the narratives, they are significant for the meanings they carry.

This study first shows how sharply the same spatial type is stratified by status. For poor women, the street is a space of necessity and threat. Emine's streets are woven from fear of the police, the risk of rape, and the prospect of hunger, and Zeliha is excluded and humiliated when she enters a coffeehouse. Well-off women reach the street, the casino and the beach almost only in male company or within socially approved rituals.

Ayla's attachment to her own quarter turns to dread once she crosses into Fatih. Celile's casino and seaside, pleasant while she is a wife, turn hostile when she leaves her husband. Fazilet's movements shrink to the Moda district and its evening promenade. The sex workers' case is the most paradoxical. Cevriye claims the streets of Galata and Beyoğlu as her own precisely because she is excluded from domestic space. In Şoför Mustafa, fifteen years later, the same kind of space has become one of violence for Zerrin and Melek. In spatial terms, poor women and sex workers cluster around Beyoğlu and Fatih, while well-off women are placed in Beyoğlu, Kadıköy and the Islands. Istanbul thus appears not as one public realm but as a set of unequally accessible places.

Read across the three decades, these findings do not describe a linear emancipation. For poor women, the street remains a space of risk from the 1930s to the 1960s, and for well-off women, visibility grows without a corresponding growth in autonomy. After 1950, the room for movement narrows for several groups. The novels therefore register what legal reform alone could not alter: who may enter a place, when, and under whose protection. The hospital, however, behaves differently. Across the corpus, it is the category that most consistently turns a woman's situation, largely regardless of her status. The following section therefore asks how this healing space can be read through topoanalysis, before the Findings set out how it operates in the novels.

Reading Hospitals through Women and Status: Identity and Transformation

Reading the hospital here does not mean assessing its therapeutic performance or its built form. The question put to each hospital passage is what happens to a woman's use of public space when she enters it, and whether the answer changes with her status. Topoanalysis and the chronotope serve as reference points for this question rather than as complete frameworks. From topoanalysis, the reading keeps the classification of a place by the feelings it leaves: topophilic, topophobic, or paradoxical. From the chronotope, it keeps the node, the point at which time condenses in a place and the character's condition turns. Gender roles and status stay fixed as variables across both. Every hospital is therefore read as a place entered by a specific woman, in a specific manner, at a specific point in her story.

The corpus first shows that the hospital changes the terms on which a woman is admitted to public space. In the street, the casino, or the beach, her entry depends on who she is and who accompanies her. In the hospital, it depends on the condition of her body. For the length of the stay, the wife, the servant, the mother, and the artist are first of all patients. The study adds that these spaces act impartially toward status and identity. The eclipse is only temporary, and that temporariness gives the space its narrative force. The woman must leave, and what she has become by the time she leaves is what the plot examines.

Emine shows what this means for a low-status woman. She is an orphan, poor, a servant, and a wife forced into marriage with an older, wealthy man. After being falsely accused of theft, she flees into streets that the novel codes as topophobic, a place of fear of the police, hunger, and disorientation. She enters the hospital not by choice but after a traffic accident in those streets. She is still alone, yet she feels safer. The elderly doctor who treats her sees his recently deceased daughter in her and, because she has nowhere to go, takes her into his home. In topoanalytic terms, the hospital is topophilic, and that topophilia attaches as much to what the place opens as to the place itself. In chronotopic terms, it is a threshold between past and future, the door through which her happiest period begins. Her time there is limited, since recovery forces her to leave, but that limit is what makes it a threshold. For low-status women, the study concludes, health spaces are among the rare places where gender- and class-based discrimination recedes for a while.

High-status women reach public space under different conditions. Their use of the street, the casino, or the pier is typically accompanied or ritually sanctioned, and the hospital has to be read against that background. In Kendine Tapan Kadın, the clinic is coded as a space of transformation and topophilia for Nazan, who gains awareness there after an experience of violence and decides to change her life. The study reads this as a sign that awareness is given a spatial counterpart and is not only individual. İki Kadın İki Aşk places the body at the center. Macide is a trained pianist, a wife, and a mother. After learning of Cemil's betrayal, she attempts suicide, injures her hand and can no longer play, and she abandons her identity as an artist. The healing of this

injury after surgery is the novel's node and marks her transformation. The patient identity here does not simply suspend her other identities. It is the place where one is lost, and another can be recovered. One reading is that an identity tied to a particular part of the body makes the hospital a site of social as well as physical repair.

Çılgın Gibi complicates this picture. Celile's use of the casino, beach, pier, and boat is topophilic as long as she is a wife and accompanied, but that belonging rests on her position and her husband's protective frame, not on an independent subjectivity. At the Maçka clinic, the companion is no longer a husband but a lover, and she uses the space alone. The clinic is bound up with abortion and anxiety, and the study codes it as topophobic and as a space of transformation and loss. Where the other hospitals suspend norms, here the norm returns, because she arrives as a woman who has violated it. The study accordingly describes high-status women's relation to health spaces as more complex and contradictory. One way to put it is that the hospital's indifference to status is functional rather than affective. It acts as a node regardless of the woman's status, but the emotional charge of that node depends on where she stands in relation to gender norms.

Taken together, these readings explain why the study treats health spaces as the category that most consistently takes on a nodal function independent of status. The comparison with other categories sharpens the point. Open-air, transport, entertainment and dining spaces depend on status and companionship and are the most fragile. Accommodation, education and work spaces keep access restrictions most static. Health spaces alone are entered by a woman on the strength of her body, often alone, and with other identities set aside. This access has limits. The hospital works as a threshold rather than a destination, and the life that follows takes place elsewhere. Reading it through women and status therefore shows both what the hospital grants and how far that grant extends.

Conclusion and Recommendations

This study set aside the hospital's curative function and asked what else the institution signifies when women encounter it in literary narratives. Ten novels by Suat Derviş, set in Istanbul and written between the early 1930s and 1963, were read through selected concepts from topoanalysis and the chronotope, with gender and status held as explicit variables. Each space was classified by the feeling it leaves, and its transformation was traced through the narrative knots at which a woman's condition turns. The analysis concerns textual construction rather than material fabric. Its conclusions therefore describe how the hospital is represented in relation to women. They do not describe how any actual hospital performs or is built.

The first conclusion concerns public space as a whole. In these novels, women's use of public space is not independent of status. Poor women experience the open street as a place of necessity and threat, consistently from the 1930s to the 1960s. Well-off women reach the street, the casino, and the beach almost only in male company or within socially approved rituals, so their topophilia is conditional rather than free. Sex workers stand in a paradoxical relation to the same spaces. Cevriye claims the streets of Galata and Beyoğlu as her own because she is excluded from domestic space. In the novel written fifteen years later, the same kind of space has become a site of violence. Istanbul therefore appears not as one public realm but as a set of unequally accessible places. Legal reform did not produce a linear emancipation. It enabled women's visibility, but that visibility was secured through accompaniment, class privilege, and social approval rather than spatial autonomy. After 1950, the room for movement narrowed for several groups. Physical accessibility and free experience of a place are therefore separate conditions.

The second conclusion concerns the hospital, which behaves differently from the street, the domestic interior, and the gazino. A woman enters it on the strength of her body's condition rather than her standing or her escort, and for the length of her stay she is first and foremost a patient. This designation temporarily eclipses her other identities. It also suspends the gender norms and class hierarchies that govern her movement elsewhere. In Emine, the hospital is the topophilic threshold between a past of fear and a future in which the doctor who treats her takes her in. In Kendine Tapan Kadın, the clinic is where Nazan, after meeting resistance at the wedding venue and suffering violence in a hotel room, reaches an awareness that finds a spatial counterpart. In İki Kadın İki Aşk, Macide's recovery after surgery is the node at which the loss of her identity as a pianist

begins to reverse. Across these novels, health spaces take on a nodal function more consistently than any other category, regardless of the woman's status or the period.

Two qualifications keep this conclusion precise. First, the hospital's indifference to status is functional, not affective. Çılgın Gibi shows that the same node can carry dread. At the Maçka clinic, Celile arrives as a woman who has violated the norm, and the space is coded as topophobic and as a space of loss. Topophilia is therefore the hospital's dominant charge, not its invariable one. Second, the equality the hospital offers is temporary. It works as a threshold rather than a destination, and the life that follows takes place elsewhere.

Together, these conclusions bear on the wider question of women's presence in public space. What makes public space unequal in these narratives is less its openness than its terms of entry: who accompanies the woman, what status she holds, and under whose protection she moves. The hospital shows what happens when those terms loosen, and in doing so it makes them visible. The study also offers a procedure that does not begin from assumptions about which spaces count as significant. The categories of topophilic, topophobic, paradoxical, and intermediate space, the notion of the node, and the explicit use of gender and status can be carried to other authors, cities, and periods. It extends the topoanalytic vocabulary beyond Bachelard's largely domestic examples. The findings also support treating literary narrative as a source of spatial knowledge that complements archives and technical drawings. A plan can show where a door stands, but narrative records who hesitates before it, at what hour, and under whose protection.

The limits of the study should be stated plainly. It rests on one author, one city, and one period. It concerns representation rather than measured behavior. Its hospital findings draw on a small number of novels. They are best read as a tested procedure and a set of grounded propositions, not as general claims about women's experience of hospitals.

Several recommendations follow. For research, the most immediate step is to extend the corpus to the author's other novels and short stories from the same period and to test whether the hospital's nodal function holds there. Comparative work on other authors would show how far these patterns belong to a single writer's vision rather than to the period. Applying the procedure to other literary traditions, such as French, English, or Russian, would test what is universal and what is culturally specific. Multi-source designs that read literary space alongside archival documents, oral histories, and architectural records would reconstruct past urban experience more fully than fiction alone can.

For design practice, the findings argue against the neutral user. Decisions on access points, visibility angles, lighting, boundary elements, and circulation should rest on differentiated user scenarios that consider gender, status, accompaniment, and period-specific patterns of use. In open public spaces, low-status women's topophobia is tied to secluded, derelict, or poorly surveilled places. This calls for attention to sightlines, continuous lighting, open and multi-layered circulation, and resting points for different user groups. Healing architecture, as discussed above, aims at well-being beyond clinical function. Representing the hospital as a threshold suggests that its entry and exit deserve attention comparable to that given to the ward, since the return to the street is the moment when a woman's status resumes its hold. This last point is offered as a direction for inquiry rather than an established finding.

References

Bachelard, G. (2014). *The Poetics of Space*. (Trans: M. Jolas.). Boston: Beacon Press.

Bakhtin, M. M. (1981). *The Dialogical Imagination Four Essays.* (Trans: C. Emerson and M. Holquist). Austin: University of Texas Press.

FGI, (2022). FGI Guidelines documents (Guidelines for Design and Construction of Hospitals, Guidelines for Design and Construction of Outpatient Facilities, Guidelines for Design and Construction of Residential Health, Care, and Support Facilities). https://fgiguidelines.org/codes/editions/ Erişim tarihi: 09.11.2025

Harris, D., Baker, E., Svacina, J., & Funderburk, L. (2024). A systematic approach to evidence-based design for measurable health and wellness outcomes: Curating and translating evidence to practice. HERD: Health Environments Research & Design Journal (17-1), 17-29. https://doi.org/10.1177/1937586723120933

NHS. (2013a). Health Building Note 09-02: Maternity care facilities. NHS England. https://www.england.nhs.uk/wp-content/uploads/2021/05/HBN_09-02_Final.pdf

NHS. (2013b). Health Building Note 11-01: Facilities for primary and community care services. NHS England. https://www.england.nhs.uk/wp-content/uploads/2021/05/HBN_11-01_Final.pdf

NHS. (2014). Health Building Note 00-01: General design guidance for healthcare buildings. NHS England. https://www.england.nhs.uk/wp-content/uploads/2021/05/HBN_00-01-2.pdf

NHS. (2015). Health Building Note 08-02: Dementia-friendly health and social care environments. NHS England. https://www.england.nhs.uk/publication/dementia-friendly-health-and-social-care-environments-hbn-08-02/

Park H. Y. (2024). Hospital space interpreted according to Heidegger's concepts of care and dwelling. Medical humanities, 50(1), 135–143. https://doi.org/10.1136/medhum-2023-012696

Massey, D. (1994). *Space, Place and Gender*. Polity.

McDowell, L. (1999). *Gender, Identity and Place: Understanding Feminist Geographies*. University of Minnesota Press.

Merleau-Ponty, M. (2017). Algının Fenomenolojisi. (Trans: E. Sarıkartal ve E. Hacımuratoğlu). İstanbul: İthaki Yayınları.

Mills, A. (2007). Gender and Mahalle (Neighborhood) Space in Istanbul. *Gender, Place & Culture,* 14(3), 335-354.

Norberg-Schulz, C. (1971). *Existence, Space and Architecture.* Prager.

Oakley, A. (1972). *Sex, Gender and Society.* London: Temple Smith.

Pallasmaa, J. (2006). *An Architecture of the Seven Senses, Questions of Perception*. William Stout Publishers.

Pocock, D. (1981). Introduction: Imaginative literature and the geographer. D. Pocock (Ed.), Humanistic Geography and Literature: Essays on the Experience of Place (pp. 9-19). London: Croom Helm.

Rendell, J., Penner, B. ve Borden, I. (2003). Gender Space Architecture: An interdisciplinary introduction. Routledge.

Sancar, S. (2013). *Erkeklik: İmkânsız İktidar Ailede, Piyasada ve Sokakta Erkekler*. İstanbul: Metis Yayınları.

Serin Güner, A. P. ve Gökmen, H. (2020). Mimarlık ve Edebiyat İlişkisine Dair Yapılmış Akademik Çalışmaların Bir Sınıflandırması. *İdealkent,* 11(31), 1722-1763. doi:10.31198/idealkent.829055

Spurr, D. (2012). Architecture and Modern Literature. Ann Arbor: University of Michigan Press.

Szpakowska-Loranc, E. (2019). On the Relationship between Architectural and Literary Narrative. IOP Conference Series: Materials Science and Engineering. (C. 471). Institute of Physics Publishing. doi:10.1088/1757-899X/471/7/072014

T.C. Sağlık Bakanlığı. (2010). Türkiye Sağlık Yapıları Asgari Tasarım Standartları kılavuzu.

Topolovská, T. (2022). Reading buildings: The textual turn of architecture as a parallel to the spatial turn in literary studiesi. *Ars Aeterna*, 14(1), 58-70. doi:10.2478/aa-2022-0006

Tuan, Y.-F. (1990). Topophilia: A Study of Environmental Perception, Attitudes, and Values. Columbia University Press.

Tuncer, Selda. (2014). Going Public: Women's Experience of Everyday Urban Public Space in Ankara Across Generations Between the 1950s and the 1980s. (Dissertation) ODTÜ.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. science, 224(4647), 420-421.

Walby, S. (2016). *Patriyarka Kuramı.* (H. Osmanağaoğlu, Trans.). Ankara: Dipnot Yayınları.

WHO. (2025). WHO remains firmly committed to the principles set out in the preamble to the Constitution. https://www.who.int/about/governance/constitution Erişim tarihi: 02.12.2025.

Wolff, J. (1985). The Invisible Flâneuse. Women and the Literature of Modernity. *Theory, Culture & Society*, 2(3), 37-46.

Yıldırım, A. and Şimşek, H. (2021). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*. Seçkin Akademik ve Mesleki Yayınlar.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FROM SPATIAL LOSS TO DIGITAL MEMORY: PRESERVATION AND TRANSMISSION OF URBAN MEMORY AFTER EARTHQUAKES

Elif ATICI TEKTAŞ
Assistant Professor, Balıkesir University, Faculty of Architecture, Department of Architecture, Balıkesir-Türkiye ORCID: 0000-0001-7163-2660
Melike KALKAN
Assistant Professor, Uşak University, Faculty of Architecture, Department of Architecture, Uşak-Türkiye, ORCID: 0000-0003-2436-4426

Abstract

Beyond causing physical destruction in the urban environment, earthquakes alter, transform, or obliterate the spatial relationships that individuals and societies establish with the past. The disappearance of structures, streets, and public spaces damages people's ties to the past, thereby hindering the transmission of the memories, everyday life practices, and social meanings accumulated in these spaces to the future. However, the loss of physical space does not imply the total erasure of the memory associated with that space. This study aims to theoretically examine the issue of preserving and transmitting urban memory in the aftermath of earthquakes through the lens of digital memory. The central question of the study concerns how the memory of physically lost urban spaces can be documented and transmitted to future generations via digital tools. In this context, the study explores the relationships between the concepts of urban memory, collective memory, spatial loss, sense of place, and digital heritage. Digital archives, historical photographs, oral history recordings, and three-dimensional modeling methods are regarded as tools capable of documenting the physical characteristics and social significance of lost spaces. While discussing the potential of digital representation to make past spaces visible again, the study also considers the limitations of existing documentation and the relationship between digital reconstruction and historical reality. In this context, digital memory is approached not merely as a literal reproduction of the physical environment, but as a multi-layered preservation and transmission strategy that integrates the tangible and intangible traces associated with a space. The study aims to contribute to the development of a theoretical framework within the fields of architecture and urban conservation regarding digital methods for preserving urban memory in the aftermath of earthquakes.

Keywords: Urban memory, earthquake, spatial loss, digital memory, digital reconstruction.

Introduction

Human beings possess an inherent sense of living together, shaped by the values that define their existence. Urban life, characterized by this coexistence, provides opportunities for people to engage in shared experiences. The urban spaces where these interactions occur serve as collective settings—places where people forge and share memories together. Such collective spaces endure as environments where individuals accumulate memories within the city. Their presence fosters a sense of belonging among urban residents, thereby strengthening the vitality of urban life. However, these spaces can sometimes disappear over time—whether due to human intervention or as a result of disasters. Earthquakes are one such factor; when urban spaces are destroyed by an earthquake, it is not merely their physical existence that is lost, but also the settings that once hosted shared experiences. This leads to the erasure of the traces that residents have left upon the city. Such circumstances can result in alienation within urban life and a diminished sense of belonging. Research indicates that, in the aftermath of an earthquake, factors such as a need for belonging, a desire for solidarity, and economic necessity have prompted individuals to live with relatives and close kin. This has led to a shift from the nuclear family toward an extended family structure, characterized by the practice of three generations living together (Akyıldız & Sığın, 2024). Consequently, for a variety of reasons,

these spaces often cannot be physically reconstructed. At this juncture, digital technologies offer an opportunity to reconstruct the spaces of memory—the sites of urban recollection—within a virtual environment, independent of physical conditions.

The formation of the past occurs inevitably as time progresses. Time passes, and the past is formed. Everything experienced over time is recorded in memory. Memory sustains its existence through the values that fortify it; for this reason, memory renders recollections valuable (Nora, 2006). Rooted in the city, society, and social life, memory—influenced by various factors—highlights a significant connection to space (Nora, 1989). Urban memory enables the reconstruction of spaces from the past and their revival within the human mind. The collective life inherent to urban existence is inextricably linked to urban memory. Collective memory denotes a process—intimately connected to the present—that encompasses sharing a common past, remembering, forgetting, and shaping the future (Olgun, 2009). Furthermore, collective memory not only bears the traces of the past but also manifests itself within contemporary life, as the acts of remembering and forgetting occur in the present moment (Jedlowski, 2001). Through the social interactions that define life within a city, elements of urban memory and the city's cultural values are transmitted from one generation to the next—underscoring the intrinsic relationship between collective memory and society (Connerton, 1999). For memory to endure—that is, to avoid being forgotten—it requires repetition and continued exposure (Bergson, 1970). Within the urban landscape, spaces that facilitate shared experiences serve as pivotal reference points for the formation and sustainability of collective memory. Yet, the values embedded in urban memory can inevitably be lost—for instance, as a result of natural disasters such as earthquakes.

In 2025, the Emergency Events Database recorded 358 disasters resulting from natural hazards. These disasters led to 16,607 deaths, affected 110.2 million people, and caused economic losses amounting to 169.68 billion USD. A disproportionately large share of disaster-related deaths occurred in Asia, a trend largely attributed to severe earthquakes in Myanmar and Afghanistan (EM-DAT, 2025). Earthquakes, which represent a significant category of disasters, can impact cities rapidly and on a large scale, leading to loss of life, the destruction of structures, and the disruption of urban life (Gök and Yavaş, 2024). Such losses weaken not only the physical environment but also the emotional and social bonds that urban residents have forged with their surroundings; the destruction of structures creates a significant void in the collective memory and the city's urban identity (Dinç, 2025). Addressing this void requires more than just the reconstruction of destroyed buildings; it necessitates a holistic documentation of the city's historical layers and the meanings that have accumulated upon them (Özdede et al., 2021). As an example of this, Yetişkin (2026) conducted a study on the 1939 and 1992 Erzincan earthquakes and their relationship to memory. According to this study: Oral narratives, knowledge transmitted through education, monumental structures, reconstructed urban spaces, and cultural productions play a significant role in the intergenerational transmission and continuity of the social memory surrounding the experience of an earthquake. Individual memory becomes collective through experiences within a space and social interactions. Through human experiences and shared interactions, a space is continuously reshaped, thereby acquiring social meaning. In this regard, a sociological approach—grounded in the reciprocal interaction between individual and collective memory—provides a vital theoretical framework for examining the social impacts of disasters and their reflections on memory (Yetişkin, 2026). Another study supporting this perspective focuses on the collection of data concerning urban space and the city of Antakya following the earthquake of February 6, 2023. Similar to the study conducted in Erzincan, this research involved interviews with participants. It suggests that, upon returning to the city after the earthquake, settling into new buildings within the old neighborhoods helps maintain a strong and vibrant connection between the past and the present. It is believed that when providing an address, linking the new location to the former space fosters a connection between the past and the future, thereby triggering the revival of memories (Cengiz, 2026).

As evidenced by these studies, the relationship between spaces lost to an earthquake and their new replacements—facilitated by the revival of past memories and the insights gained through interviews—plays a crucial role in intergenerational transmission. Furthermore, the availability of data regarding a place both

before and after an earthquake is essential to this process of transmission. In this context; Intangible forms of transmission—such as laments, poetry, stories, and cinema—also gain value. It has become possible to ensure the continuity of these spaces, which cannot be preserved in a tangible sense, through the use of digital technologies (Atıcı Tektaş, 2024).

Digital technologies offer diverse possibilities for enhancing memory—both in the context of urban memory and in relation to cognitive functions. For instance, closed-loop video games support cognitive control, virtual reality aids long-term and spatial memory, and mobile meditation applications target attention and stress management. In this context, personalized approaches and non-invasive brain stimulation provide alternative methods for improving cognitive performance. Furthermore, mobile technologies facilitate the measurement of cognitive skills and the monitoring of progress. It is noted that the deployment of these technologies should adhere to principles of scientific validity, reliability, and accessibility (Ziegler et al., 2022).

In this regard, digital twin technologies and virtual reality applications enable the reconstruction of existing urban spaces within a digital environment, allowing them to be experienced virtually. By utilizing real-time data, digital twins contribute to the modeling and analysis of urban spaces, as well as to sustainable urban planning. On the other hand, evaluating cities solely through numerical data risks overlooking social, cultural, and human values. As noted by Hassan (2025) —drawing upon Heidegger's concepts of "enframing" (*Gestell*) and *poiesis*—it is essential to consider human experience, cultural heritage, and spatial memory, in addition to the technological contributions provided by digital twins. Virtual reality and augmented reality technologies contribute to the intergenerational transmission of urban memory by enabling the experience—through simulations—of digital twin models representing urban spaces from the past. These technologies offer more than just an experience of physical modeling; by integrating audio recordings from individuals who lived through the past—along with memories gathered via oral history methods—these simulations also allow for the reconstruction of social life (Atıcı Tektaş & Öztürk, 2024).

Building on these premises, this study proposes a scalable methodology for preserving spatial memory data—from both before and after an earthquake—through digital technologies, ensuring its restoration to the urban community and its long-term sustainability.

Materials and Methods

This study aims to propose an adaptable methodology that utilizes digital tools to preserve the urban memory of urban spaces—which have lost their physical existence following an earthquake—and to transmit this memory to future generations. To this end, drawing upon the concepts of memory and urban memory, a qualitative pilot study was conducted to identify digital tools for preserving these values within a digital environment. In this study, the city of Antakya—which sustained extensive damage following the February 6 Kahramanmaraş earthquakes—was analyzed in terms of its spatial context; the data obtained were then structured for integration into digital twin and virtual reality applications. During this structuring process, oral narratives and visual documents were mapped onto spatial records, creating a layered dataset that represents both the past and present states of each location. This layered structure enables the reconstruction of these spaces within a digital environment—preserving them despite the loss of their physical form—and facilitates their incorporation into virtual reality simulations.

Findings and Discussion

On February 6–7, 2023, earthquakes with magnitudes of 7.7 and 7.6 Mw, centered in Kahramanmaraş, Turkey, had a profoundly negative impact on the surrounding areas. In the affected cities, numerous structures were destroyed, and many people lost their lives. This catastrophe resulted in the sudden disappearance of both human lives and the values inherent to the urban environment. The impact of the

earthquakes was devastating in both physiological and psychological terms. Figures 1 and 2 present images of the urban center of Antakya (Hatay) from before and after the earthquakes, illustrating a significant transformation in the city's fabric. The destruction of the city's physical infrastructure also meant the loss of the familiar spaces that were meaningful to its residents. Consequently, the reconstruction process must be undertaken with a commitment to preserving the values of both the city and its inhabitants.

Figure 1. Antakya (Hatay) before the earthquake and during the earthquake (Google Earth)

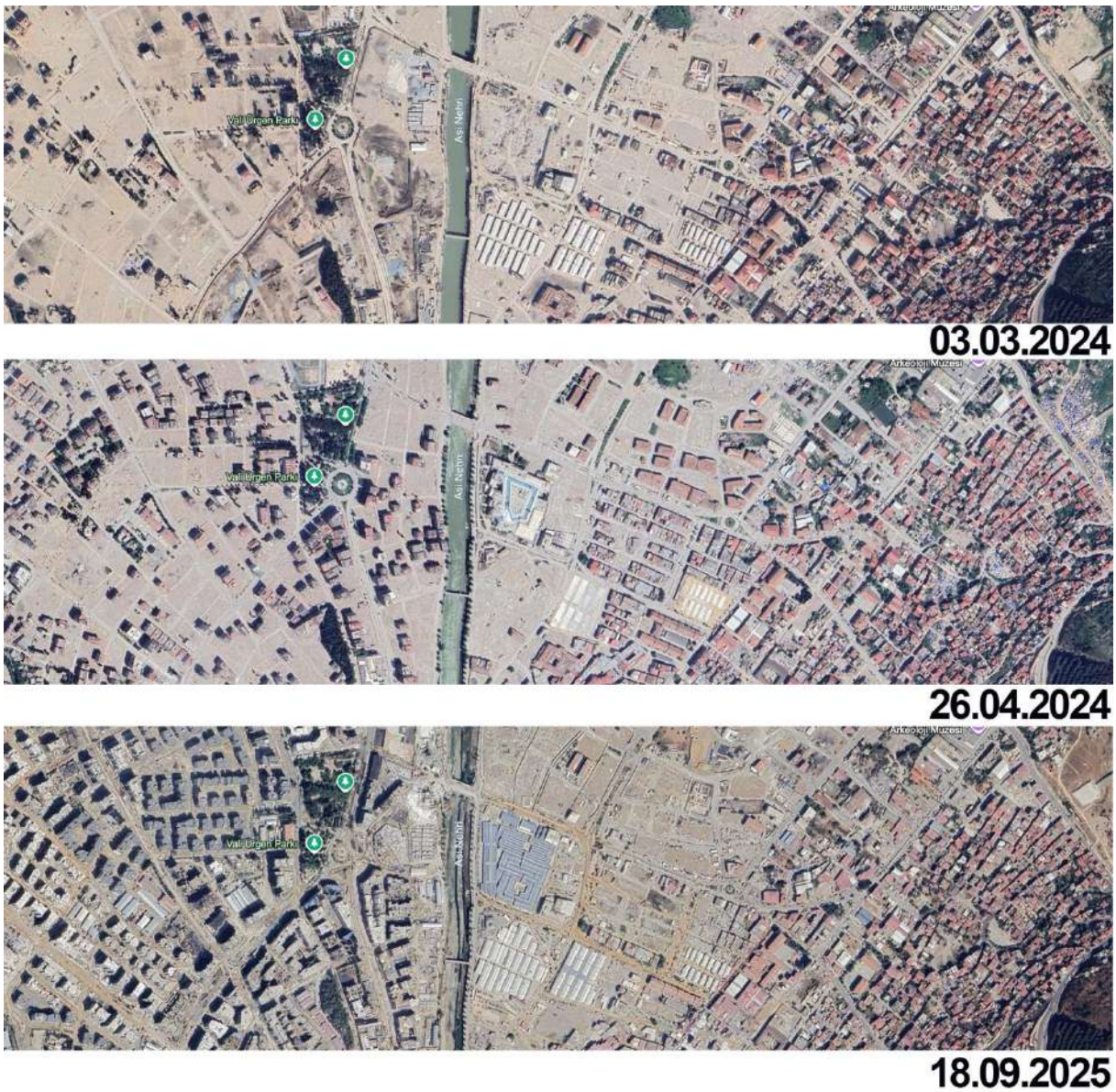


Figure 2. Antakya (Hatay) after the earthquake (Google Earth)

The study proposes a developable method for utilizing digital technologies to preserve and pass on values associated with the city and its inhabitants to future generations. This method provides a digital data bank—storing information related to the city—for use during the reconstruction process, while also facilitating the creation of virtual environments that enable residents to recall their past experiences.

Conclusion and Recommendations

Earthquakes can weaken the connection that urban residents have with the past by affecting urban spaces—and the data regarding "memory-places" that emerge from the shared experiences within those spaces. This study aims to propose a method for sustaining the memory of places that have physically disappeared, utilizing digital technologies. This proposal is illustrated in Figure 3.

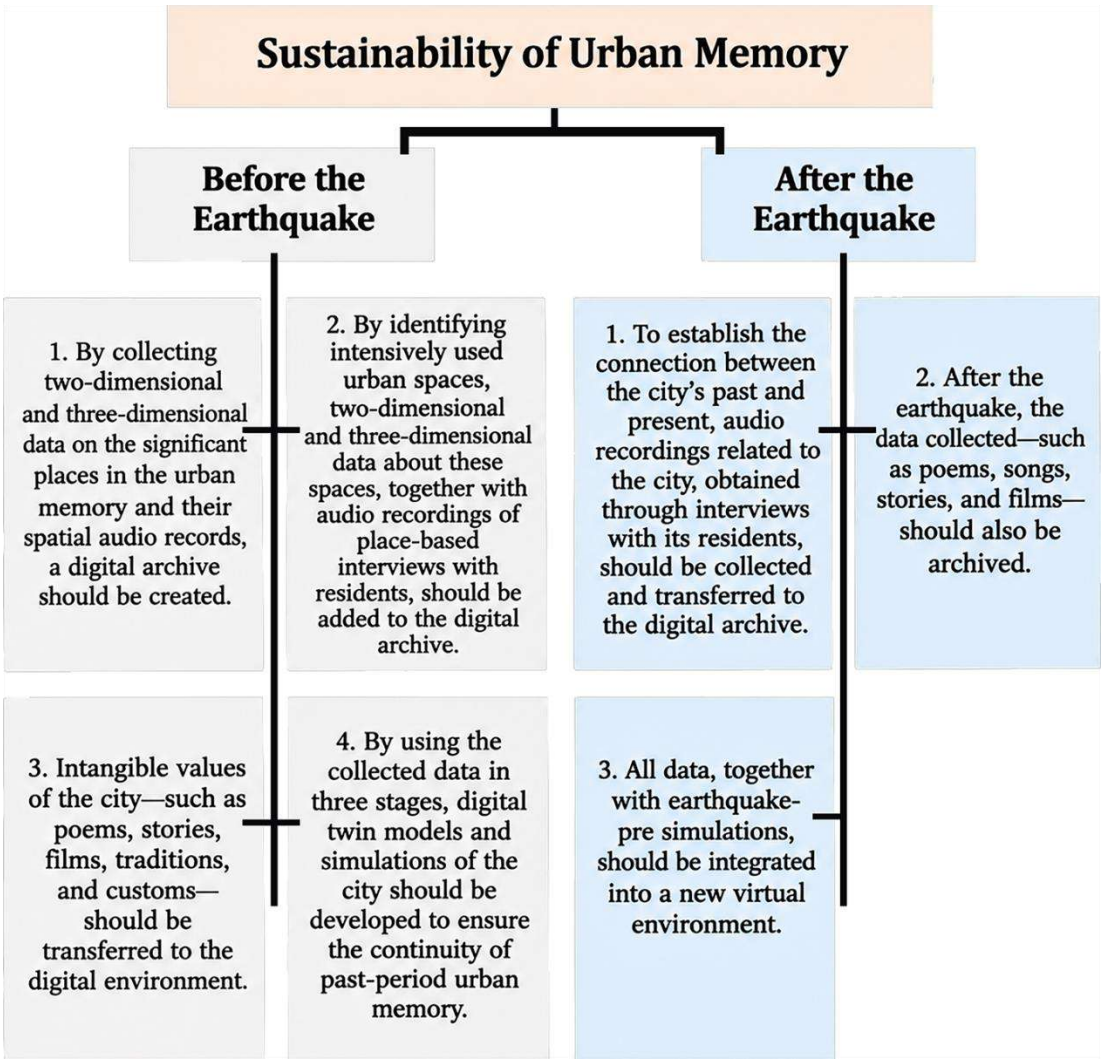


Figure 3. A proposal for a developable method concerning the relationship between earthquakes and memory

As shown in Figure 3, digital technologies do not focus solely on the physical structure of a city; they must also encompass the experiences of its inhabitants and the social meanings attributed to its spaces. This perspective suggests that transferring urban memory into a digital environment requires more than merely creating a digital replica; it entails preserving the memories of those who lived in these spaces, along with their shared social experiences, to ensure their long-term sustainability. These findings indicate that, in the post-earthquake reconstruction of cities, digital twin and virtual reality applications can serve as complementary tools for restoring social ties severed by the loss of physical space. In this context,

addressing digital twin and virtual reality applications for the sustainability of post-earthquake urban memory within a multidisciplinary framework requires integrating technical modeling processes with oral history and mechanisms for social participation. Supporting this integration through a participatory data-generation process—one that centers on the experiences of the city's inhabitants and the meanings they attach to its spaces—will ensure that the resulting digital records are preserved as a form of cultural heritage that is sustainable in both scientific and social terms.

References

Akyıldız, N. A., & Sığın, A. (2024). Turkish Family Structure in the February 6 Kahramanmaraş Earthquakes: Rising Traditional Codes. Avrasya Uluslararası Araştırma Dergisi, 12(39), 117-134, https://doi.org/10.33692/avrasyad.1416663

Atıcı Tektaş, E. (2024). A method proposal for transferring urban memory to the future with digital technologies: Eskişehir Hamamyolu example. Unpublished doctoral dissertation. Eskişehir: Eskişehir Osmangazi University, Graduate School of Natural and Applied Sciences.

Atıcı Tektaş, E., & Öztürk, A. (2024). An Approach to the Process of Transferring Collective Memory to Digital Media. International Journal of Social Sciences, 8(2), 141-156, http://dx.doi.org/10.30830/tobider.sayi.20.28.

Bergson, H. (1970). Matter and Memory. (N. M. Paul, & W. Palmer, Dü) London: New York: Humanities Press, Inc.

Cengiz, A. K. (2026). Yerinden Edilen Anılar: 6 Şubat Sonrası Antakya'da Kent Belleği Çalışması. (A. K. Cengiz, ed.). In, Afet Sonrası Bir Kenti Hatırlamak: Antakya'da Kent Belleği. Ankara: Nobel Akademik Publishing.

Connerton, P. (1999). Toplumlar Nasıl Anımsar (Ç. A. Şenel, ed.) İstanbul: Ayrıntı Publishing.

Dinç, Y. (2025). Changing urban space perception in behavioral geography: The case of earthquake cities. *İdealkent*, (48), 472-510.

Em-Dat. (2025). 2025 Disasters in Numbers. https://files.emdat.be/reports/2025_EMDAT_report.pdf (Access date: 25.10.2026).

Gök, S. B., Yavaş, M. (2024). Assessment of Earthquake Risk in Urban Development Areas. *Journal of Natural Hazards and Environment*, *10*(1), 140-154.

Hassan, M. M. (2025). Digital Twins in Architecture and Urban Planning. European Journal of Architecture and Urban Planning, 5(1), 1-9, https://doi.org/10.24018/ejarch.2026.5.1.70190.

Jedlowski, P. (2001). Memory and Sociology: Themes and Issues. Time and Society, 10(1), 29–44, https://doi.org/10.1177/0961463X01010001002.

Nora, P. (1989). Between Memory and History: Les Lieux de Mémoire. Representations(26), 7-24, https://doi.org/10.2307/2928520.

Nora, P. (2006). Hafıza Mekanları. (M. E. Özcan, ed.) Ankara: Dost Publishing.

Olgun, İ. (2009). Relations beetwen urban reading and memory in the process of urban change. İstanbul, Unpublished doctoral thesis: Mimar Sinan University, Institute of Science and Technology.

Özdede, S., Doğan, D., Zengin, M. (2021). Kolektif bellekte antik kentlerin izi: Denizli kenti örneği. *Journal of Architectural Sciences and Applications*, *6*(2), 688-703.

Yetişkin, F. N. (2026). The Relationship Between Social Memory and Space: The 1939 and 1992 Erzincan Earthquakes. Pamukkale University Journal of Social Sciences Institute(75), 98–119, https://doi.org/10.30794/pausbed.1732611.

Ziegler, D. A., Anguera, J., Gallen, C., Hsu, W.-Y., Wais, P., & Gazzaley, A. (2022). Leveraging technology to personalize cognitive enhancement methods in aging. Perspevtive, https://doi.org/10.1038/s43587-022-00237-5, 475-483.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

WOOL AS A CLIMATE-SENSITIVE INSULATION ALTERNATIVE WITH TRACES OF THE PAST: THE ERZURUM EXAMPLE

Eda Gizem Almalı
Asena Soyluk
0009-0004-4266-1373, Master's Student, Gazi University, Institute of Science, Department of Architecture, Ankara, Turkey.
0000-0002-6905-4774, Prof. Dr., Gazi University, Institute of Science, Department of Architecture, Ankara, Turkey.

Abstract

Climate change and its effects are one of the most important problems of our time. Increased use of fossil fuels as a result of human and technological activities is causing an increase in greenhouse gases in the atmosphere. Climate change triggers extreme weather events. If necessary, precautions are not taken, many disasters related to heat and cold will inevitably have an adverse impact on our planet. Buildings are among the places most affected by climate change, increasing energy consumption. Therefore, reducing energy consumption in buildings is a primary goal for many countries. In this study, the city of Erzurum, a cold climate region, was chosen, and the traditional architectural approaches used in traditional Erzurum houses in the past are explained. The necessity of thermal insulation, one of the measures taken today to improve climate resistance in buildings, is also discussed. Considering the increased energy consumption in the production phases of thermal insulation materials, the use of petroleum-based synthetic materials, and the potential harm to nature, the need for new alternative insulation materials is increasing. Wool, an animal fiber, has recently been the subject of many researches and applications due to its natural, ecological, renewable, sustainable, and durable properties. Studies have evaluated the performance of insulation materials made using sheep wool and goat hair, and positive results have been observed. In conclusion, due to the benefits of using wool from the sheep and goats that are widely raised in Erzurum as a thermal insulation material, its use in the city has been recommended.

Keywords: climate change, cold weather conditions, wool as thermal insulation, resilience, architectural precautions, sustainability.

1.INTRODUCTION

Global warming and climate change are among the greatest challenges of our time. Therefore, climate-responsive building design plays a crucial role in addressing these issues. For this reason, "climatic conditions" must be carefully considered during the design and construction of cities and buildings. This involves selecting appropriate sites for development, ensuring harmony with the topography, and correctly implementing passive design strategies—such as proper orientation, building form, spacing between structures, and material selection (Karagöz & Yılmaz, 2016).

Ensuring urban resilience is of great importance for contemporary urban spaces. Events stemming from global warming and climate change negatively affect cities, leading to numerous problems that diminish the quality of life (Topal & Tatar, 2023). The current rise in urban population density, combined with factors such as industrial activity, has driven an increase in energy demand. This has led to a greater reliance on fossil fuels, thereby contributing to air pollution, global warming, and climate change. A significant portion of this growing energy demand is consumed by heating, cooling, and ventilation systems within buildings. Under these circumstances, thermal insulation has become essential for making building envelopes more resilient to environmental factors and climatic conditions (Taştemir, 2020). Common thermal insulation materials currently used in buildings include glass wool, rock wool, EPS, XPS, rubber foam, polyethylene foam, and wood-shaving boards (Yıldırım, 2021). While these materials offer comfort and variety, they often contain

substances that can be harmful to human health and the environment, and their production processes are highly energy-intensive. Globally—and particularly in Europe—there is a growing interest in alternatives that are more ecological, sustainable, accessible, and environmentally friendly (Tuzcu, 2007).

Climate not only influences the socio-economic conditions of societies but also plays a significant role in shaping the spaces they design for habitation. The distinct climates, vegetation, and terrain of various regions have influenced the planning and positioning of houses, as well as the configuration of all their components, including exterior facades and roof systems (Önal, 2023). Furthermore, the traditions and cultural structures of societies also shape architecture, imbuing it with a traditional character (Karpuz, 1979). Anatolia encompasses diverse climatic zones. Geographical conditions—which can shift in response to climatic influences—affect the materials used and, consequently, the design of homes. The construction techniques employed during the design process also vary according to these conditions. Materials such as adobe, stone, and timber necessitate different approaches across various climatic zones. As a result, a variety of architectural structures and settlement patterns have emerged (Sağlam, 2019).

Located in a cold climate zone, the houses of Erzurum—when examined in this context—serve as a significant example of the traditional Turkish house typology, not only from an architectural perspective but also from a sociocultural one. The region's harsh climate, high altitude, characteristic building materials, and the lifestyle of its inhabitants have shaped the spatial organization of these dwellings, establishing them as a form of tangible cultural heritage (Şimşek Beyaz, 2025).

Erzurum houses represent a distinct approach within Turkish architecture due to certain unique characteristics. The courtyard, a standard feature in the traditional Turkish house plan, has evolved in Erzurum into an enclosed courtyard—a transition space necessitated by the harsh climatic conditions. Within this space, the tandoor room has become a functional area serving multiple purposes: it acts as a hub for various activities, a gathering place, and a source of warmth (Karpuz, 1979). The layout of the ground floor—incorporating a stable, a hayloft, and a pantry situated near the tandoor room—was designed to minimize the time residents needed to spend outdoors during the cold winter months (Coşkun, 2019). Furthermore, the use of walls constructed from locally sourced stone, combined with small windows and flat earthen roofs, renders these structures resilient and well-protected against the cold. The materials employed in their construction were selected for their local availability, climate resistance, and durability (Şimşek Beyaz, 2025).

This study investigates thermal insulation materials that can be produced using sheep's wool and goat hair as alternatives to existing insulation products. Particularly in regions like Erzurum, where small-ruminant livestock farming is prevalent, the development of thermal insulation materials based on these raw materials could play a significant role in both environmental protection and economic development.

2. COLD CLIMATE REGION: ERZURUM

2.1. Location of Erzurum Province

Located in the Eastern Anatolia Region, Erzurum is situated between 40° North latitude and 41° East longitude (Şimşek Beyaz, 2025). Surrounded by the Palandöken Mountains to the south and the Kargapazarı Mountains to the north, the province is established at an altitude of approximately 1.900 meters. With a surface area of 25.066 km², it is the fourth-largest province in Turkey by area (Erzurum Provincial Directorate of Culture and Tourism, n.d.). Volcanic mountains, which account for approximately 64% of the province's total area, fragment the city's landscape (Sağlam, 2019). According to data from the Turkish Statistical Institute (TÜİK, 2026), the population of Erzurum in 2025 was recorded as 736.877.

2.2. Climate of Erzurum Province

Erzurum is one of the highest and coldest provinces in Turkey, characterized by a harsh continental climate. Winters are very cold and snowy, summers are very hot and dry, and the spring seasons are rainy (Erzurum Metropolitan Municipality, n.d.). The average annual precipitation is recorded at 460,5 mm, and rainfall is irregular. According to the statistical data for Erzurum province from the Turkish State Meteorological Service (1991–2020 normals), the average annual temperature in Erzurum is approximately 5,3°C. Long-term

measurements indicate that the average temperature for the warmest month (August) is approximately 19,5°C, while the average for the coldest month (January) is approximately -10,2°C (Turkish State Meteorological Service [MGM], n.d.-a). General statistical records (1929–2025) show a maximum temperature of 36,5°C and a minimum temperature of -37,2°C (MGM, n.d.-b). The fact that the ground is covered with snow for approximately 113.1 days per year has influenced the design of structures and the selection of materials used in construction (Şimşek Beyaz, 2025).

Because Erzurum is shielded from maritime influences, it experiences extreme heating during the summer months and intense cooling during the winter, resulting in significant temperature fluctuations. Furthermore, the arrangement of the surrounding mountains—which encircle the city—contributes to various physiological and pathological processes, including evaporation, the solidification of water, the freezing of biological tissues, and transpiration (Sağlam, 2019).

2.3. Livestock Activities

In 2024, Erzurum had an inventory of 709.861 head of cattle and 837.683 head of small ruminants (Erzurum Provincial Directorate of Agriculture and Forestry, 2025). The most prominent small ruminant breeds in Erzurum are the "Morkaraman" (a type of fat-tailed sheep) and the "Turkish Hair Goat". These animals are highly resilient to climatic conditions. The natural environment and the extensive pastures available in Erzurum provide a significant advantage for the region in terms of the number of small ruminants (Northeast Anatolia Development Agency [KUDAKA], 2017).

2.4. Traditional House Architecture and Spatial Organization in Erzurum

An examination of houses in Erzurum reveals that they do not conform to traditional "Turkish house plan types." This is because the harsh, prolonged winter conditions in Erzurum have influenced both daily life and architectural elements. In Erzurum houses, the primary shaping factor is the orientation of the tandoor house (a room containing a traditional ground-level oven/hearth). The hall-like room—a characteristic feature of traditional Turkish house plans—is either reduced in size or entirely absent in these dwellings (Kayserili, 2011). The function of the hall-like room is instead fulfilled by the tandoor house, which is connected to the courtyard. While the courtyard in typical Anatolian houses is an open space, in Erzurum houses, it has evolved into a common area that facilitates access to other sections on the ground floor (Turhan, 2020).

2.4.1. Tandoor House with an Inner Courtyard

In his study, Karpuz (1979) defines Erzurum houses as a " Type of Tandoor House with an Inner Courtyard" Access to the courtyard is gained from the street through a doorway. The ground floor houses the tandoor room, various living chambers, a stable, and a hayloft—the latter two being positioned in close proximity to the main structure. The stairs leading to the living quarters on the upper floor are also located here (Önal, 2023). The tandoor room is a versatile space that integrates multiple functions, including cooking, dining, heating, resting, and storage. Its structural characteristics, which resemble those of the tents used by Turkic peoples in Central Asia, reflect a continuity of cultural ties. Much like the hearth found in Central Asian Turkic tents, the tandoor serves as the focal point of the space (Şimşek Beyaz, 2025). The roof of the tandoor room is typically constructed using a technique known as a swallowtail ceiling. At the apex of this dome-like structure lies an opening—a skylight—which provides natural illumination and ventilation, while also allowing smoke to escape. Due to the harsh climatic conditions, there are no additional windows in the walls of these tandoor rooms (Başaran, 2025).

2.4.2. External Appearance and Facade Character

The influence of the harsh climate is also evident on the facades of traditional Erzurum houses. While their exterior appearance is generally simple, they rank among the most notable traditional historical homes in Anatolia due to their interior ornamentation. These houses typically consist of one or two stories (Yılmaz et al., 2003). To ensure resilience against both climatic conditions and earthquakes, the ground-floor walls—constructed from stone—are exceptionally thick. The upper stories, by contrast, are built using brick or rubble stone. A distinctive feature of Erzurum houses is the presence of horizontal timber beams embedded within the

walls; these provide structural flexibility, making the buildings more resistant to demanding environmental conditions (Önal, 2023). Between these beams are square-sectioned wooden elements. Measuring 1 to 1,5 meters in length, these elements serve as scaffolding during the construction of the walls. They are particularly common on facades that require frequent repairs due to the impact of the local climate (Şimşek Beyaz, 2025).

On the exterior, windows are designed to be small on the ground floor and larger on the upper levels. On the ground floor, the windows are positioned near the ceiling—a design choice intended both to ensure privacy and to minimize heat loss in rooms used during the winter (Sağlam, 2019). The windows typically feature a splayed design, widening toward the interior. Between the inner and outer casements, iron grilles are installed (Başaran, 2025).

2.4.3. Roof Structure

In Erzurum houses, the roof structure typically takes the form of a flat roof. This design also applies to the roofs of ancillary structures such as barns and haylofts. It appears to be a measure taken against the cold climate; this approach facilitates the easy removal of snow—which accumulates on the roofs due to the heavy snowfall that persists for much of the year—by allowing it to be shovelled off (Önal, 2023). These flat roofs, constructed by compacting earth over a timber framework, feature "spouts". These spouts serve as channels that facilitate the drainage of water from the roof while also adding visual interest to the building's facade. They are crafted from various materials, including wood, terracotta, or basalt stone. Through these channels, snowmelt and rainwater that accumulate on the roof can be easily drained away (Başaran, 2025).

2.4.4. Construction Material

The primary construction materials used in Erzurum houses include stone, brick, earth, timber, and certain metals. Black stone is used for foundations due to its resistance to moisture and dampness; grey stone is typically used for the walls of most houses because it is easy to work with; and camber stone (a specific type of stone) is found in some of the more affluent residences (Karpuz, 1979). The stones used in Erzurum houses are sourced from volcanic rock formations in the immediate vicinity of the city. As these materials are abundant and easily accessible, they help reduce construction costs while also being highly suitable for cold climates (Sağlam, 2019).

Earth is used as a binding agent for the walls, while brick is employed for chimneys, interior partition walls, and certain sections of the exterior facades. Brick plays a significant role in thermal insulation. Additionally, reeds and rushes are used for roof coverings. Constructed from locally sourced materials, Erzurum houses are durable and feature highly functional spatial layouts, with an organization of space that aligns with the local social way of life (Şimşek Beyaz, 2025).

3. TRADITIONAL ARCHITECTURE RESILIENT TO CLIMATE CHANGE AND COLD WEATHER CONDITIONS

Climate refers to the effects associated with weather patterns observed in a region over many years. It is one of the most significant factors influencing the living conditions of societies. Climate change, on the other hand, is defined as shifts in the climatic parameters that have prevailed in a region over a long period. It is a global issue that affects the entire world. In an increasingly globalized world, the rise in technological advancements and human activities has led to an increase in energy consumption (Balçık, 2026). Fossil fuels are commonly used to meet these energy needs, which has resulted in the depletion of non-renewable energy sources and an increase in carbon emissions. Driven by the effect of rising greenhouse gases, global warming has occurred, and climate change has reached dangerous proportions (Taştemir, 2020).

The effects of global warming have given rise to "extreme weather events" driven by climate change. In cold climate regions, in particular, rising ocean temperatures cause storms and hurricanes to intensify, leading to destructive events (Samancı & Toy, 2024). Beyond the negative impacts associated with rising seasonal temperatures, global warming may also increase the frequency of cold-weather events. Sudden drops or spikes in temperature—consequences of climate change—can trigger various disasters. Examples of these adverse

outcomes include increased snowfall followed by rapid melting, the formation of ice masses due to repeated freezing cycles, and flooding caused by rising sea levels (Yılmaz, 2024).

Buildings have a significant impact on the rise in global energy consumption. A substantial amount of energy is expended throughout the entire lifecycle of a building—from its initial construction to its operational phase, which includes heating, cooling, and ventilation (Taştemir, 2020). The construction sector accounts for 36–40% of energy consumption, 39% of CO2 emissions, and 25% of material consumption (Denes et al., 2022). When considering cities and buildings as a whole, climate change and its potential consequences underscore the importance of urban resilience. Buildings should be constructed using durable and sustainable materials and designed in a manner that is appropriate for the local climate (Topal & Tatar, 2023). Furthermore, in countries like Turkey that are dependent on external sources for energy, the cost-effectiveness of thermal insulation materials is a critical consideration (Yıldırım, 2021).

Traditional houses in Erzurum are among the most distinctive examples of Anatolian architecture, designed to withstand a cold climate. Beyond merely providing shelter, these homes reflect a synthesis of social life and harmony with nature (Turhan, 2020). Their construction prioritizes the use of accessible, locally sourced materials that are well-suited to the climate and environmental conditions. Stone, brick, and timber are the primary building materials, typically employed using a masonry construction technique (Başaran, 2025). Features such as thick stone and adobe walls, a limited number of small windows, earthen roofs, and an inward-facing courtyard layout are all intended to protect the house from cold winds and heat loss. Furthermore, windows are sparse and small on the northern side and lower levels, while they are more numerous and larger on the southern facades. The structure's design—which widens toward the interior—allows sunlight to easily penetrate the rooms. Transom windows located above the doors opening into the courtyards provided natural light in the days before electricity (Şimşek Beyaz, 2025). To manage snow accumulation and keep building entrances clear, the doors are generally oriented toward the south (Sağlam, 2019).

4. ERZURUM HOUSES OF TODAY

In contemporary Erzurum, traditional one- or two-story structures have been replaced by multi-story apartment buildings. Due to advancements in technology, concrete is now used in the construction of these homes (Yılmaz et al., 2003). Often disregarding Erzurum's specific climatic conditions, modern buildings continue to be constructed with wall thicknesses sometimes falling below 20 cm—a choice driven by cost-efficiency. An examination of these modern structures reveals that they are built with very large dimensions, lack wall and window systems capable of retaining heat, and feature expansive windows ill-suited for a cold climate. This makes heating the residences difficult and leads to higher energy consumption. To address this issue, the people of Erzurum employ a thermal insulation system known as "cladding". This approach reduces heat loss, resulting in energy savings of up to 50% (Kayserili, 2011). In Turkey, the insulation of buildings and the achievement of energy efficiency are governed by the "TS 825 Thermal Insulation Standard for Buildings" (Taştemir, 2020). Commonly used thermal insulation materials include rock wool, glass wool, XPS (extruded polystyrene), EPS (expanded polystyrene), rubber foam, and polyethylene foam (Yıldırım, 2021).

5. THERMAL INSULATION MATERIALS

According to the European Commission's communication COM/2016/051, 75% of the energy consumed in buildings is derived from fossil fuels, while 18% comes from renewable sources (Hegyi et al., 2021). Approaches aligned with directives on the "Energy Performance of Buildings" mandate the construction of energy-efficient and sustainable buildings. In this context, the concept of a "nearly zero-energy building" has emerged, aiming to minimize carbon dioxide emissions by reducing the energy consumed for heating and cooling (Zach et al., 2012). Reducing energy consumption in buildings can be achieved through the use of insulation materials. The purpose of insulation—beyond mitigating the impact of greenhouse gases—is to ensure thermal comfort for occupants throughout both summer and winter. Materials commonly used for this purpose, such as glass wool, rock wool, and polyester, are synthetic products. While these materials provide thermal insulation, they also pose risks to human health and the environment (Ahmed et al., 2019). The environmental impact associated with the use of such materials has raised concerns, leading to an increased

focus on the use of biological, ecological, natural, and renewable products instead of petroleum-based materials (Corscadden et al., 2014). Furthermore, it is essential to adhere to the "European Green Deal," which outlines objectives such as mitigating the effects of global warming, increasing the use of renewable energy sources, and reducing the impact of greenhouse gases (Atbir et al., 2023). This agreement, to which Turkey is also a party, encourages a shift toward natural products (Eastern Anatolia Development Agency [DAKA], 2023).

When used correctly, natural fibers—insulation materials that are more easily sourced locally and can be recycled—offer superior thermal comfort compared to many commonly used thermal insulation materials, while also providing positive benefits for both the environment and human health. In this context, natural fibers such as sheep's wool and goat hair have become the subject of recent research (Parlato & Porto, 2020). Sheep's wool, in particular, is gaining increasing popularity within the construction sector. Wool production takes place in many countries, most notably in France, the United Kingdom, Italy, the United States, Japan, and Germany (Tuzcu, 2007).

6. NATURAL INSULATION MATERIAL ALTERNATIVE: WOOL

6.1. Features of Wool

Wool consists of approximately 82% keratin, 17% non-keratin proteins, and about 1% lipids and polysaccharides. Due to its high protein content, it can absorb and neutralize heavy metals, harmful volatile organic compounds (VOCs), and other hazardous gases (Bosia et al., 2015). Sheep wool fibers possess a tubular, fibrous structure containing micro-voids (Denes et al., 2022). It is a material characterized by a scaly, fine structure; it is crimped, typically off-white in color, highly malleable, and can range in length from 3,8 to 76 cm (Yıldırım, 2021). When an external directional force is applied, wool fibers tend to entangle, resulting in a unique bonding process known as "felting." Wool fibers are hygroscopic, meaning they absorb moisture from the air (Denes et al., 2022). It has a low thermal conductivity. Sheep wool exhibits high elongation at break—ranging from 25% to 35%—as well as significant tensile strength (Parlato & Porto, 2020).

6.2. Advantages of Using Wool in Insulation

6.2.1. Thermal Performance

Thermal conductivity is an important factor in evaluating insulation materials (Maldonado-Alameda et al., 2023). Thanks to the voids on the surface of its fibers, wool traps air and prevents the formation of thermal bridges. This slows down heat transfer, thereby providing effective insulation (Atbir et al., 2023). With a thermal conductivity of 0.034–0.054 W/mK and a high thermal resistance of 2.5–2.6 m^2/W, sheep's wool meets the standards for insulation materials. Based on these values, wool can demonstrate superior thermal performance compared to polystyrene-based insulation materials (Parlato & Porto, 2020).

6.2.2. Acoustic Performance

Acoustic performance is of great importance for buildings. Due to increasing urbanization, noise pollution is on the rise, making sound-absorbing insulation materials ever more significant. Wool can effectively control noise from external sources, such as human activity and traffic (Hohemberger et al., 2026). The porous and heterogeneous structure of sheep's wool facilitates the superior dispersion of sound waves. Consequently, wool possesses excellent sound-absorbing properties, delivering high performance in sound insulation (Szczecina et al., 2026).

6.2.3. Moisture Retention and Indoor Air Quality

Thanks to its porous structure, wool retains moisture and releases it into the environment when ambient humidity levels drop. This process is significant for purifying indoor air (Zach et al., 2012). Wool can hold a high volume of water vapor without undergoing any changes to its physical or thermal properties (Ahmed et al., 2019). Furthermore, due to its natural felting characteristic, it can release stored moisture into drier environments (DAKA, 2023). With its excellent moisture-regulating capacity, wool can also capture harmful volatile compounds—such as formaldehyde and other aldehydes—that are emitted into indoor spaces from

paints, furniture, and various building materials. In this way, it contributes to indoor comfort by purifying the air, which is highly beneficial for the health of the occupants (Hohemberger et al., 2026).

6.2.4. Fire Resistance

With an ignition temperature in the range of 750°C–800°C, wool is fire-resistant. Due to the nitrogen and moisture content within its structure, wool is difficult to ignite and generally tends to self-extinguish once the source of the fire is removed. Unlike many synthetic products, wool does not melt or drip; instead, it chars (Yıldırım, 2021).

6.2.5. Occupational Health and Safety

During production and transport, wool insulation materials are less abrasive and irritating than other types of insulation (Hohemberger et al., 2026). They do not contain the harmful chemical substances found in many insulation materials currently on the market. Consequently, there is no need for protective clothing, masks, or goggles during installation, making them very safe for workers in this field. Sheep's wool can be easily processed and utilized without harming the environment, and it is self-extinguishing in the event of a fire (Ahmed et al., 2019).

6.2.6. Usage Advantage

Wool insulation materials can be used for insulating roof spaces, walls, and floors in any climatic zone. In warm climates, the water within the wool fibers evaporates, absorbing heat from the interior and cooling the space. In cold climates, the wool retains moisture, preventing thermal bridges and condensation, thereby helping to keep the interior warm (Parlato & Porto, 2020). Conventional thermal insulation materials are typically applied to the exterior of buildings, as using them internally would reduce the available interior volume. Furthermore, in the absence of adequate ventilation, such materials can lead to increased humidity, which may promote the proliferation of harmful microorganisms. However, thin mats made from sheep's wool can be incorporated into interior designs by supporting them with wooden battens or panels (Hegyi et al., 2021).

6.2.7. Environmental Benefits

Existing thermal insulation materials produced from fossil fuels possess high embodied energy; consequently, their production consumes significant amounts of energy. Furthermore, these materials are difficult to recycle and cause environmental harm at the end of their service life. In contrast, sheep's wool has lower embodied energy, requiring less energy during production (Hohemberger et al., 2026). Due to their low carbon footprint, they do not contribute to environmental pollution. Once their primary function has ended, insulation materials made from wool can be reprocessed into raw material and used to create other products. Additionally, they provide protection against solar radiation by mitigating the harmful effects of sunlight (DAKA, 2023). Wool is an "intelligent" material that adapts to external conditions, thanks to properties such as its ability to regulate moisture and its reactivity toward formaldehydes (Hegyi et al., 2021).

6.3. Disadvantages of Sheep's Wool as an Insulation Material

Today, sheep's wool is sourced from a limited number of suppliers. Consequently, insulation materials made from sheep's wool are more expensive than alternatives such as glass wool. In North America, vendors market "Black Mountain" insulation—a product originating from the United Kingdom—at high price points (Corscadden et al., 2014). While procuring sheep's wool can be costly in regions where it is not produced, it can be obtained at a low cost in areas where wool is produced, often by utilizing what would otherwise be considered waste. Although the initial investment may be high, the thermal insulation provided over the long term can easily offset these costs. Furthermore, other widely used global insulation materials are mass-produced, making them a more attractive option for the construction sector (Hohemberger et al., 2026). If not processed correctly, sheep's wool can develop issues such as unpleasant odors or moth infestations, particularly in humid environments; therefore, biocides must be applied during the production process—a practice that may carry environmental risks (Parlato & Porto, 2020). Additionally, because sheep's wool is softer than many other types of insulation, its performance may decline if subjected to excessive pressure. Moreover, the process

of transforming raw, shorn wool into clean fleece requires washing, which leads to increased water consumption (Midolo et al., 2024).

6.4. Wool Production and Marketing Activities Worldwide

In 2023, total global wool production reached approximately 746.000 tons (Kosova et al., 2025). These animal fibers, produced by the millions of tons worldwide each year, serve as a resource for investment across various sectors. Turkey, China, Australia, the United Kingdom, and New Zealand are leading producers of raw wool, with Turkey accounting for 3,3% of this global output. Raw wool is an easily accessible, healthy, and recyclable material; however, its economic utilization remains limited. When processed into felt, cleaned wool can be used in textiles, as an underlay material in the automotive industry, in the production of tents and carpets, and as an alternative to conventional insulation materials in the construction sector (DAKA, 2023). In Turkey, approximately 90.000 tons of raw wool are produced annually; while 10% of this is utilized, the vast majority ends up as waste (Yıldırım, 2021). Although sheep are raised in many parts of the world, their wool is frequently treated as waste. Nevertheless, countries such as Australia, New Zealand, the United Kingdom, and Austria produce insulation materials derived from sheep's wool (Vėjelis et al., 2023).

6.5. Studies Investigating the Insulation Performance of Wool Insulation Materials

6.5.1. Examples from Abroad

In a project conducted jointly by the Vienna University of Technology and the Brno University of Technology—as part of an Austria-Czech collaboration—an 80 mm-thick thermal insulation material was produced from sheep's wool. This material was tested under various conditions, specifically evaluating its thermal conductivity, moisture resistance, and sound insulation properties—all of which are critical for durable and reliable applications. The test results indicate that the thermal insulation derived from sheep's wool possesses properties comparable to those of mineral or rock wool, and in certain applications, it even performs better (Zach et al., 2012).

Within the scope of the Italy-based "Cartonlana" project, a new insulation material has been developed by combining wool—classified as special waste in Italy—with raw wool sourced from Austria and New Zealand. The semi-rigid Cartonlana panels, which are 5–12 cm thick and composed of 70–80% sheep's wool fused with 20–30% polyester fiber, were evaluated based on insulation parameters such as thermal conductivity, acoustic absorption coefficient, formaldehyde absorption, and the thermal transmittance of walls; these results were then compared with those of existing insulation materials. It has been observed that this material is competitive with popular insulation products in terms of both thermal conductivity and acoustic absorption. Recognized as an ecological construction product due to its durability and adaptability, Cartonlana panels offer new opportunities for both the waste management and sheep-rearing sectors (Bosia et al., 2015).

In a study conducted in the Jammu and Kashmir (J&K) region of India, sheep wool, goat hair, and horse mane hair were processed to create felt. The moisture absorption and thermal conductivity properties of the resulting insulation materials were measured, and the average values were reported. It was observed that sheep wool and goat hair absorb nearly equal amounts of moisture, and that goat hair possesses lower thermal conductivity compared to both sheep wool and horse mane hair. Scientific research indicates that the fibers from the region's wool-bearing goats have a remarkably low thermal conductivity value of 0,0314 W/mK. Given that India faces an energy crisis—and considering that temperatures in the country's high-altitude regions can plummet to as low as -40°C—insulation materials produced from sheep wool and goat hair emerge as an ideal alternative for building insulation (Ahmed et al., 2019).

At the Harmeny Woolen Mill, located in the Central North River area—within the Canadian province of Nova Scotia—wool insulation material has been produced in the form of batts (slabs). It has been observed that the thermal performance of this wool insulation is comparable to that of other materials, such as fiberglass, polystyrene, and cellulose insulation (Corscadden et al., 2014).

One of the design solutions developed by the team at the St. Catherine Design Center in Egypt’s Sinai region—leveraging local traditional knowledge—is the "Trombe window." Instead of conventional shuttered window

casements, this design utilizes a wooden frame with two horizontal, hinged sections covered in goat-hair fabric. The high thermal conductivity of the goat hair provides effective shading during the summer and helps retain heat in the winter. Furthermore, when it rains, the pores of the goat-hair fabric close, preventing water from entering. The material's inherent ability to retain moisture also facilitates humidity regulation (Dabaieh, 2014). In another study conducted in Egypt, a year-long simulation was performed using climate data from eight cities across the country's hot-arid and hot-humid regions. The results demonstrated that wool insulation enhances the energy efficiency of buildings, even in hot climates. In desert environments, sheep's wool insulation outperforms expanded polystyrene (EPS) when used with concrete block walls, proving to be both technically and economically advantageous. Sheep's wool insulation can reduce cooling energy consumption by up to 16% and CO2 emissions by up to 12% (Hetimy et al., 2026).

A study conducted on wool insulation material produced in New Zealand has shown that wool possesses properties similar to those of glass fiber, while being more effective at reducing sound levels (Corscadden et al., 2014). Furthermore, research into the insulation performance of sheep's wool panels—conducted in New Zealand and Northern Ireland—has revealed that wool resembles mineral wool. The most significant features that distinguish this material from others are its environmental friendliness and its compressibility, which results in lower transportation costs (Parlato & Porto, 2020).

In Romania, non-woven sheep's wool thermal insulation mats, produced for experimental purposes, were tested on walls, ceilings, and floors to evaluate their water permeability. The products were found to offer good thermal insulation performance—while maintaining breathability, regulating moisture, and reducing harmful volatile substances—and to improve indoor air quality (Hegyi et al., 2021).

In Jordan, experiments were conducted to compare the thermal properties of waste sheep wool with those of imported insulation materials. It was observed that wool-based insulation can compete with 3 cm-thick polystyrene boards and rock wool in terms of thermal conductivity (Alma'atah & Alkhamis, 2020).

A cement-based insulation material has been developed by combining waste sheep wool fibers—produced in Spain—with magnesium phosphate cement (MPC), an industrial by-product. The thermal, mechanical, and physical properties of this material were tested, revealing that its thermal and acoustic insulation performance is comparable to that of other existing insulation materials. Given its sustainable nature, it has been noted as a viable option for exterior facade insulation and soundproofing (Maldonado-Alameda et al., 2023). In another study conducted in Spain, an insulation material was produced using wool from the "Latxa" sheep breed—raised in northern Spain—by incorporating soy protein isolate and coffee grounds (the latter added for insecticidal purposes). The 60 mm-thick samples produced yielded positive results in tests concerning thermal conductivity, sound absorption, and resistance to insect infestation (Urdanpilleta et al., 2025).

Research conducted in Morocco aims to produce unbaked, solid bricks by combining sheep's wool with clay—a material that is local, durable, abundant in the country, and cost-effective. It has been observed that the thermal insulation test results for the resulting material are comparable to those of conventional materials currently in use (Atbir et al., 2023).

"Ghezel" sheep, which inhabit the northwestern region of Iran, produce wool that is too dark in color for use in clothing or textiles, rendering it a waste product. These sheep were crossbred with the "Arkharmerino" breed. The wool from the resulting offspring was shorn, spun into yarn, and used to produce thick, woven fabrics. It was observed that the samples produced are comparable to glass fiber and mineral wool in terms of their acoustic and thermal properties. This material has been identified as a suitable covering for non-woven surfaces in the interior decoration of buildings (Mohammadi Ghermezgoli et al., 2021).

Woolcool®, a sheep's wool insulation material originating from the United Kingdom, is used in the transport of chilled food products; it is reported to maintain the temperature of these products between 2 and 8 degrees Celsius for up to 72 hours (Szczecina et al., 2026).

Traditional tents made from goat hair—used by Middle Eastern nomads since ancient times—offer high durability in the hot desert climate, thanks to their superior shading and cooling properties. When exposed to rain, the fibers within the goat hair swell, rendering the material waterproof. Furthermore, the natural oils

present in goat hair possess moisture-repellent characteristics. Utilizing this resource, which is exceptionally resilient against various weather conditions, aligns with global sustainability goals. Given its biodegradable and renewable nature, it serves as an alternative to synthetic fibers (Allafi et al., 2026).

6.5.2. Examples from Türkiye

In a project conducted by Selçuk University, a thermal insulation material made from sheep's wool has been developed for use as an alternative insulation solution in buildings. Through this project, sheep's wool—regarded as one of the highest-quality insulation materials in the world due to its natural, "smart," and nanotechnological fiber properties—can now be utilized for insulation and climate control in homes (İhlas News Agency, 2017).

In a project carried out by students and their supervising teachers at the Samsun Atakum Vocational and Technical Anatolian High School, insulation boards were developed by combining materials that have lost their economic value—specifically sheep's wool, goat hair, and pine needles—with cement-based or water-based binders. It was observed that the goat hair-based insulation material has a thermal conductivity coefficient (0,035 W/mK) superior to that of many insulation products currently on the market, making it highly suitable for use in roofing applications. This initiative is expected to contribute to the economy by repurposing waste and natural materials (İhlas News Agency, 2025).

As part of a study conducted by Gaziantep University, a heat and sound insulation panel was developed by blending goat hair—obtained from hair goats in the Mediterranean region—with polyester fibers. Tests on the thermal conductivity, durability, air permeability, and acoustic properties of these panels revealed that they are more efficient in terms of sound and heat insulation compared to commonly used insulation materials (Özdemir, 2023).

A boron-infused sheep’s wool insulation material, developed by Konya Technical University, was compared against materials such as EPS and rock wool in terms of thermal and acoustic insulation, using a full-scale (1:1) building model. The test results demonstrated that a 1 cm thick layer of the sheep’s wool insulation performs comparably to a 5 cm thick layer of rock wool or EPS, while also providing superior acoustic insulation. Its low production cost, combined with its health-friendly and ecological nature, makes sheep’s wool an attractive insulation option (Yıldırım, 2021).

7. CONCLUSION AND RECOMMENDATIONS

Throughout history, humanity has prioritized adapting to climatic conditions when constructing dwellings, drawing upon ancient, time-honored knowledge. Long before the advent of modern technology, people designed spaces that utilized passive systems in harmony with nature. Their choice of materials was consistently guided by the geographical characteristics, climatic conditions, and socio-cultural contexts of each region. However, the progression of technology, the rise of industrialization, and shifting global circumstances have gradually transformed these traditional building practices. Global warming—exacerbated by the use of fossil fuels and various human activities—is driving climate change. This phenomenon alters regional climates, leading to more intense heat or an increase in the frequency of cold-weather events. Such extreme weather conditions have resulted in higher energy consumption for the heating and cooling of buildings. Many nations, particularly in Europe, have adopted and implemented measures to enhance energy efficiency in buildings and build resilience against climate change. Today, contemporary construction often diverges from traditional architectural principles. In spaces designed without due consideration for climatic conditions and environmental factors, thermal insulation has become a critical issue. While insulation materials developed for this purpose are highly effective at ensuring thermal comfort and reducing energy consumption, their production processes—which often involve high energy expenditure, the use of finite petroleum-based raw materials, and the creation of synthetic components—can be detrimental to both the environment and human health.

Efforts to utilize new, natural, sustainable, renewable, clean, climate-conscious, and ecological insulation materials are gaining traction. In this context, alternative insulation materials have been developed using animal fibers—specifically those obtained from sheep and goats—and compared against conventional

materials. The results indicate that insulation materials derived from wool exhibit performance levels comparable to those of widely used products such as rock wool and glass wool. Despite the significant global scale of sheep and goat farming, the fact that the fibers obtained from these animals often end up as waste causes harm to both the environment and the economy. Such natural, ecological, and sustainable materials should be incorporated into building construction, and this initiative should be supported through appropriate government policies.

In the province of Erzurum—a region with a cold climate—there is significant potential for sheep and goat farming, which is well-supported by local conditions. Utilizing the wool from these small ruminants to produce thermal insulation materials for use in building components—such as walls, roofs, and floors—would be highly beneficial from a sustainability perspective. Integrating traditional methods with technological approaches will help mitigate the adverse effects of climate change, contribute to the preservation of the natural environment, and support the economy.

REFERENCES

Ahmed, A., Qayoum, A., & Mir, F. Q. (2019). Investigation of the thermal behavior of the natural insulation materials for low temperature regions. *Journal of Building Engineering, 26,* Article 100849. https://doi.org/10.1016/j.jobe.2019.100849

Allafi, F. A., Ab Kadir, M. O., & Lalung, J. (2026). Advancements application of natural goat hair fiber as a renewable energy source: A review. *International Journal of Energy Research, 2026,* Article 8856498. https://doi.org/10.1155/er/8856498

Alma'atah, B. M., & Alkhamis, T. M. (2020). Sustainability of sheep fleece utilization in Jordan as an insulation material to decrease environmental pollution, increase farmers' income, and create new job opportunities. *Journal of Environmental Protection, 11*(10), 821–837. https://doi.org/10.4236/jep.2020.1110051

Atbir, A., Taibi, M., Aouan, B., Khabbazi, A., Ansari, O., Cherkaoui, M., & Cherradi, T. (2023). Physicochemical and thermomechanical performances study for Timahdite sheep wool fibers application in the building's insulation. *Scientific Reports, 13*(1), Article 5038. https://doi.org/10.1038/s41598-023-31516-9

Balçık, S. (2026). *Binaların sürdürülebilir yenilenmesi üzerine model önerisi: Sivas tren garları alan çalışması* (Tez No. 995218) [Doctoral dissertation, Eskişehir Technical University]. YÖK National Thesis Center.

Başaran, Ş. (2025). *Geleneksel Erzurum evlerinin tipolojik analizi* (Tez No. 922655) [Master's thesis, Atatürk University]. YÖK National Thesis Center.

Bosia, D., Savio, L., Thiebat, F., Patrucco, A., Fantucci, S., Piccablotto, G., & Marino, D. (2015). Sheep wool for sustainable architecture. *Energy Procedia, 78,* 315–320. https://doi.org/10.1016/j.egypro.2015.11.650

Corscadden, K. W., Biggs, J. N., & Stiles, D. K. (2014). Sheep's wool insulation: A sustainable alternative use for a renewable resource? *Resources, Conservation and Recycling, 86,* 9–15. https://doi.org/10.1016/j.resconrec.2014.01.004

Coşkun, E. (2019, April 10). *Erzurum evleri*. *Erzurum Sevdası Dergisi*. https://erzurumsevdasi.com/2019/04/10/erzurum-evleri/

Dabaieh, M. (2014). Energy efficient design strategies for contemporary vernacular buildings in Egypt. In M. Correia, G. Carlos, & S. Rocha (Eds.), *Vernacular heritage and earthen architecture: Contributions for sustainable development* (pp. 599–604). Taylor & Francis. https://doi.org/10.1201/b15685-104

Dénes, T.-O., Iştoan, R., Tămaş-Gavrea, D. R., Manea, D. L., Hegyi, A., Popa, F., & Vasile, O. (2022). Analysis of sheep wool-based composites for building insulation. *Polymers, 14*(10), Article 2109. https://doi.org/10.3390/polym14102109

Doğu Anadolu Kalkınma Ajansı. (2023, March). *Yün işleme tesisi fizibilite raporu*. https://www.kalkinmakutuphanesi.gov.tr/assets/upload/dosyalar/yun-isleme-tesisi-fizibilite-raporu.pdf

Erzurum Metropolitan Municipality. (n.d.). *Erzurum coğrafyası*. Retrieved October 29, 2026, from https://www.erzurum.bel.tr/erzurum-cografyasi

Erzurum Provincial Directorate of Agriculture and Forestry. (2025, April). *Erzurum ili brifing raporu* [Presentation]. https://erzurum.tarimorman.gov.tr/Belgeler/Brifing%20Raporlar%C4%B1/brifing_nisan_2025.pdf

Erzurum Provincial Directorate of Culture and Tourism. (n.d.). *Coğrafya*. Republic of Türkiye Ministry of Culture and Tourism. Retrieved November 5, 2026, from https://erzurum.ktb.gov.tr/TR-56063/cografya.html

Hegyi, A., Bulacu, C., Szilagyi, H., Lăzărescu, A.-V., Meiţă, V., Vizureanu, P., & Sandu, M. (2021). Improving indoor air quality by using sheep wool thermal insulation. *Materials, 14*(9), Article 2443. https://doi.org/10.3390/ma14092443

Hetimy, S., Megahed, N., Abo Eleinen, O., & Elgheznawy, D. (2026). Assessment of sheep wool as a sustainable building insulation material in hot climate zones. *Architectural Engineering and Design Management, 22*(3), 870–899. https://doi.org/10.1080/17452007.2025.2560472

Hohemberger, L. F., Salbego, A. G., Galery, H. R., Cornélio, J. P. L., Cardoso, F. A. R., & Armas, L. E. G. (2026). Sheep wool as a sustainable building insulation: A systematic review of properties, environmental impacts and future perspectives. *International Journal of Building Pathology and Adaptation, 44*(8), 2173–?. https://doi.org/10.1108/IJBPA-11-2025-0305

İhlas Haber Ajansı. (2017, September 26). *Selçuk Üniversitesi, koyun yününden ısı yalıtım malzemesi geliştirdi*. Haberler.com. https://www.haberler.com/selcuk-universitesi-koyun-yununden-isi-yalitim-10068417-haberi/

İhlas Haber Ajansı. (2025, May 16). *Koyun yünü, keçi kılı ve çam ağacı yaprağı yalıtım malzemesi oldu*. https://www.iha.com.tr/samsun-haberleri/koyun-yunu-keci-kili-ve-cam-agaci-yapragi-yalitim-malzemesi-oldu-238534850

Karagöz, D., & Yılmaz, A. (2016, February 10–12). *İklime duyarlı kentsel tasarım parametrelerinin soğuk iklim koşulları açısından irdelenmesi* [Conference presentation]. International Winter Cities Symposium, Erzurum, Türkiye, 166–183.

Karpuz, H. (1979). *Erzurum evlerinin Türk-İslâm mesken mimarisindeki yeri* (Tez No. 367269) [Doctoral dissertation, Atatürk University]. YÖK National Thesis Center.

Kayserili, A. (2011). *Erzurum şehri'nin kültürel coğrafyası (maddi kültür öğelerine göre)* (Tez No. 304070) [Doctoral dissertation, Atatürk University]. YÖK National Thesis Center.

Kosova, N., Pomitun, I., Kosov, M., Kosov, V., & Slinko, V. (2025). Prospects for alternative use sheep wool. *The Scientific and Technical Bulletin of the Institute of Animal Science NAAS of Ukraine, 133*, 34–45. https://doi.org/10.32900/2312-8402-2025-133-34-45

Kuzeydoğu Anadolu Kalkınma Ajansı. (2017). *Erzurum ili'nde küçükbaş hayvancılık* (Report No. EYDO/SAR/17/01). https://kudaka.gov.tr/assets/upload/dosyalar/ERZURUMKUCUKBAS.pdf

Maldonado-Alameda, A., Alfocea-Roig, A., Huete-Hernández, S., Giro-Paloma, J., Chimenos, J. M., & Formosa, J. (2023). Magnesium phosphate cement incorporating sheep wool fibre for thermal insulation applications. *Journal of Building Engineering, 76*, Article 107043. https://doi.org/10.1016/j.jobe.2023.107043

Midolo, G., Del Zoppo, M., Porto, S. M. C., & Valenti, F. (2024). Recycling of wasted wool fibers from sheep shearing for green building components: A review. *Case Studies in Construction Materials, 21,* e03623. https://doi.org/10.1016/j.cscm.2024.e03623

Mohammadi Ghermezgoli, Z., Moezzi, M., Yekrang, J., Rafat, S. A., Soltani, P., & Barez, F. (2021). Sound absorption and thermal insulation characteristics of fabrics made of pure and crossbred sheep waste wool. *Journal of Building Engineering, 35*, Article 102060. https://doi.org/10.1016/j.jobe.2020.102060

Önal, R. Ç. (2023). Geleneksel konut mimarisinde iklim ve topoğrafyaya bağlı farklılıkların Erzurum ili kuzey ilçeleri üzerinden değerlendirilmesi. *Ordu Üniversitesi Sosyal Bilimler Enstitüsü Sosyal Bilimler Araştırmaları Dergisi, 13*(1), 333–352. https://doi.org/10.48146/odusobiad.1242549

Özdemir, F. (2023, June 12). *Gaziantep Üniversitesinde keçi kılından yalıtım malzemesi üretildi*. Anadolu Agency. https://www.aa.com.tr/tr/bilim-teknoloji/gaziantep-universitesinde-keci-kilindan-yalitim-malzemesi-uretildi-/2920335

Parlato, M. C. M., & Porto, S. M. C. (2020). Organized framework of main possible applications of sheep wool fibers in building components. *Sustainability, 12*(3), Article 761. https://doi.org/10.3390/su12030761

Sağlam, T. (2019). *Geleneksel Erzurum evleri, restorasyonları ve ev yaşantısı* (Tez No. 622697) [Doctoral dissertation, Atatürk University]. YÖK National Thesis Center.

Samancı, Ö. N., & Toy, S. (2024). Soğuk iklim kentlerinde iklim değişikliğine uyumlu kentsel tasarım ilkeleri. *Doğu Coğrafya Dergisi, 29*(51), 90–99. https://doi.org/10.17295/ataunidcd.1453087

Szczecina, J., Szczepanik, E., Barwinek, J., Szatkowski, P., Niemiec, M., & Molik, E. (2026). Valorisation of sheep wool fibers in sustainable energy-efficient materials: Thermal and acoustic properties of bio-based composites for low-carbon construction. *Energies, 19*(3), 866. https://doi.org/10.3390/en19030866

Şimşek Beyaz, Y. (2025). *Geleneksel Erzurum evlerinde biçimsel yapı ve biçime etki eden sosyokültürel faktörler üzerine bir inceleme* (Tez No. 967357) [Doctoral dissertation, Fatih Sultan Mehmet Vakıf University]. YÖK National Thesis Center.

Taştemir, İ. A. (2020). *Farklı iklim bölgelerinde yapı kabuğunda ısıl kütlenin bina enerji etkinliğine ve ısıl konforuna olan etkisi* [Master's thesis, Mimar Sinan Fine Arts University]. ProQuest Dissertations & Theses Global.

Topal, E., & Tatar, E. (2023). Kentsel dirençlilik üzerine mekân odaklı araştırmalar. *Mimarlık Bilimleri ve Uygulamaları Dergisi, 8*(Special Issue), 547–566. https://doi.org/10.30785/mbud.1333803

Turhan, A. (2020). *Gravürden siyah beyaz fotoğrafa Erzurum evleri* (Tez No. 617221) [Master's thesis, Atatürk University]. YÖK National Thesis Center.

Turkish State Meteorological Service. (n.d.-a). *İllere ait mevsim normalleri (1991–2020): Erzurum*. Retrieved November 5, 2026, from https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=H&m=ERZURUM

Turkish State Meteorological Service. (n.d.-b). *İllere ait genel istatistik verileri: Erzurum*. Retrieved November 5, 2026, from https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=A&m=ERZURUM

Turkish Statistical Institute. (2026). *Cinsiyete göre nüfus: Erzurum, 2025* [Data set]. Population Statistics Portal. Retrieved November 5, 2026, from https://nip.tuik.gov.tr/

Tuzcu, T. M. (2007). *Hygro-thermal properties of sheep wool insulation* [Master's thesis, Delft University of Technology]. TU Delft Repository. https://resolver.tudelft.nl/uuid:6f32b195-f2b7-41e4-b70e-adae72c078e9

Urdanpilleta, M., Leceta, I., Martín-Garín, A., Millán-García, J. A., Guerrero, P., & de la Caba, K. (2025). Valorized sheep wool biocomposites towards a more sustainable building sector: Thermal insulation, sound

absorption, and resistance against insects. *Developments in the Built Environment, 21*, Article 100608. https://doi.org/10.1016/j.dibe.2025.100608orcid

Vėjelis, S., Skulskis, V., Kremensas, A., Vaitkus, S., & Kairytė, A. (2023). Performance of thermal insulation material produced from Lithuanian sheep wool. *Journal of Natural Fibers, 20*(2), 2237682. https://doi.org/10.1080/15440478.2023.2237682

Yıldırım, G. Ş. (2021). Bor katkılı koyun yününün yalıtım malzemesi olarak kullanılabilirliğinin araştırılması ve mevcut yalıtım malzemeleri ile karşılaştırılması (Tez No. 704841) [Master's thesis, Konya Technical University]. Konya Technical University Institutional Repository. https://gcris.ktun.edu.tr/bitstream/20.500.13091/2281/1/704841.pdf

Yılmaz, F. (2024). The problems related to snow load according to the effect of climate change on the roofs of traditional Turkish houses (Tez No. 911079) [Master's thesis, Gazi University]. YÖK National Thesis Center.

Yılmaz, S., Irmak, M. A., & Zengin, M. (2003). Geleneksel Erzurum evlerinde mekan kullanımı. Atatürk Üniversitesi Ziraat Fakültesi Dergisi, 34(2), 173–178. https://dergipark.org.tr/tr/pub/ataunizfd/article/40810

Zach, J., Korjenic, A., Petránek, V., Hroudová, J., & Bednar, T. (2012). Performance evaluation and research of alternative thermal insulations based on sheep wool. *Energy and Buildings, 49*, 246–253. https://doi.org/10.1016/j.enbuild.2012.02.014

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

RECLAIMED SURFACES: SPATIAL DYNAMICS OF UNAUTHORIZED STREET ART AT KARAKOY FERRY TERMINAL

Ayse Gul GEMCI
ORCID 0000-0003-1856-5336, Istanbul Sabahattin Zaim University, Department of Interior Architecture and Environmental Design, Istanbul, Türkiye.

Abstract

Unauthorized street art is often treated by urban authorities as a form of visual disorder requiring removal. This study examines it as a spatial practice through which individuals appropriate urban surfaces and negotiate their use and meaning. The theoretical framework draws on Lefebvre's concepts of appropriation and domination to explain the relationship between everyday spatial practices and institutional control. De Certeau's concept of everyday tactics further informs the examination of unauthorized interventions. The study focuses on how street art interacts with the architectural surfaces of Karaköy Ferry Terminal and its surroundings. It also considers how the appearance, removal, and reappearance of graffiti contribute to changes in the visual character of public space. Two research questions guide the study. First, how do the location, visibility, and physical characteristics of urban surfaces influence the placement of unauthorized street art? Second, how do the removal and reappearance of these interventions affect the visual identity and everyday use of public space?

The research adopted a qualitative case study approach focusing on Karaköy Ferry Terminal and its surrounding pedestrian routes, underpasses, and transitional spaces in Istanbul. Fieldwork was conducted between 2024 and 2026. Three field observation sessions and ten photographic records documented sixteen street art interventions. The observations recorded their location, surface characteristics, and visibility within the study area. Visual and observational data were analyzed using MAXQDA. Qualitative content analysis was organized around four dimensions: spatial context, physical and visual transformation, patterns of spatial use, and temporal change. The analysis examined the relationship between street art and architectural surfaces, including documented instances of removal, overwriting, and reappearance. Preliminary findings suggest that street art interventions are concentrated on visible surfaces near pedestrian routes and transitional spaces. Surface materials and textures appear to influence the form and scale of these interventions. The removal of graffiti does not necessarily prevent further interventions. In some cases, new markings appear on previously altered surfaces, creating successive layers of visual change. These observations suggest that the same architectural surface can become a recurring site of informal expression and spatial control.

The findings indicate that architectural surfaces change through repeated interventions and practices of removal. These processes illustrate how everyday appropriation and spatial regulation interact over time. The study contributes to architectural discussions on informal spatial practices by examining the temporal changes of urban surfaces. It also offers insights into the management of transit-related public spaces, where unauthorized expression and institutional control coexist.

Keywords: Street art; appropriation; public space; temporality; transit spaces; Istanbul.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

COMPARATIVE ASSESSMENT OF SEISMIC ISOLATION EFFECTS ON THE EARTHQUAKE RESPONSE AND STRUCTURAL COST OF AN EIGHT-STORY REINFORCED CONCRETE BUILDING

Mehmet Erzi
Mehdi Öztürk
Istanbul Arel University, Graduate School of Education, Civil Engineering Program, Istanbul, Türkiye, 0009-0001-3413-7342
Istanbul Arel University, Department of Civil Engineering, Istanbul, Türkiye, 0000-0003-4147-0431

Abstract

This paper examines the influence of base isolation on the reported seismic response and preliminary structural construction cost of an eight-story reinforced concrete residential building. Two configurations, one fixed-base and one base-isolated, were considered with the same superstructure and material assumptions. The story height and overall height were 3.00 m and approximately 24.00 m, respectively. C30/37 concrete and B420C reinforcing steel were specified. The natural vibration periods, base shear forces, floor displacements, interstory drift ratios, and internal force demands reported in an ETABS-based master's thesis were compared. The first-mode period increased from 0.82 s to 2.18 s, whereas the X-direction base shear decreased from 4,820 kN to 1,730 kN (64.11%). The maximum reported interstory drift ratio decreased from 0.69% to 0.42%. In parallel, the estimated initial construction cost increased from TRY 10,161,500 to TRY 11,355,400 (11.75%). The comparisons indicate potentially beneficial reductions in superstructure seismic demands, accompanied by higher initial cost. Since isolator mechanical parameters, detailed seismic inputs, and original software outputs are not fully documented in the source thesis, the figures presented should be understood as reported case-study results rather than independently validated design calculations.

Keywords: Seismic isolation; reinforced concrete; base shear; structural dynamics; construction cost.

INTRODUCTION

Earthquake-resistant design of reinforced concrete (RC) buildings has traditionally relied on the strength, stiffness, and ductility of structural members to resist seismic actions and dissipate earthquake-induced energy. Although conventional seismic design approaches can provide adequate life safety, significant inelastic deformations and damage to structural and non-structural components may still occur during strong ground motions. In this context, seismic isolation has emerged as an effective strategy for modifying the dynamic characteristics of buildings and limiting the seismic demands transmitted to the superstructure. By introducing a flexible interface between the foundation and the structural system, base isolation can increase the fundamental vibration period and, under appropriate ground-motion conditions, reduce the acceleration response, base shear forces, and interstory drift demands. Recent investigations of conventional RC buildings have demonstrated the potential of isolation systems to improve seismic performance, particularly when combined with complementary energy-dissipation mechanisms (Ozer and Inel, 2025; Li et al., 2025).

Seismic isolation systems are generally classified into elastomeric and sliding-based devices, each exhibiting different stiffness, damping, and energy-dissipation characteristics. Lead-rubber bearings and conventional elastomeric bearings provide horizontal flexibility through rubber deformation, whereas friction pendulum systems accommodate lateral movement through controlled sliding along curved surfaces. The effectiveness of these systems depends not only on the elongation of the structural period but also on their nonlinear force–displacement behavior and capacity to accommodate repeated seismic displacements. Experimental investigations involving RC frames equipped with double friction pendulum bearings have demonstrated the potential of these devices to limit structural damage under severe earthquake excitations (Lei et al., 2023). Similarly, numerical assessments of irregular RC buildings have indicated that friction pendulum isolation can

substantially reduce base shear demands compared with corresponding fixed-base configurations (Güneş, 2021).

Despite these advantages, the response of base-isolated structures is strongly influenced by ground-motion characteristics and the mechanical properties of the isolation system. In particular, near-fault ground motions containing pronounced velocity pulses may impose considerable displacement demands on isolation bearings. Güneş (2022) demonstrated that pulse characteristics can significantly affect isolator displacement, while Rostami and Poursha (2021) investigated how near-fault and far-fault excitations and record-scaling approaches influence the seismic response of isolated building frames. Furthermore, variations in structural mass and stiffness may modify the dynamic characteristics of isolated systems and alter their seismic demand distribution (Kiral et al., 2025). These findings indicate that evaluating the effectiveness of base isolation requires consideration of both structural response reduction and isolation-system deformation capacity.

Another critical consideration is the interaction between isolation displacement, earthquake directionality, and the surrounding structural environment. Although isolation devices may reduce the forces transmitted to the superstructure, excessive horizontal movements can increase the risk of pounding against neighboring buildings or surrounding retaining walls. Mavronicola et al. (2020) demonstrated the importance of ground-motion incidence angle, mass eccentricity, and torsional effects in the seismic response of isolated buildings subjected to possible impact conditions. In addition, the stability of individual isolators and their ability to maintain adequate vertical load-carrying capacity remain essential aspects of seismic safety. Arré et al. (2025) examined uplift mechanisms in friction pendulum isolation systems, emphasizing that isolator stability should be considered alongside the conventional response parameters used in design.

The assessment of seismic isolation should therefore extend beyond the comparison of fundamental periods and base shear forces. Seismic resilience and damage-related performance indicators are increasingly recognized as important criteria in evaluating isolated structural systems. He et al. (2025) proposed a resilience assessment framework based on multidimensional fragility relationships for structures equipped with friction pendulum bearings, highlighting the importance of uncertainty and multiple performance limit states. Such approaches provide a broader perspective on structural safety by considering potential damage levels and post-earthquake functionality. Moreover, the long-term effectiveness of isolation devices may be affected by changes in friction, stiffness, and damping characteristics. Calvi et al. (2026), through full-scale dynamic field testing of an existing base-isolated residential building, provided evidence of the relevance of aging effects and in-service mechanical properties to the assessment of isolation performance.

From an engineering decision-making perspective, structural performance improvements should also be evaluated in relation to construction feasibility and economic implications. The incorporation of seismic isolation devices introduces additional requirements associated with bearing procurement, installation, foundation-level detailing, and the accommodation of isolation displacements. On the other hand, reductions in seismic force demands may create opportunities for more efficient superstructure design. These potential benefits should be considered together with installation costs, maintenance requirements, and expected reductions in earthquake-induced damage. Consequently, a meaningful comparison between fixed-base and isolated RC buildings should address both seismic response indicators and the initial structural construction cost, while recognizing that construction cost alone does not represent the full life-cycle economic benefit of seismic protection.Against this background, the present study investigates the comparative seismic behavior of an eight-story reinforced concrete (RC) residential building with fixed-base and base-isolated configurations.

The assessment focuses on fundamental vibration periods, base shear forces, story displacements, interstory drift ratios, internal force demands, and preliminary structural construction costs. By comparing these parameters, the study aims to evaluate the potential benefits of seismic isolation in reducing earthquake-induced forces and deformation demands, while also considering its economic implications. Particular attention is given to the relationship between improved seismic performance and the additional initial costs

associated with isolation systems. The investigation is based on numerical results reported in the source thesis rather than independently repeated simulations. Therefore, the findings are interpreted within the limitations of the available modeling information, emphasizing the need for further verification of isolator properties, displacement capacities, and seismic design requirements.

MATERIALS AND METHODS

Reference building and configurations

The reference structure is an eight-story reinforced concrete residential building. Each story was taken as 3.00 m high, giving an approximate total height of 24.00 m (Fig. 1). The structural system includes reinforced concrete columns, beams, shear walls, and floor slabs. The source thesis specifies C30/37 concrete and B420C reinforcement. It describes a regular and symmetric plan arrangement but does not provide a complete numerical schedule of grid spacings and member cross-sections sufficient for independent reconstruction of the structural model. The regular structural configuration was intended to provide a consistent basis for evaluating the influence of seismic isolation on the building's overall dynamic response. Furthermore, maintaining identical material properties and structural geometry in both configurations allows the effects of the isolation system to be examined without introducing additional variations in the superstructure. This modeling strategy helps establish a consistent reference framework for identifying differences in seismic response between the two structural configurations.

Two configurations were compared. In the fixed-base model, the reinforced concrete system is directly supported at the foundation. In the base-isolated model, isolation elements were placed between the foundation and superstructure. The source states that the superstructure layout, materials, occupancy loads, site conditions, and seismic assumptions were kept unchanged so that the differences could be attributed to the presence of the isolation layer. This comparative approach provides a basis for assessing changes in structural vibration characteristics, lateral force demands, and displacement response associated with the introduction of seismic isolation. Consequently, the comparison focuses on the influence of base isolation while minimizing the effects of variations in the primary structural characteristics.

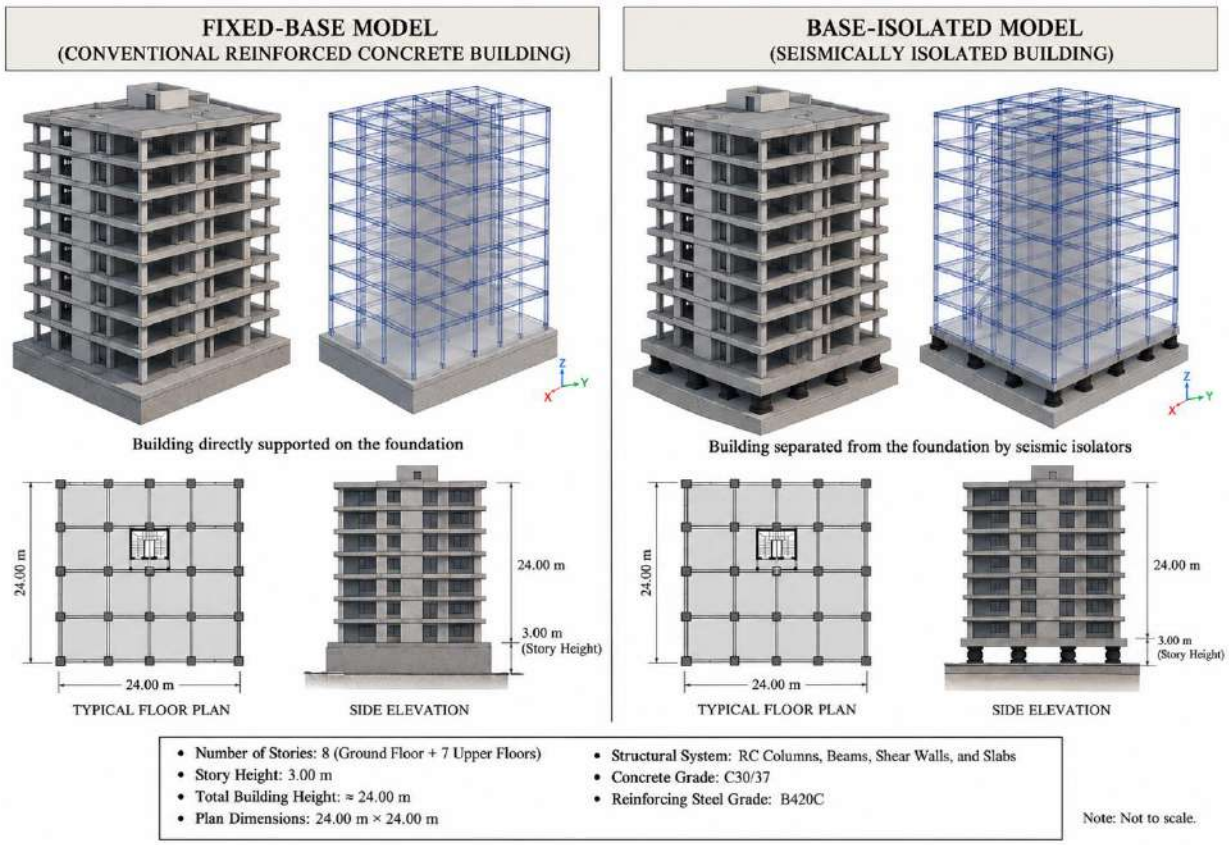


Figure 1. Three-dimensional structural models, typical floor plans, and side elevations of the fixed-base and base-isolated eight-story reinforced concrete buildings.

Reported analysis framework and comparison measures

According to the source thesis, the numerical modeling was carried out using ETABS. Modal periods and modal mass participation, X- and Y-direction base shears, horizontal floor displacements, interstory drift ratios, and maximum forces in selected column, beam, and wall elements were reported. The comparison also included estimated quantities and costs for concrete, reinforcing steel, formwork, and isolation hardware. The reported percentage variation was evaluated relative to the fixed-base value, as expressed by Equation (1).

$$\text{Change (\%)} = [(\text{Isolated value} - \text{Fixed-base value}) / \text{Fixed-base value}] \times 100 \quad (1)$$

The source thesis does not fully document bearing count, location, constitutive force–displacement laws, effective stiffness and damping, numerical earthquake input, or original ETABS output files. These omissions limit independent reproducibility. Consequently, no additional numerical parameters or assumed earthquake records have been introduced in this paper.

RESULTS

Modal properties and lateral-force demand

Table 1 summarizes the modal characteristics and lateral-force results reported in the original thesis. A substantial increase in the first three natural vibration periods is observed for the base-isolated configuration, indicating a significant modification of the structural dynamic characteristics. The fundamental period increased from 0.82 s to 2.18 s, corresponding to an increase of approximately 165.85%. Similarly, the base shear force in the X direction decreased from 4,820 kN to 1,730 kN, while the corresponding value in the Y

direction decreased from 4,610 kN to 1,650 kN, representing reductions of approximately 64.11% and 64.21%, respectively. These findings suggest that the introduction of the isolation layer reduces the effective lateral stiffness of the overall structural system, resulting in longer vibration periods and lower seismic force demands transmitted to the superstructure. The comparable reductions observed in both principal directions also indicate a relatively consistent response of the isolated configuration under the reported seismic loading conditions. Overall, the results are consistent with the fundamental principles of seismic isolation, highlighting its potential to reduce earthquake-induced lateral forces and improve the seismic response of reinforced concrete buildings.
Table 1. Reported modal properties and base shear forces of the two configurations.

Parameter	Fixed-base	Base-isolated	Change (%)
Mode 1 period (s)	0.82	2.18	+165.85
Mode 2 period (s)	0.76	1.94	+155.26
Mode 3 period (s)	0.68	1.71	+151.47
Modal mass participation (%)	96.4	97.1	+0.73*
Base shear X (kN)	4,820	1,730	−64.11
Base shear Y (kN)	4,610	1,650	−64.21

*Change in modal mass participation is in percentage points as reported in the source table.

Story displacements and interstory drift

The horizontal floor displacements for the fixed-base and base-isolated configurations are presented in Table 2. At the first floor, the base-isolated structure exhibits slightly greater horizontal displacement, which may be associated with the additional flexibility at the isolation level. However, this trend changes toward the upper stories, where the isolated configuration generally exhibits lower displacement demands. At the roof level, the reported X-direction displacement decreases from 84.6 mm to 78.1 mm, corresponding to a reduction of approximately 7.68%, while the Y-direction displacement decreases from 80.2 mm to 74.4 mm, representing a reduction of approximately 7.23%. Furthermore, the maximum interstory drift ratio decreases from 0.69% to 0.42%, equivalent to a relative reduction of 39.13%. These findings suggest that seismic isolation can limit relative deformation demands in the superstructure, potentially reducing damage associated with excessive interstory drift. Nevertheless, the results should be interpreted carefully because the reported values do not explicitly distinguish between isolation-layer displacement and superstructure deformation. A comprehensive assessment therefore requires separate consideration of absolute floor displacements, relative interstory deformations, and maximum isolator displacement demands.

Table 2. Reported horizontal floor displacements in both principal directions (mm)

Story	Fixed X	Isolated X	Fixed Y	Isolated Y
1	8.6	10.2	8.1	9.7
2	17.4	18.1	16.5	17.4
3	28.3	27.5	26.9	26.2
4	39.7	37.8	37.5	36.1
5	51.8	48.9	48.7	46.5
6	63.6	59.4	59.8	55.9
7	74.9	69.5	70.8	65.9
8 / Roof	84.6	78.1	80.2	74.4

These values require careful interpretation. In base-isolated buildings, displacement of the isolation layer and displacement of the superstructure relative to that layer are different quantities. The thesis does not establish whether the reported roof displacements are absolute, measured from the base, or measured relative to the isolation interface. Therefore, a direct claim that total building displacement is necessarily reduced would not be justified without the original output definitions.

Structural member force demands

The largest reported force demands in the selected reinforced concrete members are summarized in Table 3. For the isolated model, reductions are reported in the maximum axial force of columns, bending moments of columns and beams, and bending and shear actions in shear walls. These values suggest reduced force transfer to the superstructure under the considered loading assumptions; however, member identities and associated governing load combinations were not available in the source table.

Table 3. Maximum structural member actions reported for the two models

Member action	Fixed-base	Base-isolated	Change (%)
Column axial force (kN)	1,860	1,420	−23.66
Column bending moment (kN·m)	425	286	−32.71
Column shear (kN)	218	145	−33.49
Beam bending moment (kN·m)	285	194	−31.93
Beam shear (kN)	176	121	−31.25
Wall bending moment (kN·m)	4,680	3,020	−35.47
Wall shear (kN)	1,240	795	−35.89

Initial construction cost

The economic comparison in the source thesis comprises concrete, reinforcement, formwork, and isolator-related costs. The reported total structural construction cost is TRY 10,161,500 for the fixed-base building and TRY 11,355,400 for the isolated building. The additional cost of TRY 1,193,900 corresponds to an increase of 11.75% relative to the conventional solution. The thesis reports reductions in superstructure material quantities, but these savings do not compensate for the initial cost of installing isolators. Detailed bills of quantities, bearing unit prices, price dates, and independent cost verification were not included in the material available for this paper; accordingly, the figures should be read as illustrative initial-cost estimates rather than general market benchmarks.

Table 4. Summary of reported preliminary structural construction costs

Configuration	Reported total cost (TRY)	Difference (TRY)	Change (%)
Fixed-base	10,161,500	—	—
Base-isolated	11,355,400	+1,193,900	+11.75

DISCUSSION

A prolonged fundamental period and reduced base shear are the strongest findings of the reported comparison. Nevertheless, a favorable global response in a simplified comparison is not equivalent to satisfying the design and verification requirements for an actual isolation system. The stability and capacity of the bearings must be assessed under axial load and lateral deformation, and design displacement demand must be checked together with the available movement gap and building service connections. A reliable design comparison must also identify the seismic hazard level, damping assumptions, governing combination, and whether member demands are derived from linear or nonlinear analysis.

An additional limitation concerns the stated investigation of multiple isolator types. The thesis reviews elastomeric and sliding bearings conceptually, but the numerical comparison shown here is based on an isolated versus a non-isolated configuration; it does not provide a consistent set of structural analyses with multiple isolator types applied to the same building. Thus, the results cannot support a quantitative ranking among lead-rubber, high-damping rubber, and friction pendulum devices. Future analysis should document bearing parameters and perform comparable nonlinear time-history analyses with appropriate ground-motion sets.

Finally, the estimated 11.75% increase refers to initial structural construction cost only. A broader economic appraisal would also consider expected earthquake losses, post-earthquake downtime, replacement costs of isolation bearings, maintenance, and the functional requirements of the building. Such life-cycle quantities cannot be inferred from the data in the thesis and were not assessed in this paper.

CONCLUSION

The comparative assessment of an eight-story reinforced concrete residential building with and without seismic isolation yielded the following findings:

The fundamental vibration period increased from 0.82 s to 2.18 s following the implementation of the seismic isolation system.

The base shear forces decreased by approximately 64% in both principal horizontal directions.

The maximum reported interstory drift ratio decreased from 0.69% to 0.42%.

The maximum internal force demands in the columns, beams, and shear walls were reduced in the base-isolated configuration.

The estimated initial structural construction cost increased from TRY 10.16 million to TRY 11.36 million, corresponding to an increase of approximately 11.75%

REFERENCES

Arré, M., Almazán, J. L., and Auad, G. (2025). Analysis of uplift in structures with friction pendulum isolators: Relevant parameters and mitigation measures. Journal of Building Engineering, 112, 113695. https://doi.org/10.1016/j.jobe.2025.113695

Calvi, P. M., et al. (2026). Dynamic field testing of a 15-year-old friction pendulum base-isolated residential building. Soil Dynamics and Earthquake Engineering, 200, 109802. https://doi.org/10.1016/j.soildyn.2025.109802

Güneş, N. (2022). Effects of near-fault pulse-like ground motions on seismically isolated buildings. Journal of Building Engineering, 52, 104508. https://doi.org/10.1016/j.jobe.2022.104508

He, P., Ma, Y., and Liu, C. (2025). Seismic resilience assessment of base-isolated structures with friction pendulum isolation bearings based on two-dimensional fragility. Journal of Building Engineering, 103, 112202. https://doi.org/10.1016/j.jobe.2025.112202

Kiral, A., Tonyali, Z., and Elias, S. (2025). Optimizing seismic performance of base-isolated buildings with mass and stiffness variations under near and far fault ground motions. Structures, 76, 109026. https://doi.org/10.1016/j.istruc.2025.109026

Lei, Y., Shang, Q., Song, W., Yu, Y., Pan, P., and Wang, T. (2023). Shaking table tests of base-isolated reinforced concrete frame by double friction pendulum bearings. Journal of Building Engineering, 106240. https://doi.org/10.1016/j.jobe.2023.106240

Li, J., et al. (2025). Effect of base isolation devices and buckling-restrained brace dampers, used individually and in combination, on the seismic performance of conventional reinforced concrete buildings. Structures, 81, 110323. https://doi.org/10.1016/j.istruc.2025.110323

Mavronicola, E. A., Polycarpou, P. C., and Komodromos, P. (2020). Effect of ground motion directionality on the seismic response of base isolated buildings pounding against adjacent structures. Engineering Structures, 207, 110202. https://doi.org/10.1016/j.engstruct.2020.110202

Meral, E. (2021). Determination of seismic isolation effects on irregular RC buildings using friction pendulums. Structures, 34, 3436–3452. https://doi.org/10.1016/j.istruc.2021.09.062

Ozer, E., and Inel, M. (2025). The effect of single and combined use of base isolator and fluid viscous damper on seismic performance in a conventional RC building with torsional irregularity. Journal of Building Engineering, 101, 111898. https://doi.org/10.1016/j.jobe.2025.111898

Rostami, A., and Poursha, M. (2021). A lateral load distribution for the static analysis of base-isolated building frames under the effect of far-fault and near-fault ground motions. Structures, 34, 2384–2405. https://doi.org/10.1016/j.istruc.2021.08.125.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

ENHANCING THE EFFICIENCY OF PHOTOCATALYTIC AMOXICILLIN REMOVAL THROUGH RESPONSE SURFACE METHODOLOGY: A COMPARATIVE ANALYSIS OF LITERATURE-BASED AND EXPERIMENTALLY REFINED BOX–BEHNKEN DESIGNS

Şeyma Aydın
Oktay Özkan
0000-0002-4026-177X, Erciyes University Graduate School of Natural and Applied Sciences, Faculty of Engineering, Environmental Engineering Department, Kayseri, Turkey.
0000-0003-3864-711X, Erciyes University, Faculty of Engineering, Environmental Engineering Department, Kayseri, Turkey.

Abstract

In recent years, increasing concern has been directed toward the environmental impacts of antibiotics, as conventional wastewater treatment systems have limited effectiveness in completely removing these contaminants. Among the most frequently prescribed antibiotics worldwide, amoxicillin is recognized as a priority pharmaceutical pollutant in environmental monitoring studies.
In the present study, the photocatalytic degradation of amoxicillin in aqueous media was optimized using Response Surface Methodology (RSM) based on a Box–Behnken Design (BBD). The effects of pH (X_1), photocatalyst dosage (X_2), and initial amoxicillin concentration (X_3) were investigated. Factor levels were established based on both literature-derived values (R1) and preliminary experimental findings (R2). Analysis of variance (ANOVA) demonstrated that both models were statistically significant ($p < 0.05$) and exhibited comparable predictive capabilities, with coefficients of determination (R^2) of 0.857 and 0.863 for R1 and R2, respectively. The R2 model showed a non-significant lack-of-fit ($p = 0.1856$), indicating an adequate representation of the experimental data. In contrast, the significant lack of fit observed for R1 ($p < 0.0001$) suggested that the model was insufficient to fully explain the system behavior. The quadratic effect of pH (A^2) and the interaction between photocatalyst dosage and initial concentration (BC) were identified as the most influential factors in the R2 model, whereas the R1 model highlighted the effects of initial concentration (C) and pH (A^2). Overall, both models revealed a pronounced nonlinear influence of pH on photocatalytic amoxicillin removal. The findings suggest that incorporating both literature-based information and preliminary experimental data into the experimental design enhances the robustness, reliability, and predictive capability of RSM-based optimization studies for photocatalytic processes.

Keywords: Amoxicillin, photocatalytic removal, Box–Behnken design, Response Surface Methodology, experimental design optimization, green-iron nanoparticles (gNPs).

ACKNOWLEDGEMENTS
This study was supported by the Erciyes University Scientific Research Projects Department under project number FBA-2025-15584.

14th INTERNATIONAL NEW YORK CONFERENCE ON EVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES

FREQUENCY DEPENDENT RESPONSE OF Bi_2O_3 PTFE EPOXY STACKS WITH FILTER PAPER

Serhat YANIK
Independent Researcher, Istanbul, Türkiye
ORCID ID: https://orcid.org/0000-0003-4897-0009
Fatih Mehmet Coşkun
Department of Engineering Physics, Faculty of Engineering and Natural Sciences, Medeniyet University, Istanbul, Türkiye
ORCID ID: https://orcid.org/0000-0001-8040-8054

Abstract

This pilot study examines two Bi_2O_3/PTFE/epoxy specimens containing a small, centrally placed filter-paper interlayer. Broadband measurements were obtained at seven recorded temperatures between 30 and 85 °C. Parallel capacitance (Cp) and loss tangent (tanδ) were recalculated from the complex admittance, and the capacitance and impedance channels were checked against those results. Restricting the comparison to 0.1 Hz–185.934 kHz and retaining points with positive conductance and susceptance gave 308 paired temperature–frequency observations. The median specimen-2/specimen-1 ratios were 1.137 for Cp and 1.142 for tanδ, although both ratios crossed unity within the measured domain. At 30 °C and 853.712 Hz, the corresponding Cp values were 6.03 and 6.98 pF, while tanδ was 0.00421 and 0.00790. Thus, neither specimen shows a uniform advantage across all frequencies and temperatures. The results refer to the effective response of the full paper-containing structure; independent specimen repeats and verified interlayer thicknesses are unavailable, so a material-specific mechanism cannot be assigned.

Keywords: Bismuth oxide; PTFE; epoxy; filter paper; admittance; dielectric spectroscopy.

14TH INTERNATIONAL NEW YORK CONFERENCE ONEVOLVING TRENDS IN INTERDISCIPLINARY RESEARCH & PRACTICES
NOVEMBER 12-15, 2026

MANHATTAN, NEW YORK CITY

REF: AKADEMİK TEŞVİK

İLGİLİ MAKAMA

14. Uluslararası New York Kongresi, 12–15 Kasım 2026 tarihleri arasında ABD / New York, Manhattan'da 29 farklı ülkenin (Türkiye-67, Diğer Ülkelerden-81) akademisyen/araştırmacılarının katılımıyla gerçekleşmiştir. Kongre 16 Ocak 2020 Akademik Teşvik Ödeneği Yönetmeliğine getirilen "Tebliğlerin sunulduğu yurt içinde veya yurt dışındaki etkinliğin uluslararası olarak nitelendirilebilmesi için Türkiye dışında en az beş farklı ülkeden sözlü tebliğ sunan konuşmacının katılım sağlaması ve tebliğlerin yarıdan fazlasının Türkiye dışından katılımcılar tarafından sunulması esastır." değişikliğine uygun düzenlenmiştir.

Bilgilerinize arz edilir,

Saygılarımla

Muntazır Mehdi

Committee Member

Contacts: https://www.nyconference.org/

Email address: info@nyconference.org

KENSINGTON
INSTITUTE
OF BUSINESS AND TECHNOLOGY
EDUCATE ★ INNOVATE ★ LEAD

An Academic and Scientific Initiative of Kensington Business and Science Group LLC
A Legal Entity Incorporated under the Laws of the State of Wyoming, United States of America
Wyoming State Registration No.: 2026-001885143 | Reference No.: KIBS/INV/2026/001

OFFICIAL PROTOCOL DECLARATION

14th International New York Conference on Evolving Trends in Interdisciplinary Research & Practices
November 12–15, 2026 | Manhattan, New York City, USA
Decision No. 301/5 | May 23, 2026

TO WHOM IT MAY CONCERN

By Decision No. 301/5, dated May 23, 2026, Kensington Institute approved the organization of the 14th International New York Conference on Evolving Trends in Interdisciplinary Research & Practices, scheduled for November 12–15, 2026, in Manhattan, New York City, USA.

This Declaration records the establishment of the Conference Organizing Committee and identifies its members and their respective roles in Annex I, which forms an integral part of this Declaration.

The Organizing Committee was responsible for coordinating conference preparations, developing the program in consultation with the Scientific Committee, liaising with partner institutions and participants, and overseeing conference logistics and official communications.

For and on behalf of Kensington Institute

Leslie R. Robinson
Managing Member
Kensington Business and Science Group
United States of America

LIST OF ORGANIZING COMMITTEE

Prof. Dr. Enrique Mallen
Prof. Dr. Luiza Gabunia
Prof. Dr. Froilan D. Mobo
Prof. Ekaterina LOMIA
Prof. Mustafa Latif Emek
Assoc. Prof. Caroline Akhras

Reference No.: KIBS/INV/2026/001