BRITISH CONGRESS

INTERDISCIPLINARY SCIENTIFIC RESEARCH & PRACTICES -VI

June 18-21, 2026



London, UK

PROCEEDINGS BOOK

Editor
Dawid WORTLEY

ISBN - 979-8-89695-480-4

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International British Congress on Interdisciplinary Scientific Research & Practices-VI

June 18-21, 2026

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Editor

Dawid WORTLEY

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adopted by Mariam Rasulan

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CONGRESS ID

TITLE OF CONGRESS

International BRITISH
Congress on Interdisciplinary Scientific Research & Practices-VI

PARTICIPATION

Keynote & Invited

DATE - PLACE

June 18-21, 2026
London, UK

ORGANIZATION

London Sovereign School

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TOTAL PAPERS: 146

The number of papers from foreign countries: **87**

The number of papers from Türkiye: **59**

LANGUAGES

Turkish, English

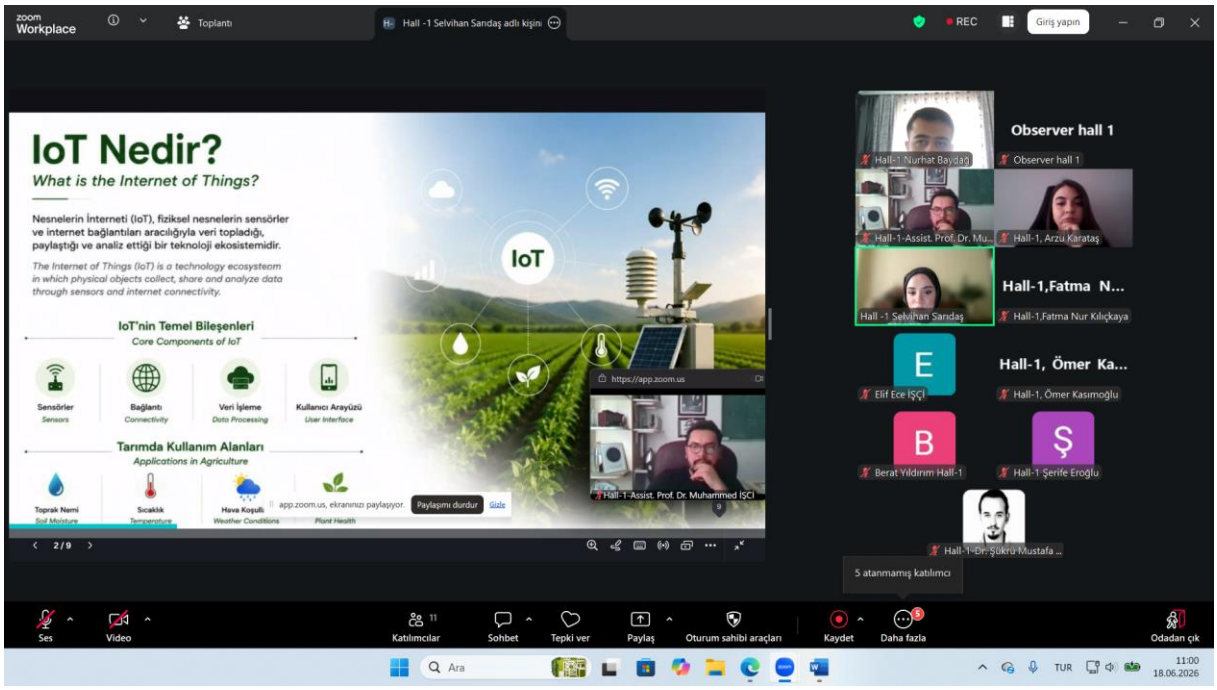
PHOTO GALLERY

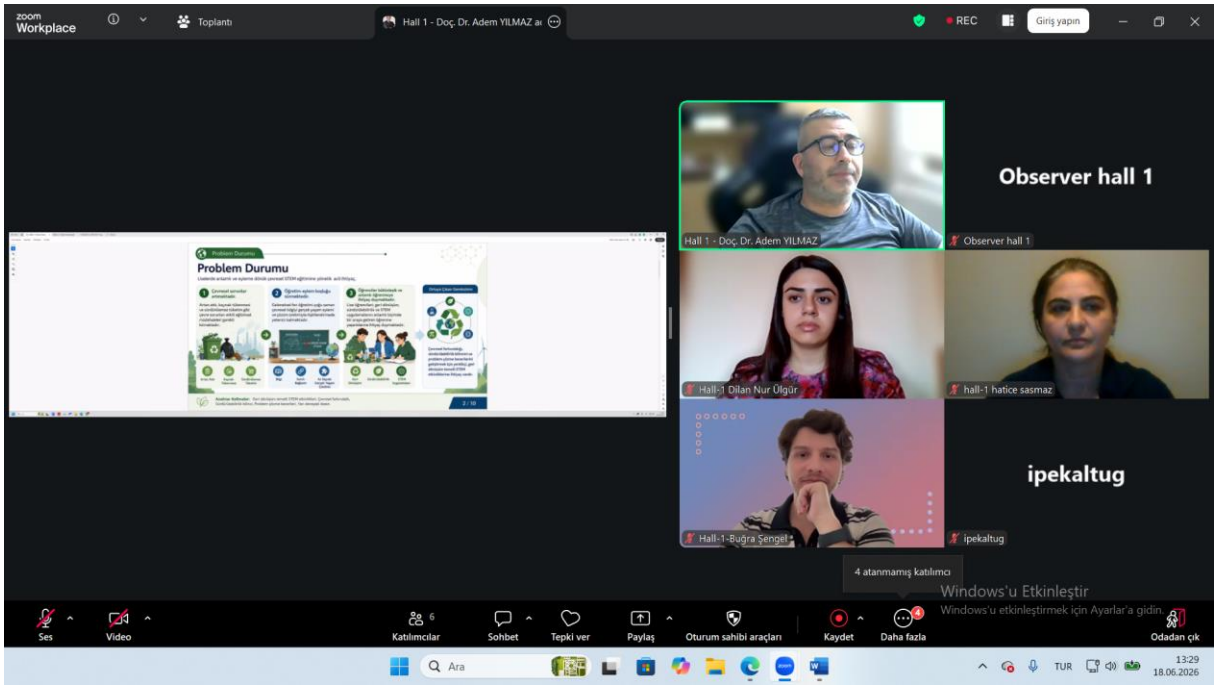


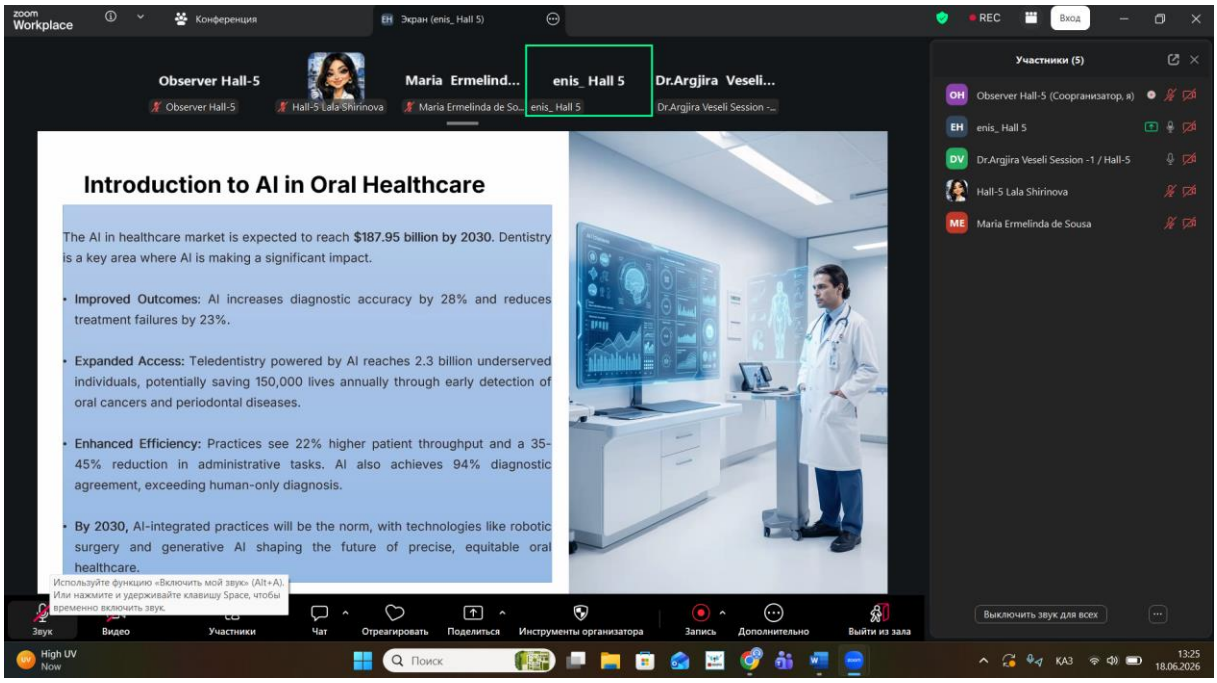


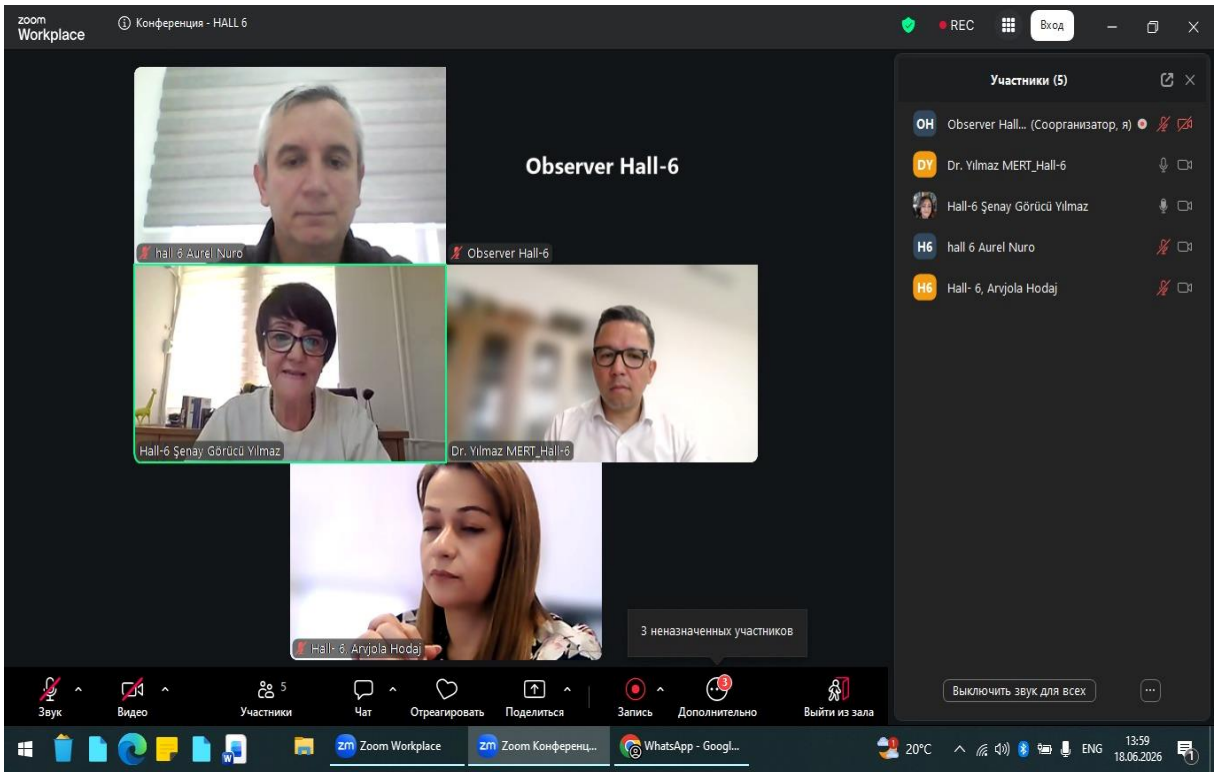


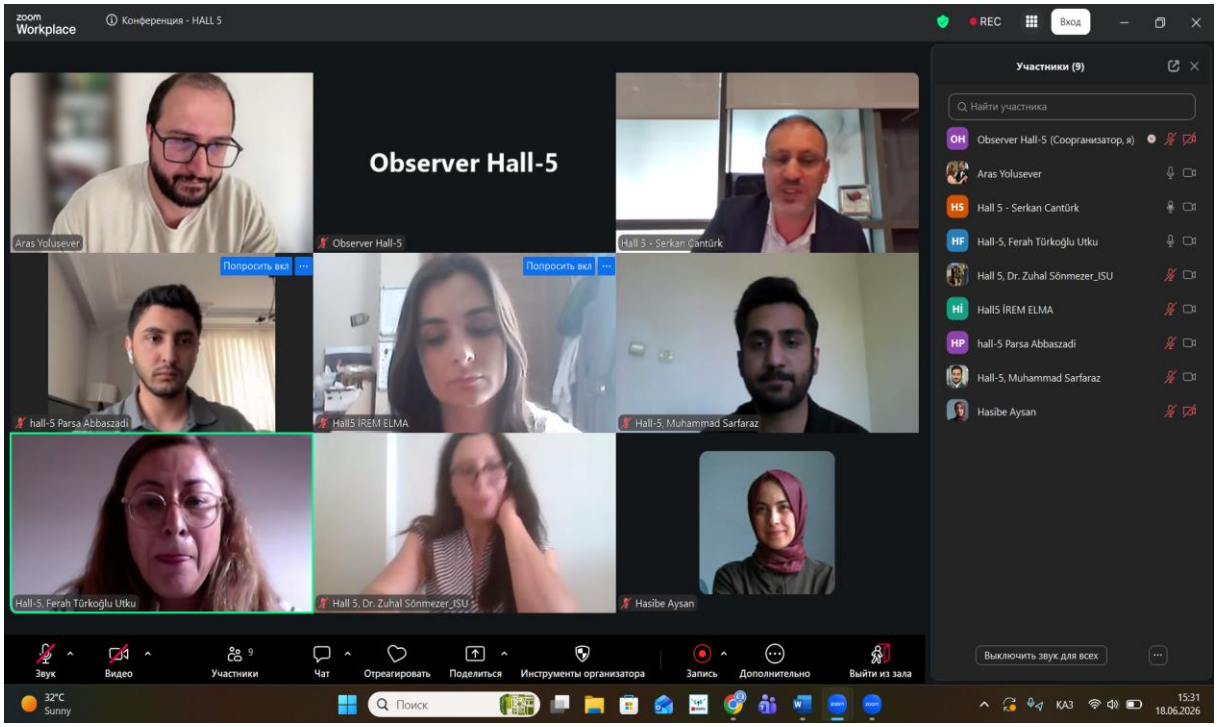


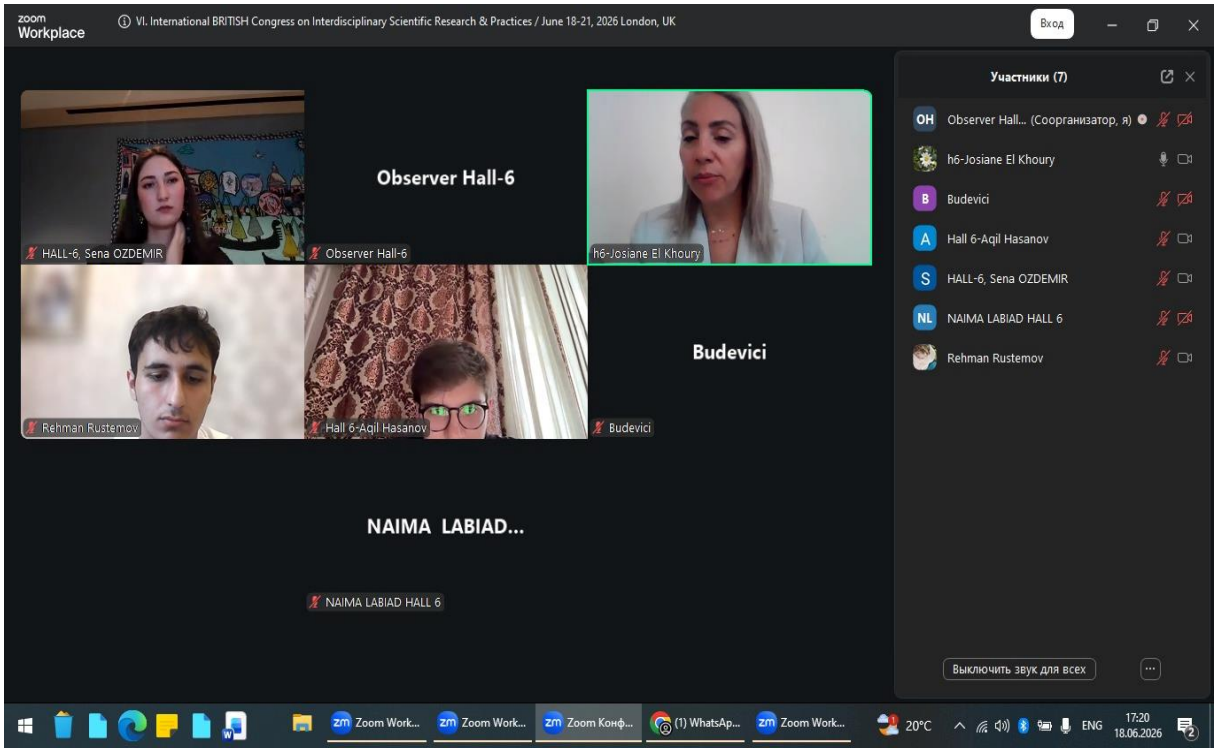

zoom Workplace
Toplantı
Hall -1 Selvihan Sarıdaş adlı kişinin...
REC
Giriş yapın
IoT Nedir?
What is the Internet of Things?
Nesnelerin İnterneti (IoT), fiziksel nesnelerin sensörler ve internet bağlantıları aracılığıyla veri topladığı, paylaştığı ve analiz ettiği bir teknoloji ekosistemidir.
The Internet of Things (IoT) is a technology ecosystem in which physical objects collect, share and analyze data through sensors and internet connectivity.
IoT'nin Temel Bileşenleri
Core Components of IoT
Sensörler
Bağlantı
Veri İşleme
Kullanıcı Arayüzü
Tarımda Kullanım Alanları
Applications in Agriculture
Toprak Nemi
Sıcaklık
Hava Koşulu
Bitki Sağlığı
IoT
app.zoom.us, ekranınızı paylaşıyor
Paylaşımı durdur
Gizle
Hall-1-Assist. Prof. Dr. Muhammed İŞCİ
Observer hall 1
Hall-1 Nurhat Baydağ
Hall-1-Assist. Prof. Dr. Mu...
Hall-1, Arzu Karataş
Hall -1 Selvihan Sarıdaş
Hall-1,Fatma N...
Hall-1,Fatma Nur Kılıçkaya
Elif Ece İŞÇİ
Hall-1, Ömer Ka...
Hall-1, Ömer Kasımoğlu
Berat Yıldırım Hall-1
Hall-1 Şerife Eroğlu
Hall-1-Dr. Şükrü Mustafa ...
5 atanmamış katılımcı
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Kaydet
Daha fazla
Odadan çık
Ara
TUR
11:00
18.06.2026

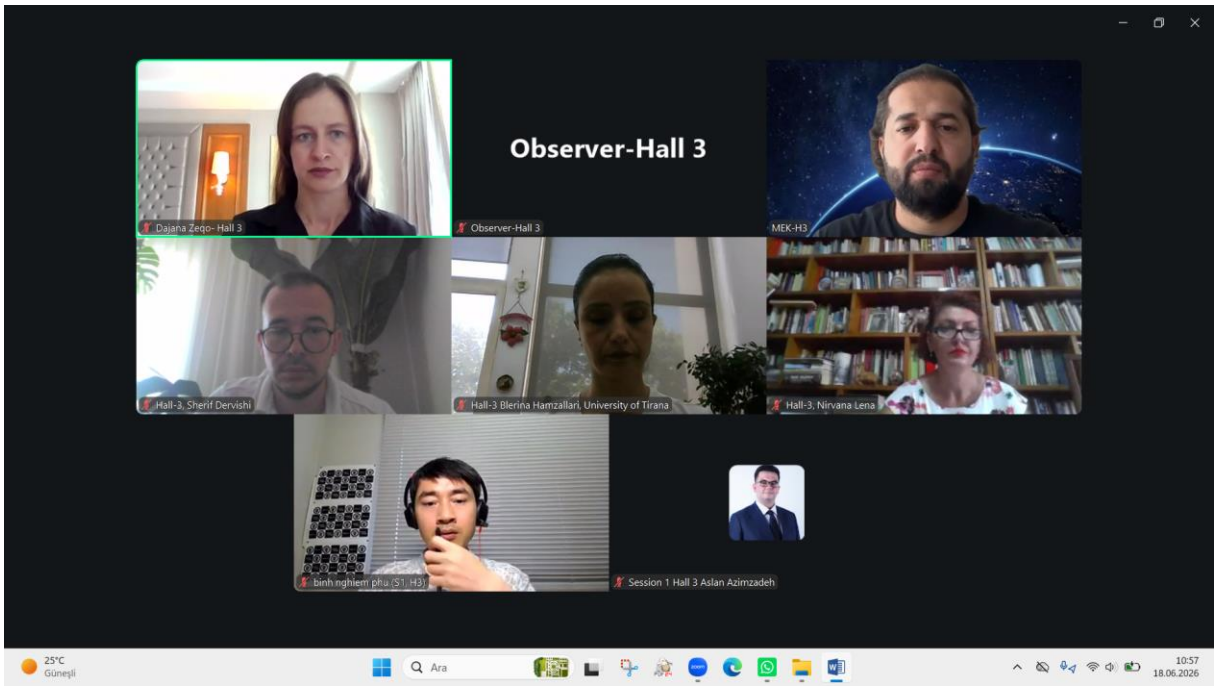

zoom Workplace
Toplantı
Hall 1 - Doç. Dr. Adem YILMAZ ...
REC
Giriş yapın
Problem Durumu
Observer hall 1
Hall 1 - Doç. Dr. Adem YILMAZ
Observer hall 1
Hall-1 Dilan Nur Ülgür
hall-1 hatice sasmaz
ipekaltug
Hall-1-Buğra Şengel
ipekaltug
4 atanmamış katılımcı
Windows'u Etkinleştir
Windows'u etkinleştirmek için Ayarlar'a gidin.
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Kaydet
Daha fazla
Odadan çık
Ara
TUR
13:29
18.06.2026


Observer Hall-5
Maria Ermelind...
enis_ Hall 5
Dr.Argjira Veseli...
Introduction to AI in Oral Healthcare
The AI in healthcare market is expected to reach $187.95 billion by 2030. Dentistry is a key area where AI is making a significant impact.
Improved Outcomes: AI increases diagnostic accuracy by 28% and reduces treatment failures by 23%.
Expanded Access: Teledentistry powered by AI reaches 2.3 billion underserved individuals, potentially saving 150,000 lives annually through early detection of oral cancers and periodontal diseases.
Enhanced Efficiency: Practices see 22% higher patient throughput and a 35-45% reduction in administrative tasks. AI also achieves 94% diagnostic agreement, exceeding human-only diagnosis.
By 2030, AI-integrated practices will be the norm, with technologies like robotic surgery and generative AI shaping the future of precise, equitable oral healthcare.
Участники (5)
Observer Hall-5 (Соорганизатор, я)
enis_ Hall 5
Dr.Argjira Veseli Session -1 / Hall-5
Hall-5 Lala Shirinova
Maria Ermelinda de Sousa


Observer Hall-6
hall 6 Aurel Nuro
Observer Hall-6
Hall-6 Şenay Görücü Yılmaz
Dr. Yilmaz MERT_Hall-6
Hall- 6, Arvjola Hodaj
3 неназначенных участников
Участники (5)
Observer Hall... (Соорганизатор, я)
Dr. Yilmaz MERT_Hall-6
Hall-6 Şenay Görücü Yılmaz
hall 6 Aurel Nuro
Hall- 6, Arvjola Hodaj

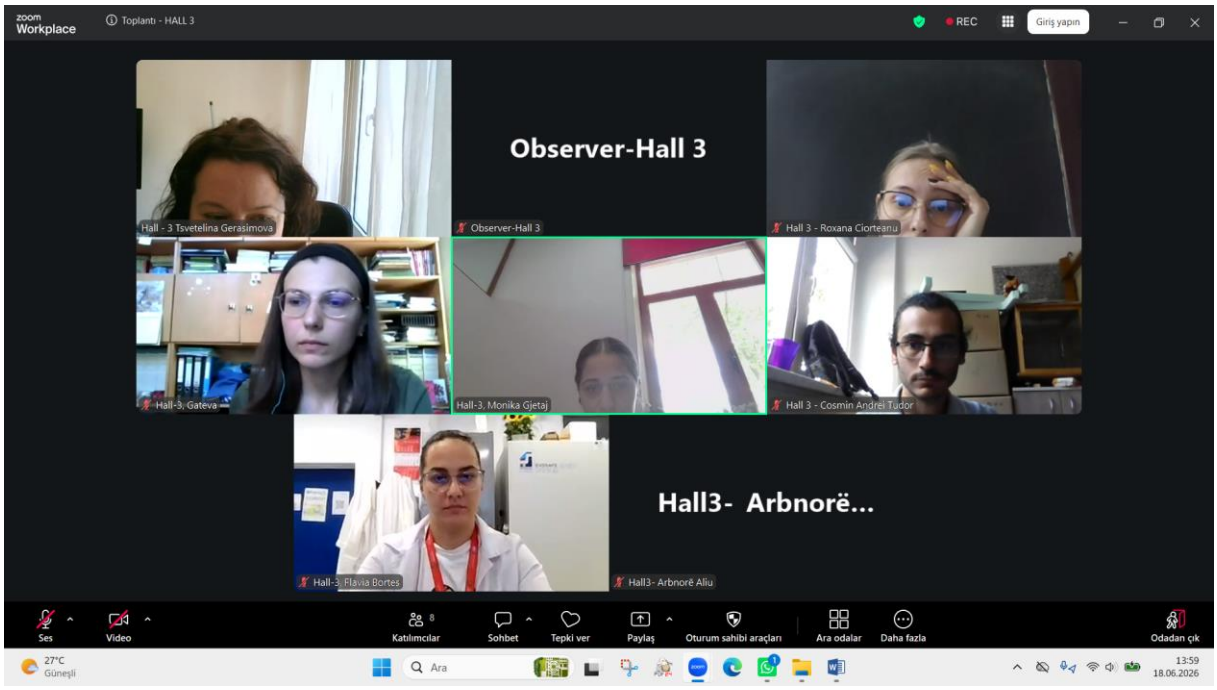

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Конференция - HALL 5
REC
Вход
Observer Hall-5
Участники (9)
Найти участника
Observer Hall-5 (Соорганизатор, я)
Aras Yolusever
Hall 5 - Serkan Cantürk
Hall-5, Ferah Türkoğlu Utku
Hall 5, Dr. Zuhal Sönmezer_ISU
HallS İREM ELMA
hall-5 Parsa Abbaszadi
Hall-5, Muhammad Sarfaraz
Hasibe Aysan
Попросить вкл
Звук
Видео
Участники
Чат
Отреагировать
Поделиться
Инструменты организатора
Запись
Дополнительно
Выйти из зала
Выключить звук для всех
32°C
Sunny
Поиск
15:31
18.06.2026

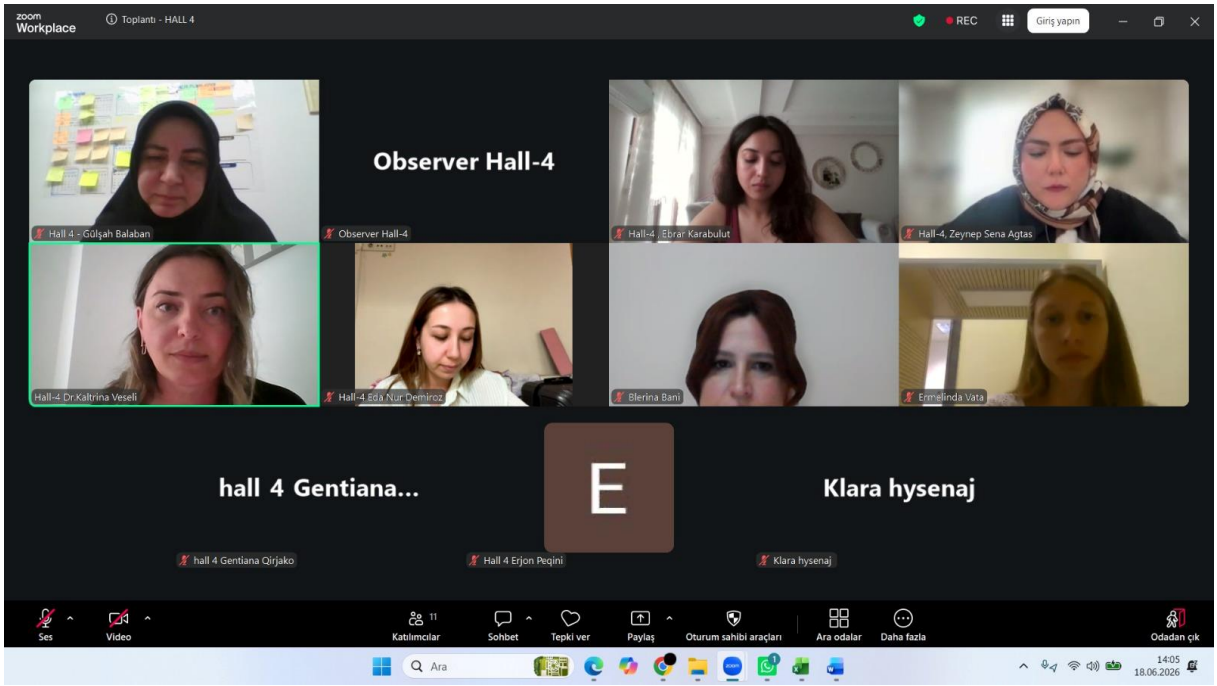

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VI. International BRITISH Congress on Interdisciplinary Scientific Research & Practices / June 18-21, 2026 London, UK
Вход
Observer Hall-6
HALL-6, Sena OZDEMIR
h6-Josiane El Khoury
Budevici
Rehman Rustemov
Hall 6-Aqil Hasanov
NAIMA LABIAD...
NAIMA LABIAD HALL 6
Участники (7)
Observer Hall... (Соорганизатор, я)
h6-Josiane El Khoury
Budevici
Hall 6-Aqil Hasanov
HALL-6, Sena OZDEMIR
NAIMA LABIAD HALL 6
Rehman Rustemov
Выключить звук для всех
Zoom Work...
Zoom Work...
Zoom Конф...
(1) WhatsAp...
Zoom Work...
20°C
ENG
17:20
18.06.2026





PROCEEDINGS BOOK


Toplantı - HALL 3
REC
Giriş yapın
Observer-Hall 3
Hall - 3 Tsvetelina Gerasimova
Observer-Hall 3
Hall 3 - Roxana Ciorteanu
Hall-3, Gateva
Hall-3, Monika Gjetaj
Hall 3 - Cosmin Andrei Tudor
Hall-3, Flavia Bortes
Hall3- Arbnorë...
Hall3- Arbnorë Aliu
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık


Toplantı - HALL 4
REC
Giriş yapın
Observer Hall-4
Hall 4 - Gülşah Balaban
Observer Hall-4
Hall-4 ,Ebrar Karabulut
Hall-4, Zeynep Sena Agtas
Hall-4 Dr.Kaltrina Veseli
Hall-4 Eda Nur Demiroz
Blerina Bani
Ermelinda Vata
hall 4 Gentiana...
E
Klara hysenaj
hall 4 Gentiana Qirjako
Hall 4 Erjon Peqini
Klara hysenaj
Ses
Video
Katılımcılar
Sohbet
Tepki ver
Paylaş
Oturum sahibi araçları
Ara odalar
Daha fazla
Odadan çık

VI. International

BRITISH

Congress on Interdisciplinary Scientific Research & Practices

June 18-21, 2026
London, UK

FACE TO FACE CONGRESS PROGRAM

VENUE

United Kingdom Supreme Court
Parliament Sq, London SW1P 3BD, United Kingdom



IN PERSON PRESENTATIONS

United Kingdom Supreme Court
Parliament Sq, London SW1P 3BD, United Kingdom

19.06.2026

Time	Title	Author/Presenter	Affiliation
Moderator: David John WORTLEY			
14:00-14:15	REIMAGINING PUBLIC HEALTH: INTEGRATING LIFESTYLE MEDICINE INTO NEIGHBOURHOOD WELLBEING CENTRES	**David John WORTLEY**	World Lifestyle Medicine Education Services, London, UK
14:15-14:30	DYNAMIC ASSESSMENT OF ELECTROLYSER TECHNOLOGIES UNDER INTERMITTENT RENEWABLE ENERGY	**Ibrahim NACHIT**	Laboratory of Renewable Energy and Dynamic of Systems, Morocco
14:30-14:45	ARTIFICIAL INTELLIGENCE IN AIRCRAFT MAINTENANCE: A BIBLIOMETRIC ANALYSIS	**Lect. Rafet ERTEKİN**	Istanbul Okan University, Türkiye
14:45 – 15:00	REFRESHMENT BREAK		
15:00 – 15:15	INTEGRATING THINKING SKILLS INSTRUCTION INTO LESSON PLANS: A CASE STUDY OF PRESERVICE TEACHERS	**Assist. Prof. Ayşegül KARABAY TURAN**	Cukurova University, Türkiye
15:15-15:30	LEGITIMACY FOR INSTITUTIONAL CORRUPTION: NORMALIZED CORRUPTION AND INSTRUMENTALISM	**Shlomo Mizrahi**	University of Haifa, Israel
15:30-15:45	EXPLAINABLE ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE HYDROGEN STORAGE MATERIALS	**El Majdouli Khaoula Chafi Mohammed**	Hassan II University of Casablanca, Morocco
15:45 – 16:00	CERTIFICATE CERAMONY		

VI. International

BRITISH

Congress on Interdisciplinary Scientific Research & Practices

June 18-21, 2026

London, UK

CONGRESS PROGRAM

Meeting ID: 862 1528 3413

Passcode: 181920

https://us02web.zoom.us/j/86215283413?pwd=C5hbOQCz7JlZjuj1LGGiPCVogOh6Gh.1

PARTICIPANT COUNTRIES (25):

UK, Türkiye, Azerbaijan, Albania, Romania, Portugal, Vietnam, TRNC, Nigeria, North Macedonia, Bulgaria, Italy, Morocco, Canada, Pakistan, USA, Republic of Kosovo, Croatia, Israel, Lebanon, Slovakia, India, Moldova, Japan, Georgia

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- ✓ Kongremizde Yazım Kurallarına uygun gönderilmiş ve bilim kurulundan geçen bildiriler için online (video konferans sistemi üzerinden) sunum imkanı sağlanmıştır.
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- ✓ Uygulama tablet, telefon ve PC'lerde çalışıyor.
- ✓ Her oturumdaki sunucular, sunum saatinden 15 dk öncesinde oturuma bağlanmış olmaları gerekmektedir.
- ✓ Tüm kongre katılımcıları canlı bağlanarak tüm oturumları dinleyebilir.
- ✓ Moderatör – oturumdaki sunum ve bilimsel tartışma (soru-cevap) kısmından sorumludur.

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- ✓ The application works on tablets, phones and PCs.
- ✓ The participant must be connected to the session 15 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.
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- ✓ 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. Hall-1, Awais Khan

Meeting ID: 862 1528 3413
Passcode: 181920

Session -1 / Hall-1
18.06.2026
Moderator: Assist. Prof. Dr. Muhammed İŞCİ
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 09:00-11:00
Ankara Local Time: 11:00-13:00

TITLE	AUTHOR(S)	AFFILIATION
DEEP LEARNING-BASED IMAGE ANALYSIS FOR IoT-ENABLED SMART AGRICULTURE SYSTEMS	Selvihan SARIDAŞ Şükrü Mustafa KAYA	Istanbul Aydin University, Türkiye
TOWARD ROBUST FAKE REVIEW DETECTION IN TURKISH E-COMMERCE: A MULTI-SOURCE SYNTHETIC DATA FRAMEWORK	Arzu KARATAŞ Ramin ABBASZADI	OSTİM Technical University, Türkiye
DEEP LEARNING-BASED WATER AREA SEGMENTATION AND WATER COVERAGE RATIO ANALYSIS IN SATELLITE IMAGES	Fatma Nur KILIÇKAYA Murat TAŞYÜREK Celal ÖZTÜRK	Kayseri University, Türkiye Erciyes University, Türkiye
BIOMETRIC VOICE AUTHENTICATION AND AI-BASED DEEPFAKE VOICE DETECTION	Bengisu BAHÇİVAN Kübra DEMİR Ömer KASIMOĞLU Zainab Alaa KAMAL Ramin ABBASZADİ	OSTIM Technical University, Türkiye
DESIGN AND IMPLEMENTATION OF AN INTEGRATED CALENDAR, TASK, NOTE, AND RESPONSIBILITY MANAGEMENT APPLICATION: ZAMAN SAYAR	Samed Alp ARSLAN	Ostim Technical University, Türkiye
BEYOND TRIAL-AND-ERROR: AUTOMATING FSS INVERSE DESIGN VIA CONDITIONAL GENERATIVE ADVERSARIAL NETWORKS	Salih BAĞCI Şerife EROĞLU Ayşegül KARTAL Elif Ece İŞÇİ	OSTIM Technical University, Türkiye
A PROPOSAL FOR A SECURE AND OBSERVABLE MICROSERVICES ARCHITECTURE FOR AI-POWERED E-COMMERCE APPLICATIONS	Onur POLAT Nurhat BAYDAĞ Esra SÖĞÜT	Bingöl University, Türkiye Gazi University, Türkiye
DESIGN AND IMPLEMENTATION OF A CULTURALLY GROUNDED, COGNITIVELY AWARE, AND CAUSALLY HONEST HYBRID RETAIL RECOMMENDATION SYSTEM: Seyr-i Öneri	Samed Alp ARSLAN	Ostim Technical University, Türkiye
A COMPARATIVE REVIEW OF TRANSFORMER-BASED NAMED ENTITY RECOGNITION MODELS FOR DOMAIN-SPECIFIC OPERATIONAL TEXT ANALYTICS	Pınar ERSOY Mustafa ERŞAHİN	Department of Research & Development, Commencis, Türkiye
COMPARATIVE DEEP LEARNING-BASED FAULT DIAGNOSIS OF A TWO-STAGE GEARBOX USING VIBRATION DATA	Muhammed İŞCİ Berat YILDIRIM	Kayseri University, Türkiye

All participants must join the conference 10 minutes before the session time.
Every presentation should last not longer than 10-12 minutes.
Kindly keep your cameras on till the end of the session.

Session -1 / Hall-2
18.06.2026
Moderator: Prof. Dr. Gülden TÜM
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 09:00-11:00
Ankara Local Time: 11:00-13:00

TITLE	AUTHOR(S)	AFFILIATION
FROM GRAMMAR TO GRAMMARING: RECONCEPTUALIZING LANGUAGE COMPETENCE IN AI-MEDIATED ELT	Faris HOCAOĞLU Nermin GÖKEL Gülden TÜM	MEB, Türkiye Çukurova University, Türkiye
RECONFIGURING PEDAGOGICAL AUTHORITY IN AI-MEDIATED LANGUAGE EDUCATION	Nermin GÖKEL Gülden TÜM Faris HOCAOĞLU	MEB, Türkiye Çukurova University, Türkiye
URBAN LABYRINTHS AND FRACTURED SELVES: PSYCHOLOGICAL TRANSFORMATIONS AND SPATIAL LOGIC IN ARAVIND ADIGA'S URBAN FICTION	Sunita Chauhan Harsha Vincent	Lovely Professional University, Phagwara, Punjab, India
ALBANIAN TEACHERS'PERSPECTIVE ON CLASSROOM LIGHTING AND READING COMPREHENSION	Irini Arapi Eftimi Sylari	University of Tirana, Albania
DOES SOCIAL MEDIA CHALLENGE BEHAVIORISM? EXPLORING LEARNER AUTONOMY AND ACTIVE PARTICIPATION AMONG EFL STUDENTS	Haytham Elaoufy	Applied Linguistics, Morocco
AI COMPETENCE OF EDUCATIONAL INSTITUTION LEADERS: HISTORICAL CONSCIOUSNESS, STRATEGIC DECISION-MAKING AND THE FUTURE OF SCHOOL GOVERNANCE	Enkelejda Billa	"Ismail Qemali" University, Albania
CRITICAL ANALYSIS OF VARIOUS FORMS OF TRAUMA IN PLAYGROUND BY RICHARD POWERS	Mukesh Kumar Sharanpal Singh	Lovely Professional University, Punjab
INTERACTIVE TEACHING AS A TOOL FOR FOSTERING CREATIVE THINKING IN PRIMARY CLASSROOMS	Narmin Cabbarlı	Azerbaijan University of Languages, Azerbaijan
RECOGNITION AND PRODUCTION OF IDIOMS AND COLLOCATIONS AMONG ALBANIAN SECONDARY SCHOOL STUDENTS	Elsuida HANI	University of Tirana, Albania

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Session -1 / Hall-3
18.06.2026
Moderator: Dr. Nirvana Lena
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 09:00-11:00
Ankara Local Time: 11:00-13:00

TITLE	AUTHOR(S)	AFFILIATION
A SOCIO-PSYCHOLOGICAL STUDY ON THE REALITY OF SECTARIANIZATION	Mehmet Emin KALGI	Ardahan University
VISITOR PERCEPTION OF AUGMENTED REALITY'S VALUES AT CASTLES IN JAPAN	Bình Nghiêm-Phú	University of Hyogo,Japan
EXPOSURE OF YOUNG PEOPLE TO VIOLENT EXTREMISM IN THE SPACE OF VIRTUAL INTERACTION	Blerina Hamzallari Rudina Rama	University of Tirana, Albania
A RANGE OF STUDENTS' PERCEPTIONS OF THE POTENTIAL IMPACTS OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES: A SOCIOLOGICAL ANALYSIS	Sherif Dervishi	University of Tirana, Tirana, Albania
ASSESSMENT OF STUDIES ON SOCIAL MOBILITY IN ALBANIA: THE NEED FOR CONSIDERATION OF INTERGENERATIONAL SOCIAL MOBILITY	Blerina Hamzallari Dajana Zeqo	University of Tirana, Albania
PASQYRA SHQIPTARE: 23 YEARS OF ETHNIC MEDIA IN CANADA: IDENTITY, TRANSNATIONALISM AND DIGITAL ADAPTATION	Nirvana Lena	University "Aleksander Xhuvani", Albania
THE INTERNAL OTHER: IMAGOLOGY AND THE CONSTRUCTION OF SELF-IMAGE IN SOCIALIST REALISM	Armand Bora	European University of Tirana
INDIAN DIASPORA ABROAD: A STUDY OF THE POLITICAL AND ECONOMIC STRUGGLE, ACHIEVEMENTS AND CONTRIBUTIONS OF THE INDIAN DIASPORA IN ZIMBABWE AND ZAMBIA	Dr. Sasmita Mohanty	University of Delhi, India
HEALTH EXPENDITURE AND ARTIFICIAL INTELLIGENCE READINESS: A GLOBAL PERSPECTIVE	Maryam Alili Aslan Azimzadeh	Secondary School No. 9, Baku, Azerbaijan Odlar Yurdu University, Baku, Azerbaijan

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Session -1 / Hall-4
18.06.2026
Moderator: Assist. Prof. Dr. Seniha DAL
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 09:00-11:00
Ankara Local Time: 11:00-13:00

TITLE	AUTHOR(S)	AFFILIATION
MED-ARB: AN EVALUATION OF A HYBRID DISPUTE RESOLUTION METHOD	Özlem BORA Hasan Ali Güçlü	Ondokuz Mayıs University, Türkiye Ufuk University, Türkiye
IS REALISM SUCCESSFUL IN EXPLAINING CHANGE IN INTERNATIONAL RELATIONS?	Kadir DUVAN	İstanbul Sabahattin Zaim University, Türkiye
THE LEGAL LIABILITY OF BOARD MEMBERS OF JOINT-STOCK COMPANIES UNDER TURKISH LAW STEMMING FROM THE PERSONAL DATA PROTECTION LAW	Seniha DAL	Marmara University, Türkiye
PROBLEMATIC OF THE RIGHT TO LIFE IN THE MOTHER-FETUS RELATIONSHIP	Z. Gönül BALKIR Tuba KUTOĞLU Yağmur KAYA	Cyprus Aydın University, TRNC
MORALLY DEFENSIBLE VOLUNTARY TERMINATION OF PREGNANCY	Z. Gönül BALKIR Tuba KUTOĞLU Yağmur KAYA	Cyprus Aydın University, TRNC
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Session -1 / Hall-5
18.06.2026
Moderator: Dr. Melikova L. A.
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 09:00-11:00
Ankara Local Time: 11:00-13:00

TITLE	AUTHOR(S)	AFFILIATION
CLASSICAL MYELOPROLIFERATIVE NEOPLASMS IN BONE MARROW BIOPSIES: A PATHOLOGY-BASED STUDY	Ejona Çeliku Majlinda Kokiçi Majlinda Ikonomi Ilda Mano Irda Rrugeja Siltana Zenelaj	Mother Teresa University Hospital, Tirana, Albania
FUNCTIONAL STATUS IN PATIENTS HOSPITALISED IN A VASCULAR SURGERY UNIT RECEIVING REHABILITATION NURSING CARE	Maria Ermelinda de Sousa	Escola Superior de Enfermagem São José de Cluny, Madeira
RECONSTRUCTION USING A FREE FIBULA FLAP AFTER MANDIBULAR RESECTION: SURGICAL STRATEGY AND PERIOPERATIVE MANAGEMENT (Clinical Case)	Mahammad Davudov Abdullayev Kamil Elchin Mammadov Namazova Kamala Abasov Valijan Aliyeva Ramila Bandi Nahid Dadashova Munevver	Azerbaijan State Advanced Training Institute for Doctors named after A. Aliyev Scientific Surgery Center named after Academician M. A. Topchubashov
SERIAL PLASMA CELL-FREE DNA MONITORING AND PCR-BASED MICROSATELLITE INSTABILITY PROFILING IN RESECTED STAGE I–II COLON CANCER	Dr. Melikova L. A.	National Oncology Centre, Azerbaijan
SHAPING THE FUTURE OF ORAL HEALTHCARE USING ARTIFICIAL INTELLIGENCE	Enis Veseli	University of Prishtina, Prishtina, Kosovo
BARRIERS TO DENTAL CARE ACCESS IN PRESCHOOL CHILDREN WITH AUTISM SPECTRUM DISORDER	Argjira Veseli Lul Raka Ivana Čuković-Bagić	University of Zagreb, Zagreb, Croatia Alma Mater Europaea Campus College Rezonanca, Republic of Kosovo University of Prishtina, Republic of Kosovo

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Session -1 / Hall-6
18.06.2026
Moderator: Prof. Dr. Şenay GÖRÜCÜ YILMAZ
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 09:00-11:00
Ankara Local Time: 11:00-13:00

TITLE	AUTHOR(S)	AFFILIATION
COMPARATIVE IN SILICO ADME PROFILING AND DRUG SIMILARITY ASSESSMENT OF SELECTED NSAID DRUGS	Yılmaz MERT Osman ÇAYLAK	Sivas University of Science and Technology, Turkiye Sivas Cumhuriyet University, Turkiye
IN SILICO DESIGN, CODON OPTIMIZATION, AND OFF-TARGET PREDICTION OF A MERCURY-INDUCIBLE SYNTHETIC OPERON	Şenay GÖRÜCÜ YILMAZ	Gaziantep University, Türkiye
PATIENT AND PROVIDER PERSPECTIVES ON HEART FAILURE MANAGEMENT IN EMERGENCY DEPARTMENTS IN PUNJAB, PAKISTAN: A QUALITATIVE STUDY	Zunaira Aziz Rubina Barolia Pammla Petrucka Nadeemullah Khan Rana Altaf Ahmad Zara Aziz	AKU Pakistan University of Saskatchewan, Canada Mukhtar A. Sheikh Hospital, Pakistan
REHABILITATION FOR ADOLESCENT IDIOPATHIC SCOLIOSIS DURING GROWTH	PhD(c)Perli Rusi Prof Dr Agron Kasa Prof Asoc Rigerta Selenica PhD(c)Olsa Meta MSc Silvio Selfo	Hospital University of Trauma, Physiotherapy, Tirana, Albania Sports University of Tirana,Albania Albanian Scoliosis Spine Clinic,Tirana, Albania
GALENIC COMPOUNDING PRACTICES IN ALBANIAN COMMUNITY PHARMACIES: A CROSS-SECTIONAL SURVEY	Arvjola Hodaj Glori Kamberi Massimo Franco	Catholic University “Our Lady of Good Counsel”, Albania Pharmacist, Tiranë, Albania. University of Bari Aldo Moro, Italy
PHARMACEUTICAL COMPOUNDS IN TIRANA RIVER	Aurora Napuce Kleva Shpati Aida Dama Aurel Nuro Bledar Myrtaj Elvin Como Albana Hasimi Gazmir Cela	Albanian University, Tirana, Albania University of Tirana, Tirana, Albania

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Session -2 / Hall-1
18.06.2026
Moderator: Assoc. Prof. Dr. Adem YILMAZ
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 11:30-13:30
Ankara Local Time: 13:30-15:30

TITLE	AUTHOR(S)	AFFILIATION
THE EFFECT OF RECYCLING-BASED STEM ACTIVITIES ON HIGH SCHOOL STUDENTS' ENVIRONMENTAL AWARENESS, SUSTAINABILITY CONSCIOUSNESS, AND PROBLEM-SOLVING SKILLS: A QUASI-EXPERIMENTAL STUDY	Adem YILMAZ Suzan AVANOĞLU	Kastamonu University, Türkiye
THE RELATIONSHIP BETWEEN DIGITAL WASTE AWARENESS AND DIGITAL ADDICTION AMONG UNIVERSITY STUDENTS	Adem YILMAZ	Kastamonu University, Türkiye
FROM STRUCTURE TO DIFFÉRANCE: DECENTRING THE SUBJECT IN STRUCTURALIST AND POST-STRUCTURALIST THEORY	Buğra ŞENGEL	Ankara Hacı Bayram Veli University, Ankara, Türkiye
INNOVATIVE TEACHING STRATEGIES IN CONTEMPORARY ENGLISH LANGUAGE CLASSROOMS	Gulgun Novruzova	Azerbaijan University of Languages, Baku, Azerbaijan
POLITICAL FRACTURES AND THEIR RELATIONSHIP WITH THEATRE: A COMPARISON BETWEEN THE AUSTRALIAN FEDERATION AND THE REPUBLIC OF TURKIYE	Hatice ŞAŞMAZ	Duzce University, Turkey The University of Sydney, Australia
THE ROLE OF WESTERN EUROPEAN LITERATURE IN THE FORMATION OF THE HISTORICAL TURKISH NOVEL GENRE	Turkan Aliyeva	Azerbaijan University of Languages, Azerbaijan
THE IDEOLOGICAL AND FORMAL TRANSFORMATION OF THE MONUMENT IN PUBLIC SPACE: FROM 19th-CENTURY NATION-STATE REPRESENTATION TO 20th-CENTURY MODERNIST SCULPTURE	Dilan Nur ÜLGÜR Hatice SÖNMEZ TÜREL Emine MALKOÇ TRUE İpek ALTUĞ TURAN	Ege University, Türkiye

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Session -2 / Hall-2
18.06.2026
Moderator: Prof. Dr. Zeynep Birsu ÇİNÇİN
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 11:30-13:30
Ankara Local Time: 13:30-15:30

TITLE	AUTHOR(S)	AFFILIATION
AI-BASED CRIME AND TERRORISM PREDICTION: A SYSTEMATIC LITERATURE REVIEW	Durmus KEYIK Fatih Vehbi CELEBI	Yildirim Beyazit University, Türkiye
A COMPARATIVE BENCHMARK OF DEEP LEARNING AND CLASSICAL MACHINE LEARNING MODELS FOR CRIME AND TERRORISM PREDICTION WITH EXPLAINABLE AI ANALYSIS	Durmus KEYIK Fatih Vehbi CELEBI	Yildirim Beyazit University, Türkiye
RETHINKING PROTEIN–PROTEIN INTERACTION PREDICTION UNDER INDUCTIVE EVALUATION	Etibar Vazirov Mehrin Mustafazade Tunjay Akbarli	ADA University, Azerbaijan Secondary School No. 229, Baku, Azerbaijan Secondary School No. 1 named after Ilgar Ibrahimov, Salyan, Azerbaijan
EXPLAINABLE ARTIFICIAL INTELLIGENCE DEFINES TRANSCRIPTOMIC ARCHITECTURES OF COLORECTAL CANCER USING OPEN GENOMIC DATA	Bengisu ARSLANTAŞ Bosko NELKOSKI Zeynep Birsu ÇİNÇİN	ADAM European Institute for Lifelong Learning, North Macedonia University of Insurance and Finance (VUZF University), Sofia, Bulgaria
ARTIFICIAL INTELLIGENCE-DRIVEN PREDICTIVE DECISION SUPPORT SYSTEMS FOR STRATEGIC RESILIENCE IN SMALL AND MEDIUM-SIZED ENTERPRISES	Bosko NELKOSKI	ADAM European Institute for Lifelong Learning, North Macedonia University of Insurance and Finance (VUZF University), Sofia, Bulgaria
PREDICTING USER SENTIMENT FROM MOBILE BANKING EXPERIENCE DIMENSIONS: A MULTILINGUAL NLP STUDY OF RAIFFEISEN BANK REVIEWS IN ALBANIA AND KOSOVO	Markela Muça Bora Lamaj Klodiana Bani	University of Tirana, Albania "Aleksander Moisiu", University of Durres, Albania
GRAPH-BASED MODELING OF HOSPITAL READMISSION RISK USING CLINICALLY-INFORMED PATIENT NETWORKS	Etibar Vazirov Nazrin Mustafazade Huseyn Aslan	ADA University, Azerbaijan Koç University, Türkiye Ankara Medipol University, Türkiye
AUTOMATION OF DATA ANALYSIS USING SQL AND BUSINESS INTELLIGENCE (BI) TECHNOLOGIES	Elza Bitsadze Lia janadze Nana oniani-saghinadze Anastasia Vardosanidze	Akaki Tsereteli State University, Georgia
AI-BASED STUDENT PERFORMANCE PREDICTION SYSTEMS USING MACHINE LEARNING	Nail Mammadov Firangiz Mahmarzayeva	Azerbaijan State Economy University, Baku, Azerbaijan. The Academy of Public Administration Under the Republic of Azerbaijan, Baku, Azerbaijan. Secondary School No. 100, Baku, Azerbaijan

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Session -2 / Hall-3
18.06.2026
Moderator: PhD. Tsvetelina Gerasimova
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 11:30-13:30
Ankara Local Time: 13:30-15:30

TITLE	AUTHOR(S)	AFFILIATION
ENVIRONMENTAL IMPACT ASSESSMENT THROUGH PHYSICO-CHEMICAL AND BIOLOGICAL ANALYSES OF WASTEWATER AND INDUSTRIAL WASTE FROM THE ARTANË MINE, ARTANË MUNICIPALITY	Skender Demaku Donika Sylejmani Arbnorë Aliu Vjollca Berisha Jetë Maliqi	University of Prishtina
CYTOGENETIC ANALYSIS OF CYTOTOXIC AND GENOTOXIC EFFECT OF ROSA GALLICA L. HYDROSOL OBTAINED BY WATER-STEAM DISTILLATION ON IN VIVO TEST-SYSTEM	Tsvetelina Gerasimova Svetla Gateva Gabriele Jovchev Elena Chayleva Ana Dobreva Milka Mileva	Institute of Biodiversity and Ecosystem Research, Bulgaria Institute for Roses and Aromatic Plants, Bulgaria The Stephan Angeloff Institute of Microbiology, Bulgaria
ACUTE AND SUB-CHRONIC TOXICOLOGICAL ASSESSMENT OF METHANOLIC LEAF EXTRACT OF GOSSYPIUM HIRSUTUM: BIOCHEMICAL, HEMATOLOGICAL, AND HISTOPATHOLOGICAL STUDIES IN WISTAR RATS	Sheriff Itopa Umar Maruf Olaide Yekeen	Federal Polytechnic Ile-Oluji, Nigeria Morgan State University, USA
MULTIVARIATE ANALYSIS AND PROBABILISTIC PREDICTION OF CRUDE OIL PRODUCTION: A CASE STUDY OF THE GORISHT OILFIELD, ALBANIA	Enkela Karroçi Monika Gjetaj	Polytechnic University of Tirana, Albania Albanian University, Albania
HYDROGEOCHEMICAL CHARACTERIZATION OF GROUNDWATER IN A CARBONATE OIL RESERVOIR	Monika Gjetaj Enkela Karroçi	Polytechnic University of Tirana, Albania Albanian University, Albania
RAPHANUS SATIVUS UNDER DUAL CO2–O3 ABIOTIC STRESS: PHOTOSYNTHETIC PARAMETERS, VOC EMISSIONS, AND BIOCHEMICAL RESPONSES	Flavia BORTES Lucian COPOLOVICI Cristian MOISA Andreea LUPITU Dana COPOLOVICI	“Aurel Vlaicu” University of Arad, Romania
SYNTHESIS AND ANTIMICROBIAL EVALUATION OF NEW PYRROLOINDOLIZINE COMPOUNDS	Roxana Ciorteanu Ioana C. Marinas Catalina Ionica Ciobanu Ionel I. Mangalagiu Ramona Danac	Alexandru Ioan Cuza University of Iasi, Romania Research Institute of the University of Bucharest (ICUB), Romania
CHIRAL COPPER(I) N ACYLTHIOUREA COMPLEXES: FROM SYNTHESIS TO HIGH HELICAL TWISTING POWER IN NEMATIC LIQUID CRYSTALS	Cosmin A. Tudor Monica Iliş Viorel Cîrcu	University of Bucharest, Romania

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Session -2 / Hall-4
18.06.2026
Moderator: Dr. Kaltrina Veseli
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 11:30-13:30
Ankara Local Time: 13:30-15:30

TITLE	AUTHOR(S)	AFFILIATION
THE IMPACT OF INCLUSIVE BASKIN SPORT ON SOCIAL INCLUSION AND SENSE OF BELONGING AMONG PERSONS WITH DISABILITIES	Ermelinda Vata Erjon Peqini	University of "Luigj Gurakuqi", Albania
BURDEN OF COVID-19 AND MENTAL DISORDERS IN ALBANIA DURING 2020-2021	Lidra Zikaj Gentiana Qirjako	Polyclinic of Specialties No.3, Albania University of Medicine, Albania
MORTALITY AND BURDEN OF DISEASE ATTRIBUTABLE TO HIGH LDL-CHOLESTEROL LEVEL IN ALBANIA, 1990-2023	Iris Mone Genc Burazeri	University of Medicine, Tirana, Albania
PREVALENCE AND DEMOGRAPHIC DISTRIBUTION OF PSYCHOSOMATIC COMPLAINTS AMONG ALBANIAN ADOLESCENTS	Rudina Çumashi Gentiana Qirjako	Institute of Public Health, Tirana, Albania. University of Medicine, Tirana, Albania.
CHILDHOOD TRAUMA AND THE DARK TRIAD: THE MEDIATING ROLE OF ALEXITHYMIA	Gülşah BALABAN Zeynep Sena AĞTAŞ Fatma Zehra KOCAKAYA Ebrar KARABULUT Eda Nur DEMİRÖZ	İstanbul Sabahattin Zaim University, Türkiye
ASSESSMENT OF RISK FACTORS AND THE ROLE OF NURSING CARE IN PATIENTS WITH SCHIZOPHRENIA	Blerina Bani Armela Kapaj Klara Hysenaj Rezarta Stena	University of Elbasan "Aleksandër Xhuvani", Albania
RELATIONSHIP BETWEEN GOUT, URIC ACID, AND CORONARY ARTERY DISEASE	Klara Hysenaj Rezarta Stena Blerina Bani Armela Kapaj Arjana Hysenaj Elis Kokolari	University of Elbasan "Aleksandër Xhuvani"
FACIAL ASYMMETRY ACROSS DIFFERENT ANGLE MALOCCLUSIONS USING STRUCTURED LIGHT 3D SCANNING	Kaltrina Veseli	Alma Mater Rezonanca College, Prishtina, Kosovo

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Session -2 / Hall-5
18.06.2026
Moderator: Assoc. Prof. Dr. Ferah TÜRKOĞLU UTKU
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 11:30-13:30
Ankara Local Time: 13:30-15:30

TITLE	AUTHOR(S)	AFFILIATION
GREEN FINANCE IN TRANSITION: A COMPARATIVE ANALYSIS OF GREEN BONDS AND GREEN SUKUK BETWEEN TURKEY AND GLOBAL LEADERS IN THE CONTEXT OF COP31 AND TURKEY'S 2053 NET ZERO AMBITIONS	Serkan CANTÜRK	Istinye University, Turkiye
LEGAL AND FINANCIAL RISK MANAGEMENT IN INTERNATIONAL TRADE: PAYMENT METHODS	Parsa ABBASZADI Hasibe AYSAN	OSTİM Technical University, Türkiye
FROM HOMO ECONOMICUS to HOMO EVOLUTIVUS: A DYNAMICAL SYSTEMS APPROACH to MICROECONOMIC DECISION-MAKING	Aras YOLUSEVER	Istanbul Kültür University, Türkiye
THE EFFECT OF PERCEPTIONS TOWARD AUGMENTED REALITY ON PURCHASE INTENTION IN PAKISTAN: THE MEDIATING ROLE OF CONSUMER ATTITUDE	Muhammad SARFARAZ Ebru SÖNMEZ KARAPINAR	Kayseri Üniversitesi, Türkiye
RETHINKING DIGITAL SOCIOLOGY IN THE AGE OF ALGORITHMIC CULTURE: A THEORETICAL REVIEW	Zuhal SONMEZER	Istinye University, Turkey
THE SHALLOWING OF ACTIVISM IN LINK CULTURE: INSTAGRAM'S "ADD YOURS" FEATURE AND SLACKTIVISM	Zuhal SONMEZER	Istinye University, Turkey
THE IMPACT OF SOCIAL MEDIA ADDICTION ON CONSPICUOUS CONSUMPTION BEHAVIOR: THE MEDIATING ROLE OF SOCIAL COMPARISON	İrem ELMA Ebru SÖNMEZ KARAPINAR	Kayseri Üniversitesi, Türkiye
MINORITY SHAREHOLDERS CALLING THE GENERAL ASSEMBLY OF JOINT STOCK COMPANY TO MEETING AND APPOINTMENT OF A TRUSTEE TO THE COMPANY	Ferah TÜRKOĞLU UTKU	Marmara University, Türkiye
DISCHARGE OF LIABILITY CASE IN JOINT STOCK COMPANIES AND TRUSTEE APPOINTMENT IN DISCHARGE CASES	Ferah TÜRKOĞLU UTKU	Marmara University, Türkiye

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Session -2 / Hall-6
18.06.2026
Moderator: Assoc. Prof. Dr. Josiane El Khoury
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 11:30-13:30
Ankara Local Time: 13:30-15:30

TITLE	AUTHOR(S)	AFFILIATION
MOBILE NOTIFICATIONS AND USER EXPERIENCE IN DIGITAL PLATFORMS: A QUALITATIVE CONCEPTUAL STUDY	MERADI Samir SALAH Samira DIOUANI Hela	Djillali LIABES University, Sidi Bel Abbés Mohamed Ben Ahmed University, Oran2
ARTIFICIAL INTELLIGENCE AND MARKETING AUDIT: TOWARDS A PREDICTIVE FRAMEWORK FOR EVALUATING DIGITAL MARKETING PERFORMANCE IN SERVICE COMPANIES	Labiad Naima Meradi Samir	Djillali Liabes University, Algeria
FREEDOM OF SPEECH IN THE CONTEXT OF STUDENTS' INVOLVEMENT IN THE UNIVERSITY SOCIAL ACTIVITIES WITHIN ONLINE ENVIRONMENT	Liliana BUDEVICI-PUIU Roberta BUDEVICI-PUIU	Moldova State University, Republic of Moldova National Consortium of the Academy of Economic Studies of Moldova and the "CONSTANTIN STERE" University of Political and Economic European Studies, Chisinau, Republic of Moldova
WHEN A SIMPLE DISH BECOMES LUXURY: RETHINKING PRICE, VALUE, AND FAIRNESS IN LOCAL FOOD MARKETS	Josiane El Khoury	University of Balamand, Lebanon
WHY WOULD AN ETHICALLY PROVEN SHOCKVERTISING CAMPAIGN BACKFIRE SO AGGRESSIVELY? ETHICS BOUNDARIES IN ADVERTISING AND AUDIENCE'S PERSPECTIVE CASE STUDY: SPINNEYS "MISSING" ADVERTISING CAMPAIGN - LEBANON 2025	Josiane El Khoury	University of Balamand, Lebanon
MEASURING FINANCIAL EFFICIENCY IN THE TURKISH AUTOMOTIVE SECTOR USING DATA ENVELOPMENT ANALYSIS: 2020–2025 PERIOD	Sena Ozdemir	Marmara University, Business Administration, Istanbul, Turkey
EXTRACTIVE POLITICS, INCLUSIVE ECONOMICS: REASSESSING INSTITUTIONAL THEORY THROUGH CHINA	Agil Hasanov Rahman Rustamov	School No. 272 named after E. Jalilov, Baku, Azerbaijan Uniser School, Baku, Azerbaijan
A COMPREHENSIVE REVIEW OF THE COMBINED IMPACT OF LIGHTWEIGHT MATERIALS AND AERODYNAMIC DESIGN ON FUEL EFFICIENCY IN AUTOMATIC TRANSMISSION PASSENGER CARS	Huseynzade Elnur Nasibli Kenan	Azerbaijan State University of Economics, Baku, Azerbaijan

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Session -3 / Hall-1
18.06.2026
Moderator: Lusjen Ismaili
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 14:00-16:00
Ankara Local Time: 16:00-18:00

TITLE	AUTHOR(S)	AFFILIATION
INVESTIGATION OF THE ROLE OF METALLIC AND BIO-MORDANTS COLORATION AND FASTNESS PROPERTIES OF WOOL GABARDINE DYED WITH DIRECT DYES	Murat Ayberk BARAN Behçet BECERİR	Bursa Uludağ University, Turkey
MATHEMATICAL MODELING FOR PROGRESSIVE PRODUCTION CURVE PROCESSING AND ESTIMATION OF RECOVERABLE OIL RESERVES (MOVABLE OIL). A CASE STUDY OF THE GORISHT-KOCUL OILFIELD, ALBANIA	Lusjen Ismaili	Ministry of Infrastructure and Energy, Tirana, Albania
OCCUPATIONAL RADIATION EXPOSURE MONITORING IN MEDICAL AND VETERINARY ACADEMIC ENVIRONMENTS: A CASE STUDY OF AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA	Yahaya Aliyu Ahmed Kehinde Usman Paul Peter Dawai	Comenius University Bratislava, Slovakia Ahmadu Bello University, Nigeria
SOME RESULTS ON THE SETS OF QUADRATIC RESIDUES AND QUADRATIC NON-RESIDUES MODULO PRIME NUMBER p WITH $p \equiv 3 (\mathrm{mod}\ 4)$	Arto Adili Adrian Naço	Fan S. Noli University, Albania Polytechnic University, Albania
INTEGRATED ASSESSMENT OF EMBODIED CARBON AND COASTAL WATER VARIABILITY UNDER POST-EARTHQUAKE URBAN RECONSTRUCTION	Stela Sefa Julian Sefa	Aleksandër Moisiu University Durrës, Albania Polytechnic University of Tirana, Albania
A TWO-PARAMETER WEIGHTED FEJÉR IDENTITY FOR HARMONICALLY CONVEX FUNCTIONS UNDER THE CAPUTO–FABRIZIO FRACTIONAL OPERATOR AND APPLICATIONS	Alba NOGA Alfred DACI Artion KASHURI	Polytechnic University of Tirana, Albania
TOWARDS DEEPER INSIGHTS INTO FRACTIONAL PROBLEMS	Manel DJEBAILI	University Larbi Ben Mhidi, Algeria

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Session -3 / Hall-2
18.06.2026
Moderator: Assoc. Prof. Dr. Serkan ELÇİN
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 14:00-16:00
Ankara Local Time: 16:00-18:00

TITLE	AUTHOR(S)	AFFILIATION
INVESTIGATION OF THE THERMAL AND EMI SHIELDING PROPERTIES OF STEEL FIBER/PA6.10 COMPOSITES	Buse Fem YILMAZ Arzu ÇANKAYA Sema SAMATYA YILMAZ Bedriye ÜÇPINAR Ayşe AYTAÇ	Epsan Plastik Kocaeli University, Türkiye Yeditepe University, Türkiye
COMPARATIVE EVALUATION OF THE REGENERATIVE EFFICACY OF LUCILIA SERICATA LARVAL SECRETIONS UNDER VARIOUS STORAGE CONDITIONS	Kübra TUĞTEKİN	Istanbul University-Cerrahpaşa, Türkiye
SYNTHESIS AND SELECTIVE METAL EXTRACTION PERFORMANCE OF A MORPHOLINE-FUNCTIONALIZED AZOCALIX[4]ARENE	Serkan ELÇİN Sahra SARAÇ	Pamukkale University, Türkiye
SYNTHESIS AND THERMAL DECOMPOSITION BEHAVIOR OF A NOVEL MORPHOLINYL-FUNCTIONALIZED AZOCALIX[4]ARENE	Serkan ELÇİN	Pamukkale University, Türkiye
NATURAL GUM-MEDIATED GREEN SYNTHESIS AND CHARACTERIZATION OF CuTiNi TERNARY NANOCOMPOSITE	Saniye TEKEREK Ayça TANRIVERDİ	Kahramanmaraş Sütçü İmam University, Türkiye
PLANT-MEDIATED GREEN SYNTHESIS OF CuO NANOPARTICLES FOR METHYL RED DYE DEGRADATION	Ayça TANRIVERDİ Saniye TEKEREK	Kahramanmaraş Sütçü İmam University, Türkiye
EFFECT OF DIFFERENT FLOUR MOISTURE LEVELS ON PROCESSING AND QUALITY ATTRIBUTES OF NOODLE PRODUCTION	Cihat GÜNER Yusuf ÇAKMAKÇI Hakan BAŞDOĞAN	Erişler Gıda A.Ş., Eriş Ar-Ge Merkezi, Türkiye

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Session -3 / Hall-3
18.06.2026
Moderator: Dr. Mas'ud Hamdan
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 14:00-16:00
Ankara Local Time: 16:00-18:00

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THE IMPORTANCE OF PHYSICS PROBLEMS SOLVED USING MATHEMATICAL METHODS IN SECONDARY EDUCATION	Lorena Kelo Arto Adili Denisa Kafazi	Fan S. Noli University, Albania
THE BIOGRAPHER'S BURDEN: SUBJUGATION OF THE FEMALE SUBJECT IN CAROL SHIELDS' MARY SWANN	İlkay Khalid	Pamukkale University, Turkey
FROM OBSTACLE TO OPPORTUNITY: THE ROLE OF CONFLICT IN FOREIGN LANGUAGE LEARNING	BELABBES Nour el houda ABOUTALIB Soukaina BENALI Hicham	Ibnou Zohr, Agadir, Morocco
A DELIBERATE HUMOUR: THE MASKS OF THE OPPRESSED TRUTH	Mas'ud Hamdan	University of Haifa, Palestine
LEARNING MANAGEMENT SYSTEMS FOR MATHEMATICS EDUCATION IN VIETNAM: A LITERATURE REVIEW	Nguyen Thi Bao Truc Hoang Thao Trang Thai Hoang Thien Nhi	Can Tho University, Viet Nam
APPROACHING ISPRING SUITE TO DESIGN QUESTION TYPES IN MATHEMATICAL TEST AT HIGH SCHOOLS	Nguyen Duc Thinh Thai Hoang Thien Nhi Bui Anh Tuan	Can Tho University, Viet Nam
DEVELOPING AN ASSESSMENT RUBRIC FOR ARGUMENTATIVE WRITING COMPETENCE IN LITERATURE AND ENGLISH FOR 10TH-GRADE STUDENTS USING THE TOULMIN MODEL	Chi Nguyen NGUYEN Tuyet Minh QUACH Thi Hang LE Thi Hoi HUYNH Thi Viet Thuan NGUYEN	Dong Thap University, Vietnam Can Tho University, Vietnam Vinschool Grand Park, Vietnam Ho Chi Minh City University of Education, Vietnam
PLEASURE BEFORE PARTICIPATION TIKTOK USES AND GRATIFICATIONS AMONG ALBANIAN ADOLESCENTS	Irena Myzeqari Anila Prethi	European University of Tirana, Albania Freelance journalist and PR expert, Tirana, Albania

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Session -3 / Hall-4
18.06.2026
Moderator: PhD. Ana-Cristina Bâlgăr
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 14:00-16:00
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TITLE	AUTHOR(S)	AFFILIATION
THE EFFECTS OF MANAGEMENT ACCOUNTING TOOLS IN SMEs PERFORMANCE. EMPIRICAL EVIDENCE FROM ELBASAN, ALBANIA	Marsel Sulanjaku Meri Muçelli	University "Aleksandër Xhuvani", Albania CFO at HFN Ltd., AmCham Committee Member & Researcher, Elbasan, Albania
IMPLEMENTATION OF SMART ENVIRONMENTAL MANAGEMENT IN THE URBAN WASTE MANAGEMENT SYSTEM: A CASE STUDY OF THE MUNICIPALITY OF DURRËS	Elma Kodra Ulpian Hoti	Aleksandër Moisiu University of Durrës, Albania
THE IMPACT OF RETURNED MIGRANTS ON AN UNEMPLOYMENT MODEL	Silva Kapia Besiana Çobani	Albanian University, Albania University of Tirana, Albania
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THE WASTE TRADE TRAP: MYTHS AND REALITIES OF WASTE COLONIALISM	Maria Francisca Marcelino	NOVA School of Law, Portugal
THE NEW LOGIC OF GERMAN INDUSTRIAL POLICY IN A FRAGMENTED WORLD	Ana-Cristina Bâlgăr	Romanian Academy, Bucharest, Romania
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THE BLINDSPOT OF MODERN ECONOMICS: SYSTEMIC RISKS AND THE IRREVERSIBLE COLLAPSE OF NATURE	Maria Constança Lameiro	ISEG, Lisbon School of Economics and Management, Portugal
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SUSTAINABLE TOURIST DESTINATIONS AND REGIONAL BRANDS: CONNECTIONS BETWEEN PARANÁ, BRAZIL, AND WESTERN PORTUGAL	Renato da Costa dos Santos Giovana Goretti Feijó Almeida Paulo Almeida	Polytechnic University of Leiria – CiTUR, Portugal
ALIGNING ALBANIA'S CARBON TAX WITH EU CIRCULAR ECONOMY TARGETS: OPPORTUNITIES AND OBSTACLES	Edvin STEFANI	Barleti University Albania

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Session -3 / Hall-5
18.06.2026
Moderator: Mehmet ÇAKIROĞLU
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 14:00-16:00
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EXERCISE-INDUCED HYPOALGESIA AND PAIN MODULATION: A REVIEW FROM A PHYSIOTHERAPY PERSPECTIVE	Mehmet ÇAKIROĞLU	Kahramanmaraş Özel İlgi Private Rehabilitation Center, Kahramanmaraş, Türkiye
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THE MEDIATING ROLES OF MENTALIZATION AND NARCISSISTIC FLUCTUATION IN THE RELATIONSHIP BETWEEN ATTACHMENT STYLES AND SELF-FRAGMENTATION	Gülşah BALABAN Ayşe Zeynep CEBECİ Elif Nisa AKMERCAN	İstanbul Sabahattin Zaim University, Türkiye
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Session -3 / Hall-6
18.06.2026
Moderator: Bogdan-Catalin Serban
Meeting ID: 862 1528 3413 / Passcode: 181920
London Local Time: 14:00-16:00
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ORGANIC- INORGANIC HYBRID MATERIALS AND THEIR APPLICATIONS: A BRIEF REVIEW	Bogdan-Catalin Serban Matei-Gabriel Ursachescu Vlad Diaconescu Caterina Maria Zetu Maria Ruxandra Salagean Diana Dumitraşcu Octavian Buiu Marius Bumbac	National Institute for Research and Development in Microtechnologies–IMT Bucharest, Romania National College "B. P. Hasdeu", Romania University of Medicine and Pharmacy "Carol Davila", Romania International Theoretical High School of Computer Science, Romania National College "Saint Sava", Bucharest, Romania Valahia University of Târgoviște, Romania
CURRENT STATUS OF NUTRITION DURING CHOLECYSTITIS IN KAZAKHSTAN	Kydyrbek Laila	University named after Khoja Ahmet Yassawi, Turkestan, Kazakhstan
CHEMISTRY AND PHARMACOLOGICAL APPLICATIONS OF Allium Sativum EXTRACTS	Vlad Diaconescu Bogdan-Catalin Serban Matei-Gabriel Ursachescu Caterina Maria Zetu Octavian Buiu Marius Bumbac Diana Dumitraşcu Maria Ruxandra Salagean	National Institute for Research and Development in Microtechnologies–IMT Bucharest, Romania National College "B. P. Hasdeu", Romania University of Medicine and Pharmacy "Carol Davila", Romania International Theoretical High School of Computer Science, Romania National College "Saint Sava", Bucharest, Romania Valahia University of Târgoviște, Romania
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DEEP LEARNING-BASED IMAGE ANALYSIS FOR IOT-ENABLED SMART AGRICULTURE SYSTEMS

NESNELERİN İNTERNETİ DESTEKLİ AKILLI TARIM SİSTEMLERİ İÇİN DERİN ÖĞRENME TABANLI GÖRÜNTÜ ANALİZİ

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ABSTRACT

In recent years, the integration of Internet of Things (IoT) technologies into agriculture has accelerated the development of data-driven smart farming applications. Sensors, intelligent devices, and imaging systems deployed in agricultural environments enable real-time monitoring and analysis of various processes such as crop growth, productivity, and disease detection. These technological advancements have increased the importance of artificial intelligence and deep learning-based image processing techniques in modern agricultural applications. This study aims to examine the role of image processing approaches in IoT-based smart agriculture systems and to discuss the potential contributions of deep learning techniques in this domain. Image analysis in smart farming environments provides significant advantages for monitoring plant health, detecting crop diseases at early stages, and evaluating agricultural productivity. Deep learning-based image processing approaches make it possible to analyze agricultural data more efficiently and accurately. Within this context, the study provides a general evaluation of deep learning-based image analysis approaches used in IoT-enabled smart agriculture environments. Based on findings reported in the literature, it is anticipated that deep learning-based image processing techniques can support effective agricultural monitoring systems and improve the efficiency of smart farming applications when integrated with IoT infrastructures. The study highlights the importance of AI-driven image analysis in smart agriculture and provides a conceptual framework for future research in this emerging field.

Keywords: Internet of Things, Smart Agriculture, Deep Learning, Image Processing, Agricultural Monitoring

ÖZET

Son yıllarda Nesnelerin İnterneti (IoT) teknolojilerinin tarım alanına entegrasyonu, veri odaklı akıllı tarım uygulamalarının hızla gelişmesini sağlamıştır. Tarım alanlarında kullanılan sensörler, akıllı cihazlar ve görüntüleme sistemleri sayesinde bitki gelişimi, ürün verimliliği ve hastalık tespiti gibi birçok süreç gerçek zamanlı olarak izlenebilmekte ve analiz edilebilmektedir. Bu gelişmeler, özellikle yapay zeka ve derin öğrenme tabanlı görüntü işleme tekniklerinin tarımsal uygulamalarda kullanılmasını önemli hale getirmiştir. Bu çalışma, IoT tabanlı akıllı tarım sistemlerinde görüntü işleme yaklaşımlarının kullanımını ve derin öğrenme tekniklerinin bu alandaki potansiyel katkılarını incelemeyi amaçlamaktadır. Akıllı tarım uygulamalarında görüntü verilerinin analiz edilmesi, bitki sağlığının izlenmesi, erken hastalık tespiti ve ürün kalitesinin değerlendirilmesi gibi kritik süreçlerde önemli avantajlar sunmaktadır. Derin öğrenme tabanlı görüntü işleme yaklaşımları sayesinde tarımsal verilerin

daha hızlı ve doğru şekilde analiz edilmesi mümkün hale gelmektedir. Çalışma kapsamında, IoT destekli akıllı tarım ortamlarında kullanılan görüntü verilerinin analizine yönelik derin öğrenme yaklaşımlarının performansına ilişkin genel bir değerlendirme sunulmaktadır. Literatür bulgularına dayalı olarak, derin öğrenme temelli görüntü işleme yöntemlerinin tarımsal izleme sistemlerinde etkili sonuçlar sağlayabileceği ve IoT altyapısı ile birlikte kullanıldığında akıllı tarım uygulamalarının verimliliğini artırabileceği öngörülmektedir. Bu bağlamda çalışma, IoT destekli akıllı tarım sistemlerinde yapay zekâ tabanlı görüntü analizinin önemini ortaya koyarak gelecekteki araştırmalar için bir değerlendirme çerçevesi sunmaktadır.

Anahtar Kelimeler: Nesnelerin İnterneti, Akıllı Tarım, Derin Öğrenme, Görüntü İşleme, Tarımsal İzleme

1. INTRODUCTION

The rapid growth of the world population and environmental factors such as climate change have made it necessary to increase productivity in agricultural production in order to ensure global food security. Traditional agricultural methods remain insufficient to meet the needs of large-scale agricultural areas due to their reliance on human-based observations, manual data collection processes, and limited analytical capabilities. This necessity has accelerated the digitalization of agriculture and enabled the integration of Smart Agriculture applications into modern production processes.

As a cornerstone of the smart agriculture ecosystem, Internet of Things (IoT) technologies enable real-time data collection from agricultural fields on a 24/7 basis through sensors, smart devices, and advanced imaging systems deployed in the field. The ability to continuously monitor critical parameters such as plant growth, crop productivity, and soil health allows farmers and researchers to develop more accurate decision-support mechanisms. However, the manual interpretation of the high-volume and complex visual data obtained from these systems creates significant time and labor costs.At this point, deep learning-based image processing techniques offer transformative solutions for the analysis of agricultural data. Deep learning algorithms, particularly through automatic feature extraction from complex visual data, can detect plant diseases at early stages and monitor plant health with high accuracy. These artificial intelligence models, when integrated with IoT infrastructure, enhance the effectiveness of agricultural monitoring systems and contribute to sustainable agriculture goals.

This study presents a holistic system design based on deep learning approaches for the analysis of image data in IoT-supported smart agriculture environments. Within the scope of the proposed design, a methodological framework is introduced for the early detection of plant diseases through a CNN-LSTM hybrid architecture deployed at the Fog layer. This framework emphasizes the importance of artificial intelligence-based image analysis in the smart agriculture ecosystem and aims to provide a guiding foundation for future experimental research.

2. RELATED WORKS

Research on image-based disease detection in Internet of Things-supported smart agriculture systems has gained momentum in recent years. These studies are generally shaped around the design of computational infrastructure, the development of image-based deep learning models, and the integration of these two components.

From the perspective of computational infrastructure, Fog and Edge approaches have become prominent, as they enable data to be processed close to its source rather than being sent directly to the cloud. Cordeiro et al. (2022) developed a smart irrigation system using deep neural networks on the Fog layer and demonstrated that the integration of Fog computing and deep learning can produce real-time and effective results in agricultural applications. In an image-based scenario, Marković et al. (2024) proposed a CNN classification model that establishes a direct connection between Cloud and Edge devices through Fog computing and is optimized to operate on resource-constrained hardware. In tomato disease classification, they showed that when the model was deployed on FPGA, its accuracy could be maintained at 95.46% with only a 0.83% decrease. Similarly, Tarek et al. (2023) designed a three-layer deep learning framework covering the edge–fog–cloud layers and demonstrated the feasibility of image-

based early disease diagnosis in a Fog environment by using a pretrained CNN architecture such as AlexNet as a feature extractor. Papanikolaou et al. (2025), on the other hand, extended the infrastructure to a distributed setting. They proposed a framework in which IoT nodes and an edge node collaboratively train an EfficientNet B0 model using the Federated Learning-based FedAvg algorithm without transferring local image data to a central server, demonstrating that an effective diagnostic process that preserves data privacy is possible.

When the performance of image-based deep learning models is evaluated, CNN-based approaches are observed to produce strong results. Andrew et al. (2022) performed disease recognition by fine-tuning pretrained architectures such as DenseNet-121, ResNet-50, VGG-16, and Inception V4 on the open-source PlantVillage dataset, which contains 38 classes and more than 54,000 images, and reported a high accuracy of 99.81% with DenseNet-121. Emphasizing the importance of data diversity, De Silva and Brown (2023) created a multispectral image dataset covering visible and near-infrared wavelengths and demonstrated the decisive role of balanced datasets in appropriate model selection by using a hybrid approach that combines CNN and Vision Transformer architectures. These studies clearly show that high accuracy values can be achieved with different visual datasets and CNN-based architectures.

Beyond instantaneous classification, hybrid approaches combining CNN and LSTM architectures have attracted increasing attention in order to model the progression of disease over time. Santoshi et al. (2026) developed an explainability-oriented hybrid framework, LDDHybridNet, which combines a compact CNN and LSTM after ROI-focused preprocessing obtained through U-Net-based segmentation. They demonstrated that the proposed framework achieved 95.37% accuracy under real field conditions and 92.84% accuracy for early-stage samples. Syed et al. (2025), on the other hand, proposed an architecture that combines the hierarchical feature extraction capability of CNN with the temporal dependency modeling capacity of BiLSTM and reported 99.37% accuracy on pepper and maize leaf datasets. These studies indicate that transforming visual features extracted from CNN into a sequential structure and feeding them into LSTM/BiLSTM layers can both improve disease detection accuracy and provide the system with temporal modeling capability. When all these studies are evaluated together, it is observed that CNN-based and CNN-LSTM/BiLSTM hybrid methods supported by visual datasets produce highly successful results in smart agriculture, while Fog and Edge architectures provide significant advantages in terms of latency and bandwidth (Kaya & Jobani, 2026). However, these components are mostly addressed separately in the literature. A holistic design that jointly employs CNN and LSTM at the Fog layer, tracks the stage-based progression of disease, and is supported by a multidimensional evaluation based on ROC/AUC analysis remains limited. Yet, the integration of these four components generates value beyond the individual contributions of each element. In this structure, CNN extracts disease-specific spatial features such as color, texture, and lesion morphology from leaf images with high accuracy. LSTM, in turn, treats these features as a sequential series and captures the temporal progression pattern of the disease, thereby transforming the system from a mere instantaneous classifier into a decision-making structure capable of producing outputs even at an early stage when symptoms are still subtle. Deploying this hybrid analysis at the Fog layer enables processing to be performed close to the data source, reducing the latency and bandwidth burden caused by continuous data transmission to the cloud. Thus, by providing farmers with near-real-time alerts, it becomes possible to shorten intervention time and prevent potential crop losses.

Supporting the evaluation with ROC/AUC analysis also completes the reliability dimension of this framework. In agricultural disease detection, classifying a diseased plant as healthy may directly lead to crop loss; therefore, relying solely on accuracy can be misleading. The sensitivity–specificity balance provided by ROC analysis offers a much more meaningful indication of the model's reliability under real-world conditions. Based on these findings, it is anticipated that similar high accuracy values can be achieved and real-time early disease detection can be enabled when a CNN-LSTM hybrid architecture deployed at the Fog layer is used with any suitable visual dataset containing healthy and diseased leaf images. The proposed study aims precisely to fill this gap by presenting a holistic smart agriculture architecture in which image data are analyzed through the combined use of CNN and LSTM at the Fog layer, addressing both instantaneous classification and the stage-based progression of disease within the same system and evaluating the process through ROC analysis.

3. SMART AGRICULTURE SYSTEM DESIGN

Smart agriculture systems integrate technologies such as IoT, wireless sensor networks, big data analytics, and artificial intelligence to enable the real-time collection, processing, and interpretation of agricultural data. In this way, parameters such as soil moisture, temperature, weather conditions, and plant health can be continuously monitored, while operations such as irrigation, fertilization, and pesticide application can be managed through data-driven decisions. In IoT-based smart agriculture systems, the collection of agricultural data through sensors, its transmission through the communication layer, and its processing in Fog/Edge and cloud layers to generate decision-support outputs are illustrated in Figure 1.

The main benefits offered by these systems include the more efficient use of inputs such as water, fertilizer, and energy, the reduction of production costs, the improvement of product quality and yield, and the support of a sustainable agricultural approach by reducing environmental impacts. In addition, opportunities such as early disease detection and accurate yield prediction strengthen producers' decision-making processes and minimize potential losses.

However, a significant portion of image-based plant disease detection studies in the literature considers disease detection as a static single-frame classification problem, while approaches aimed at capturing early-stage symptoms by modeling the progression pattern of disease over time remain limited. Similarly, these studies mostly transfer data directly to the cloud, overlooking latency and bandwidth constraints, and report their performance predominantly based on a single accuracy value. To address these limitations, this study proposes an end-to-end smart agriculture system that integrates a three-layer architecture processing data at a Fog layer close to the source, a CNN-LSTM hybrid structure that models the temporal progression of disease, and a ROC-based evaluation framework that prioritizes the cost of false negatives. In order to contribute to the existing literature on smart agriculture systems, this paper designs a smart agriculture system whose details are presented under the headings of 3.1 System Architecture, 3.2 Dataset, and 3.3 Methodology Design.

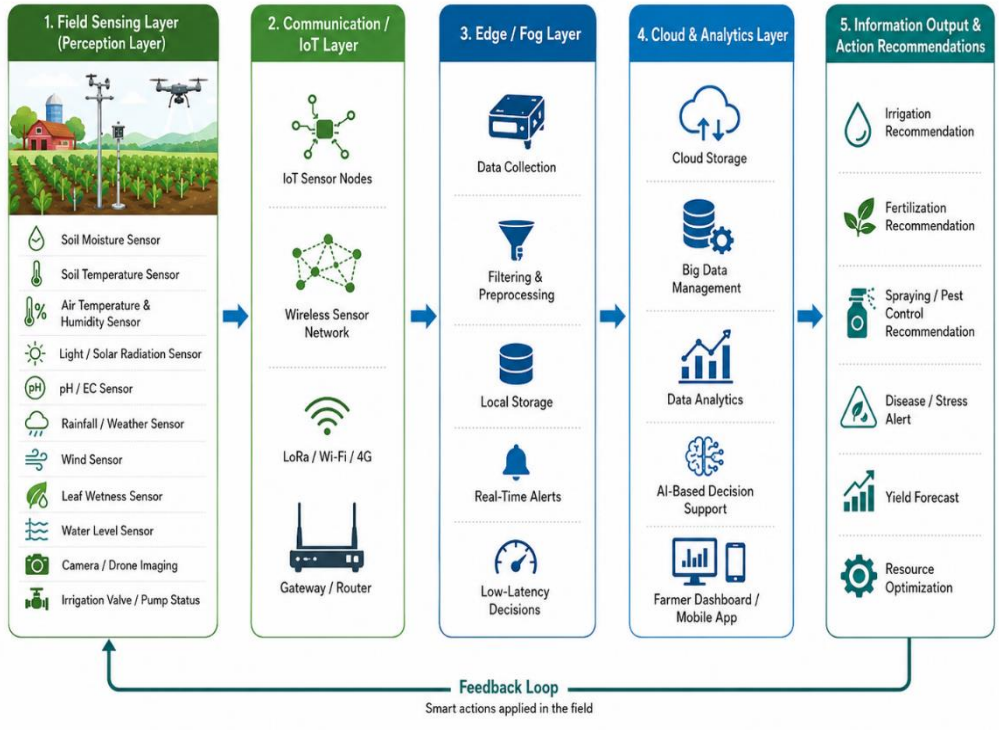


Figure 1. IoT-Based Smart Agriculture System Architecture

3.1 System Architecture

The proposed system is designed based on a hierarchical architecture consisting of three main layers in an IoT-based smart agriculture environment. The general structure of the system is presented in Figure

2. In the literature, it has been shown that Fog- and Edge-based multilayer approaches provide significant gains in terms of latency and bandwidth usage compared to the direct transfer of data to the cloud (Cordeiro et al., 2022; Tarek et al., 2023; Marković et al., 2024). The proposed design is shaped based on these findings. In the first layer, plant images and environmental data are continuously collected through IoT sensors and cameras deployed in the field environment. Instead of transmitting the collected raw data directly to the cloud, it is directed to the second layer, namely the Fog layer. The Fog layer processes data close to the source, minimizing latency, reducing bandwidth usage, and enabling real-time decision-making. Indeed, as demonstrated in the Fog-based image classification study by Marković et al. (2024), deploying deep learning analysis close to the data source eliminates continuous dependence on the cloud and enables near-real-time inference even on resource-constrained devices. Deep learning-based image analysis is performed in this layer, and the obtained results are both fed back into the system as immediate action recommendations and transmitted to the cloud layer for long-term monitoring. Through this three-layer structure, the system aims to establish a balance between low latency and high analytical capacity.

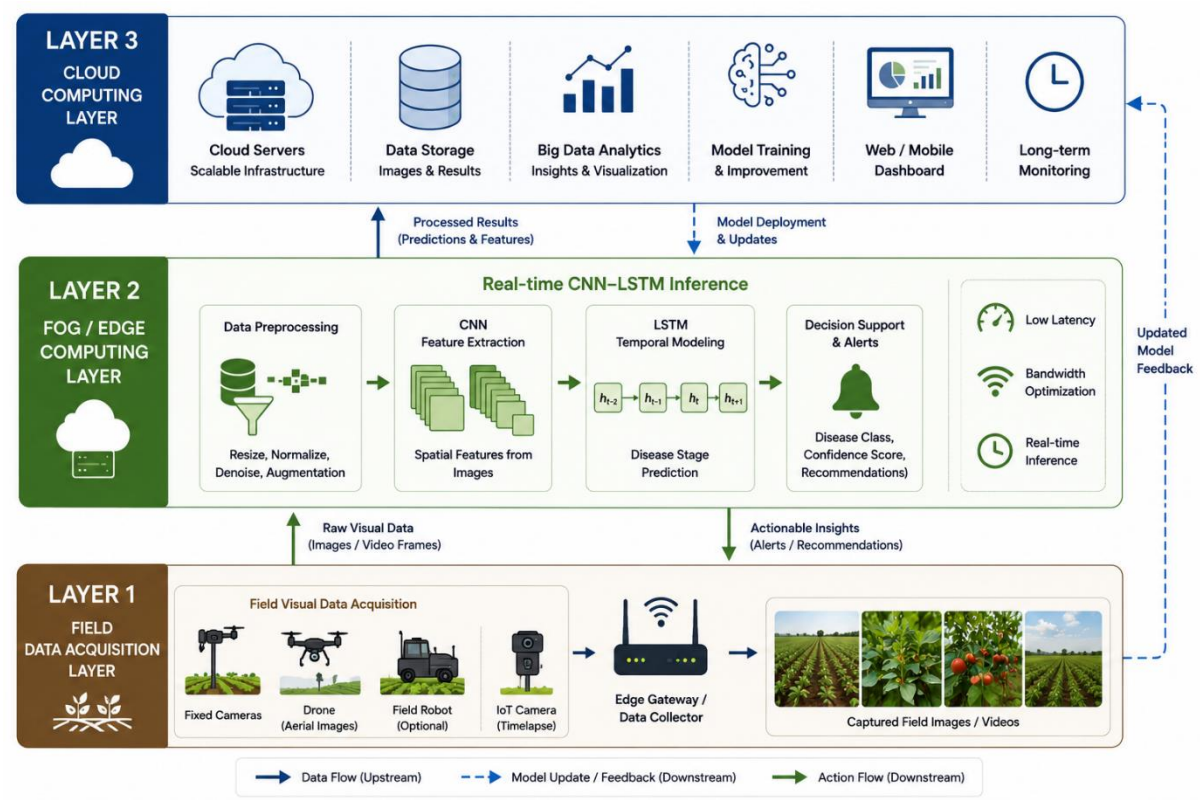


Figure 2. Three-Layer Architecture of the Proposed IoT-Based Smart Agriculture System.

3.2 Dataset

The data requirement of the proposed approach is defined not as a dependency on a specific dataset, but in terms of the characteristics that the dataset should possess. When the literature is examined, it is observed that image-based disease detection studies in smart agriculture have produced high-performance results using different data sources. For example, Andrew et al. (2022) achieved 99.81% accuracy with DenseNet-121 on the open-source PlantVillage dataset, which includes healthy and diseased leaf images of 14 plant species grouped into 38 classes. De Silva and Brown (2023) used a field-collected multispectral image dataset covering visible and near-infrared wavelengths, while Syed et al. (2025) reported 99.37% accuracy on pepper and maize leaf datasets. When these studies are evaluated together, it is understood that, even though the data sources differ, visual datasets that represent healthy and diseased leaves with sufficient diversity provide a suitable foundation for a high-performance learning process.

In this regard, the proposed system is designed to operate with visual datasets that meet specific requirements rather than being dependent on a single dataset. These requirements can be summarized as the availability of a sufficient number of healthy and diseased leaf images belonging to different plant species, the inclusion of diverse samples representing different severity levels and stages of disease symptoms, and the consideration of class balance to support the generalization capacity of the model. Alternative dataset scenarios that may satisfy these requirements include the open-source PlantVillage dataset, which contains healthy and diseased leaf images of 14 plant species grouped into 38 classes; leaf images collected directly from real field conditions; and multispectral image datasets covering visible and near-infrared wavelengths. The proposed architecture is designed to operate with any of these scenarios.

An image dataset possessing these characteristics provides a rich source for the CNN model to learn disease-specific visual features such as color, texture, and lesion morphology (Kaya Ş.M., 2025). The feature vectors obtained from this source are planned to be ordered both according to disease stages and according to images of the same plant captured at different times, thereby forming sequential input sequences for the LSTM layer. In this way, a hybrid learning process with temporal modeling capability can be derived from a static image collection. Consequently, it is anticipated that the proposed architecture can produce similar successful results with any suitable visual dataset that meets the above-mentioned requirements.

3.3 Methodology Design

The methodology proposed in this study is based on the deep learning-based analysis of leaf images obtained from IoT-supported smart agriculture environments at the Fog layer. The methodological design is structured as an end-to-end process consisting of data collection, preprocessing, feature extraction, temporal modeling, classification, inference on the Fog layer, and multidimensional performance evaluation stages (Kaya Ş.M., 2026). In the first stage, leaf images of plants are collected through IoT-supported cameras, drone imaging systems, or mobile imaging devices deployed in the field environment. These images may represent the healthy or diseased condition of the plant, as well as different severity levels and developmental stages of the disease. Thus, the proposed system is designed not only to perform instantaneous disease classification, but also to evaluate visual patterns representing the progression of disease from early to advanced stages.

In the second stage, image data are made suitable for analysis. In this context, image resizing, noise reduction, color normalization, contrast enhancement, and data augmentation procedures are applied. During the data augmentation process, operations such as rotation, cropping, horizontal/vertical flipping, brightness variation, and scaling are used to make the model more robust against different field conditions (Andrew et al., 2022). Since factors such as illumination variation, leaf angle, shadow, camera distance, and background complexity may affect model performance, especially in field environments, the preprocessing stage plays a critical role in the generalization success of the system.

In the third stage, the preprocessed images are transferred to the CNN-based feature extraction module. CNN layers automatically learn color changes on the leaf surface, texture deformations, lesion regions, edge structures, and disease-specific morphological patterns. At this stage, the CNN model transforms raw image data into more meaningful and discriminative feature vectors (De Silva & Brown, 2023). The obtained feature vectors are used not only for the classification of a single image, but also as inputs to the LSTM layer in order to model the stage-based development of disease symptoms.

In the fourth stage, the feature vectors extracted by the CNN are fed into the LSTM layer in a sequential structure. This sequential structure can be constructed in two different ways. In the first scenario, images of the same plant captured at different times are used as consecutive observations, thereby obtaining a real temporal disease progression sequence. In the second scenario, images labeled according to disease severity or stage are ordered from low severity to high severity to form a stage-based representation. Through this approach, the LSTM model can learn not only the current disease symptom visible in the image, but also the direction and progression pattern of the disease. Thus, unlike conventional single-frame classification approaches, the proposed system provides a decision-making mechanism that is sensitive to early-stage disease symptoms (Santoshi et al., 2026; Syed et al., 2025). In the fifth stage,

the output obtained from the CNN-LSTM hybrid model is transferred to the classification layer. In this layer, it can be determined whether the plant is healthy or diseased. Depending on the label structure of the dataset, the disease type or disease stage can also be classified. The model output is not limited to producing only a class label; it also provides a decision confidence score. This confidence score can be used to determine the priority level of the warning to be presented to the farmer or the decision-support system.

In the sixth stage, the trained model is intended to be executed on the Fog layer. In this approach, image data are analyzed on a Fog/Edge node located close to the field environment before being transferred directly to the cloud. In this way, bandwidth usage is reduced, latency is decreased, and near-real-time decision-making becomes possible (Marković et al., 2024; Tarek et al., 2023). The model running on the Fog layer can directly transmit action recommendations, such as irrigation, pesticide application, or field inspection, to the decision-support system when a disease is detected. Processes such as long-term analysis, model updating, and storage of historical records can be carried out in the cloud layer.

In the seventh stage, model performance is analyzed through a multidimensional evaluation framework. In this context, accuracy, precision, recall, F1-score, specificity, ROC curve, and AUC value are used as the main performance metrics. In the context of agricultural disease detection, the recall metric is particularly critical because classifying a diseased plant as healthy may cause the disease to spread and lead to crop loss. Therefore, instead of focusing only on overall accuracy, the proposed system adopts an evaluation approach that reduces the false negative rate and considers the balance between recall and specificity.

ROC analysis enables the evaluation of the system's reliability under real-world conditions by revealing how the model performs at different decision thresholds. The AUC value is used as a comprehensive indicator that summarizes the model's capacity to distinguish between healthy and diseased samples. In this context, the proposed methodology aims to evaluate not only classification performance, but also its usability as an early warning system, decision reliability, and practical applicability. As a result, the proposed methodological design integrates IoT-supported data collection, Fog-based low-latency analysis, CNN-based spatial feature extraction, LSTM-based stage-based/temporal modeling, and ROC/AUC-supported reliability evaluation within a unified framework. In this respect, the study presents an applicable, scalable, and literature-consistent deep learning architecture for the early detection of plant diseases in smart agriculture systems.

4. DISCUSSION

Considering the findings obtained from similar studies in the literature and the advantages offered by the architectural design, the proposed system is expected to produce meaningful outcomes in several key aspects. When the findings in the literature are examined, it is observed that deep learning approaches for image-based disease detection in smart agriculture achieve high performance values. Andrew et al. (2022) achieved 99.81% classification accuracy with DenseNet-121 on the PlantVillage dataset. Similarly, Syed et al. (2025) reached 99.37% accuracy on pepper and maize leaf datasets. In terms of hybrid and stage-based approaches, Santoshi et al. (2026) reported 95.37% accuracy under real field conditions and 92.84% accuracy for early-stage samples. When these findings are evaluated together, it is anticipated that the proposed system can also achieve similarly high accuracy values with a suitable visual dataset.

In terms of the contribution of the CNN component, convolutional architectures are expected to extract disease-specific spatial features such as color, texture, and lesion morphology from leaf images with high accuracy. Indeed, the high accuracy values obtained by Andrew et al. (2022) using pretrained CNN architectures demonstrate that convolutional structures can strongly learn visual patterns. De Silva and Brown (2023), on the other hand, demonstrated the adaptability of visual feature extraction to different image types by combining CNN and Vision Transformer (ViT) architectures on a multispectral dataset covering different wavelengths. In this regard, the CNN in the proposed system is expected to provide a strong initial representation during the feature extraction stage.

Regarding the contribution of the LSTM component, it is expected that the system will move beyond instantaneous classification by modeling the progression pattern of disease over time. The fact that

Santoshi et al. (2026) achieved high accuracy even on early-stage samples within a CNN-LSTM hybrid framework supports the contribution of temporal modeling to early detection. Similarly, Syed et al. (2025) showed that classification performance can be improved by combining CNN features with the temporal dependency modeling capacity of BiLSTM. Based on these findings, the LSTM layer in the proposed system is expected to provide a structure capable of producing decisions even at an early stage when disease symptoms are still subtle.

Deploying this hybrid analysis at the Fog layer is expected to significantly reduce latency and bandwidth load by performing computation close to the data source. Marković et al. (2024) showed that, in a Fog-based architecture, when the model was executed on a resource-constrained device, the decrease in accuracy could be limited to only 0.83%, from 96.29% to 95.46%. While Cordeiro et al. (2022) demonstrated that combining the Fog layer with deep learning can produce real-time and effective results, Tarek et al. (2023) showed the feasibility of image-based early disease diagnosis in a Fog environment. Papanikolaou et al. (2025) further demonstrated that diagnosis is possible in a distributed structure while preserving data privacy. Considering these findings, the proposed system is expected to remain below a practical threshold for real-time alert generation and to reduce plant loss and economic damage by shortening the farmer's intervention time. In particular, it is estimated that intervention at an early stage, when the disease is still limited to a single leaf, may significantly reduce pesticide costs and crop loss compared to intervention at an advanced stage. Supporting the evaluation method with ROC (Receiver Operating Characteristic) analysis is intended to complete the reliability dimension of the system. It is observed that studies in the literature mostly report their performance based on a single accuracy value. However, the accuracy metric alone may be insufficient to reflect the true discriminative power of the model, especially when the class distribution is imbalanced. ROC analysis visualizes the balance established by the model between recall/sensitivity and specificity at different decision thresholds, while the AUC value summarizes the overall discriminative power with a single metric. In the proposed study, the AUC value is expected to be 0.95 or above, which would indicate that the model can maintain high sensitivity while keeping the false positive rate low. Considering that classifying a diseased plant as healthy, namely a false negative, may directly lead to crop loss in agricultural disease detection, the sensitivity–specificity balance provided by ROC analysis offers a much more meaningful evaluation basis than accuracy alone and aims to reveal the reliability of the system under real-world conditions.

When all these findings are considered together, it is seen that there remains a lack of a holistic design that jointly uses CNN and LSTM architectures at the Fog layer, tracks the stage-based progression of disease, and evaluates the system multidimensionally through ROC analysis. To fill this gap, the proposed model combines the strong spatial feature extraction capability of CNN with the temporal modeling capacity of LSTM and transfers this analysis to the Fog layer, bringing together low latency and high analytical capacity under the same framework. This design is expected to enable high accuracy values with any suitable visual dataset, allow disease detection at an early stage and in a near-real-time manner, shorten the farmer's intervention time, and reveal the reliability of the system under real-world conditions through ROC-based evaluation. Thus, the proposed system is expected to offer a scalable and sustainable solution for smart agriculture applications in terms of both academic performance metrics and practical applicability.

5. CONCLUSION

In this study, a Fog layer-based hybrid deep learning architecture is proposed for the early detection of plant diseases in IoT-supported smart agriculture systems. The analysis of image data collected from the field environment through the combined use of CNN and LSTM models at the Fog layer enables both instantaneous image classification and the stage-based progression pattern of disease to be addressed within the same system. Considering the lack of a holistic design in the literature that jointly employs CNN and LSTM architectures at the Fog layer, tracks the stage-based progression of disease, and evaluates the system multidimensionally through ROC analysis, the proposed system contributes to the field as an original design in which these four components are addressed together. The hybrid learning structure established by feeding CNN feature vectors into the LSTM layer as sequential series provides an applicable solution for deriving temporal modeling from static image collections. It is anticipated

that this approach can produce high performance with any suitable visual dataset that represents healthy and diseased leaves with sufficient diversity. The multidimensional evaluation framework supported by ROC analysis makes it possible to assess not only the academic performance metrics of the model, but also its reliability under real-world conditions. Considering the potential of early disease detection to reduce plant loss and intervention costs, the proposed system is considered to provide a practical and scalable foundation for agricultural monitoring applications.

In this respect, the study is characterized as a conceptual and methodological system design based on findings from the literature rather than an experimental implementation. Therefore, the performance values presented in the text should be interpreted not as definitive experimental results, but as projected values derived from related studies. The proposed architecture is designed with the flexibility to operate under different scenarios, such as the open-source PlantVillage dataset, leaf images collected directly from the field, or multispectral image datasets covering visible and near-infrared wavelengths, without being dependent on a specific dataset. In the CNN-LSTM hybrid structure, the temporal dimension is planned to be modeled through sequential series formed both according to disease stages and according to images of the same plant captured at different times. In this way, the system is intended to learn not only instantaneous classification, but also the progression pattern of disease.

In future studies, it is aimed to experimentally validate the proposed design using time-series images collected from real field conditions, measure its generalization performance across different plant species and disease classes, and evaluate real-time inference latency on Fog/Edge hardware. Thus, the study is expected to provide an applicable and scalable foundation for further research on early disease detection in smart agriculture.

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ARTIFICIAL INTELLIGENCE IN AIRCRAFT MAINTENANCE: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

This study aims to map scientific collaborations, conceptual clusters, citation relationships, and intellectual structures through a bibliometric analysis of 73 studies indexed in the Web of Science (WoS) database between 1975 and 2025, focusing on the use of artificial intelligence in aircraft maintenance. This analysis aims to identify emerging trends and influential research to provide a foundation for future research, as well as to highlight the international scope of the field. The increasing complexity of aircraft maintenance processes has accelerated the adoption of advanced digital technologies to enhance safety, reduce costs, and improve operational efficiency. Recent academic studies show that artificial intelligence is effective in optimizing fault detection, corrosion monitoring, structural health assessment, maintenance planning, and decision support processes. It is also emphasized that it contributes to reducing downtime by accurately predicting the remaining useful life within the framework of predictive maintenance. Digital twins, mixed reality environments, and metadata-based platforms are transforming aircraft maintenance training, offering more interactive and cost-effective training experiences. The findings suggest that the literature on aircraft maintenance reflects an emerging transition toward increasingly integrated, data-driven, AI-supported, collaborative, and digitized maintenance solutions that enhance aviation safety and sustainability.

Keywords: Artificial Intelligence in Aircraft Maintenance; Machine Learning; Deep Learning; Big Data

FROM GRAMMAR TO GRAMMARING WITHIN RECONCEPTUALIZING LANGUAGE COMPETENCE IN AI-MEDIATED ELT

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ABSTRACT

Due to the increasing use of AI in language education, notions of language competence have been reconsidered. While AI-produced language may be grammatically correct with little to no effort from learners, this trend calls for a reassessment of the importance of grammar teaching in contemporary educational practices, as grammatically correct language is readily available. As a result, grammatical competence becomes less important as an immediate learning objective when accurate language structures are easily accessible. Based on these observations, the present paper argues that the conventional notion of grammar as a ready-made construct is becoming increasingly obsolete in the context of AI-powered pedagogy. Instead, by conceptualizing grammaring as a process of meaning-making, language competence can be defined in terms of how learners utilize their language resources. Hence, grammaring takes its place as a critical aspect of language competence rather than grammar itself. To examine these assumptions, the study will employ a qualitative methodology, including think-aloud protocols and a comparison of learners' performance in AI-supported and control conditions. It is expected that while AI may reduce the need to focus on accuracy, it will increase the need for higher-level decision-making. The study is expected to contribute to a better understanding of the role of grammaring in modern language competence

Keywords: grammaring; artificial intelligence in ELT, AI-mediated learning, grammar pedagogy.

INTRODUCTION

The rapid advancement of AI technology is affecting English Language Teaching by redefining the ways learners acquire, access, and utilize linguistic content. Using AI, users are able to produce linguistically correct and contextually appropriate language with relatively little effort (Olney and Cade, 2025). While these changes open new horizons in the field, they also create challenges for traditional concepts used in language teaching. Specifically, the issue concerns grammar, which in the era of AI may cease to be an object of learning and instead function as an externally produced output.

To address this issue, researchers have proposed viewing grammar as a dynamic and evolving process of meaning construction. The concept of grammaring, for example, implies the use of linguistic resources and their appropriate application depending on context and momentary communicative needs (Larsen-Freeman, 2015; Levine, 2014; Niculescu and Dragomir, 2025). This study examines linguistic competence not only in terms of language acquisition but also as learners' ability to make decisions about how to communicate (Bybee, 2010; Ellis and Larsen-Freeman, 2009). In the context of artificial intelligence, this aspect becomes particularly significant, as learners must decide which linguistic forms to use. While the importance of a prescriptive approach may diminish in such contexts, decision-making gains prominence and emerges as a significant challenge for contemporary pedagogical approaches. At the same time, given the central role of grammaring in this process, the relevance of AI becomes evident. Thus, the research questions of the present study are as follows so as to shed light on:

1. What methods do learners apply when evaluating AI-generated language forms and choosing

between them?

2. To what extent does grammaring differ in the presence and absence of AI?

3. To what extent do learners critically engage with AI output?

LITERATURE REVIEW

When grammar is considered as knowledge via traditional versus communicative approaches, historically, it is seen to be a focal point of second language pedagogy as it involves a collection of rules that students have to know and implement while forming linguistic structures. Grammar, viewed through the prism of cognitive linguistics, represents explicit knowledge that can be taught, practiced, and eventually acquired (Davronova, 2026; Ellis, 2006; Tyurkan, 2015). It forms the basis of form-focused instruction, where accuracy serves as one of the most important indicators of language competence (Almarwani et al., 2026; Setyawan, 2026; Xi, 2025). Despite the shift towards the Communicative Language Teaching paradigm and its emphasis on communicative competence, grammar remains an integral part of language education. Accuracy is perceived as a crucial aspect of successful communication; moreover, Task-Based Language Teaching requires a focus on form in order to facilitate language acquisition. However, the rule-based and knowledge-centered view of grammar has come under increasing criticism among language specialists. As a matter of fact, the primary critique concerns its inability to adequately address the dynamic nature of language learning. Usage-based linguistics emphasizes the role of patterns, frequency, and context as determinants of linguistic competence (Ellis and Larsen-Freeman, 2009). As a result, grammar needs to be regarded as a constantly evolving process rather than an object to be known and used. In this respect, from Grammar to Grammaring matter appears vital in a Complexity Theory Perspective, for this reason, Larsen-Freeman (2003) suggested a new concept of grammar referred to as grammaring. Unlike the grammar-as-knowledge approach, this concept focuses on the dynamic and process-oriented nature of grammar as an activity that uses available linguistic resources for meaning-making. In the context of grammaring, language can be viewed as a complex dynamic system resulting from interactions among different variables (Larsen-Freeman et al., 2025; Levine, 2014; Niculescu and Dragomir, 2025). In other words, grammaring implies features such as flexibility and adaptability to changing needs. As a result, language learning can be considered a complex dynamic system emerging from the interplay between the learner's knowledge and language input (Ellis and Larsen-Freeman, 2009). Even though this theoretical perspective has drawn considerable attention from researchers, research on this construct remains limited due to the lack of studies on grammaring. This means that, although many studies focus on the importance of accuracy and rules in grammar pedagogy, very few studies have been devoted to grammaring. Therefore, future research is accentuated toward inquiry this concept from the perspective of technology-assisted language learning, AI entegration into education.

The integration of AI in ELT opens up numerous opportunities for interaction, feedback provision, and language generation. AI tools that operate using large language models are capable of producing fluent and grammatically correct language across various types of tasks. Features such as instantaneous feedback, personalization, and improved access to language resources have been found to increase learner engagement and autonomy. However, there are also a number of pedagogically relevant concerns related to learners' cognitive engagement with language. The literature shows that an increased role of AI in learning may be detrimental to language acquisition, as it may reduce learners' engagement in crucial processes such as noticing, hypothesis testing, and language internalization (Georgiou, 2025; Hong and Guo, 2025; Swain, 2005).

The learning process from a sociocultural perspective involves meaningful negotiations that are central to this approach (Lantolf and Thorne, 2006). Overreliance on produced language may adversely affect this process by causing the individual to act as a passive participant rather than a language producer. Moreover, the involvement of artificial intelligence in language creation increases effectiveness and minimizes cognitive load, but it also changes the nature of the task itself (Feng, 2025; Qamar et al., 2025). The ability of the technology to generate different linguistic options assists the learner in making choices. In other words, there seems to be a shift in focus from language production to decision-making. This concept emboldens the aspect of integrating grammaring and AI-enabled language use. While the

literature on AI-assisted language learning has expanded considerably, it remains mostly focused on performance outcomes or learner experience. As for the role of grammaring as a process in this context, little emphasis has been placed on it. However, considering the changing conditions under which language use takes place when AI is involved, the role of grammaring as a means of interacting with language and developing language awareness deserves attention. If learners increasingly find themselves in situations where AI generates language, their ability to work with it in terms of interpreting, evaluating, and adapting it may become a hallmark of linguistic competence (Otuogha and Eke, 2025). Thus, there is a need for more detailed research in this area, which will help integrate grammaring into the context of AI-based language use and enable language instructors to make more effective use of this approach in practice.

METHODS

3.1. Research Design

This study adopts a qualitative research design to investigate how grammaring operates in AI-mediated language learning environments. Since the primary aim is to explore learners' cognitive and metacognitive processes—such as evaluating, selecting, and adapting linguistic forms—a qualitative approach is considered the most appropriate. Moreover, the research design includes a comparative element by examining learners' achievements under two different conditions: with and without the use of AI resources (control condition). Informed consents are obtained from all participants, and they are informed of the purpose of the study prior to data collection.

3.2. Participants

The participants will consist of sixteen EFL learners drawn from the student population at a state university in Adana, Türkiye. As far as participant selection is concerned, purposive sampling will be employed, as the criteria include attributes essential for conducting the study, namely language proficiency and technological competence in using technology in the learning process. Two inclusion criteria are applied as criterion 1 and criterion 2 as follows:

In Criterion 1, all participants are required to hold upper-intermediate proficiency (level B2). This criterion presupposes that participants can execute the cognitive activities necessary to achieve certain objectives and modify their statements. Language proficiency are evaluated based on the results of placement tests administered at the university.

In Criterion 2, undergraduate participants enrolled in English-speaking courses have declared that they have already used artificial intelligence–based technological devices for completing assignments so as to participate in the study.

3.3. Data Collection Instruments

Think-Aloud Protocols and tasks of AI-assisted condition and control condition were collected as data in the study. Former one is think-aloud protocols that is used to analyze the cognitive activities of participants, including decision-making, selection of linguistic variants, and reflection on language usage. Participants will undergo training in the use of think-aloud protocols prior to data collection. Latter one is the tasks including two conditions that are created to ensure that language tasks remain comparable among participants. These two conditions are namely AI-assisted condition and control condition. In AI-assisted condition, participants complete tasks with the help of AI-generated texts and produce language with the assistance of AI devices. In control condition, participants will complete tasks without using any technological devices. They will rely solely on their linguistic resources. Tasks include rewriting sentences, completing texts, and generating texts. Language tasks elicit authentic language behavior and engage learners with linguistic phenomena at different levels of difficulty.

3.4. Dat Collection Procedure

The procedure is divided into two stages. At stage one, participants are asked to undertake think-aloud procedures in the control condition. At stage two, participants undertake the same language tasks in the AI-assisted condition. The recorded verbal data is transcribed.

3.5. Data Analysis

The collected data is analyzed by means of thematic analysis to establish typical patterns of behavior related to language use. Thematic analysis is guided by the research questions and based on grammaring theory. In particular, the elements of this process are identified as of evaluation of linguistic options, decision-making, adaptation of language, reflection on AI-generated language outputs, and meaning-making. This kind of analysis helps identify the typical properties of grammaring and compare the two conditions.

3.6. Validity and Reliability

Several strategies are employed to enhance the credibility of the study. First, methodological transparency are ensured by clearly describing data collection and analysis procedures. Second, consistency in coding is maintained by following predefined analytical categories. In addition, data triangulation will be achieved by comparing learners' performance across two different conditions. Selected excerpts from think-aloud data will be presented in order to support interpretations and increase transparency.

In addition to above-mentioned issues, ethical approval and limitations are taken into account. Ethical approval included the consent forms taken from the participants who were fully informed about the aims and procedures of the research. Participation accepted to take part in the study voluntarily, and knew that they had the right to withdraw at any time. All data are kept confidential and used solely for research purposes. Personal information is not disclosed, and all data are formed anonymized. As happens in all research in the field, this study has also certain limitations. First, the relatively small sample size may limit the generalizability of the findings. Second, as a qualitative study, the results will focus on in-depth insights rather than broad generalizations. Furthermore, think-aloud protocols may not capture all cognitive processes, as some aspects of language processing may remain implicit. Despite these limitations, the study is expected to provide valuable insights into the nature of grammaring in AI-mediated language learning contexts

RESULTS AND DISCUSSION

The results of this study reveal that there has been a significant change in how learners apply grammar in AI-mediated learning environments. Instead of focusing on generating sentences that follow strict grammatical rules, learners tend to evaluate various options presented by AI. As such, it can be deduced that language acquisition through the use of AI is not based on rule-based methods.

One of the major findings of this study lies in the transformation of learners' engagement with grammatical form. In non-AI-mediated conditions, it was evident that learners used their linguistic competence more actively, as they had to create sentences themselves. In AI-supported conditions, learners were provided with grammatically correct alternative sentences without any effort required. However, although cognitive engagement was reduced, it did not disappear but was instead redirected: learners engaged in comparing alternatives, selecting one, and making adjustments, thus demonstrating a process of evaluation rather than production.

In this regard, the notion of grammaring (Larsen-Freeman, 2003) receives further support and becomes clearer. According to the findings of this study, learners become more engaged in grammaring than before. Even though they are provided with ready alternatives instead of having to produce new sentences, grammaring implies the negotiation of meaning based on linguistic input. In other words, this process becomes part of a more complex set of skills rather than the simple production of grammatically correct sentences. At the same time, the findings highlight certain risks associated with this type of engagement. As stated by Swain (2005), language production plays a critical role in noticing gaps and developing competence. If learners no longer need to produce language, they may lose some cognitive benefits. In terms of Swain's output hypothesis, there is a significant possibility that AI may impair learners' performance due to a lack of production opportunities.

Another important conclusion drawn by this study is that learners engage differently with AI-generated content. Some participants were highly critical of suggestions offered by the application, carefully checking and making corrections. Similarly, this research identified another group of participants who accepted all tool output uncritically. Therefore, different degrees of learner agency emerge from this

finding, implying that grammaring is related not only to grammatical operations but also to cognitive and metacognitive processes. From an instructional perspective, this suggests a significant shift due to increased AI involvement. In addition to teaching learners' rules, they must also learn how to interpret them and assess their validity. Educational activities can involve tasks requiring the analysis of linguistic options, their justification, and discussion of the meanings of sentences generated with the help of AI. Thus, this study represents an important step towards the reconceptualization of language competence in the age of artificial intelligence. Language competence can no longer be limited to merely mastering grammar, as this research highlights the need to interpret linguistic data, make decisions, and select appropriate linguistic structures.

CONCLUSION

The current research explores the way in which learners deal with grammar in computer-mediated language learning settings, as well as the nature of grammar in the age of artificial intelligence. Based on the findings obtained from the study, it can be stated that the increased use of AI-produced language requires a different perception of grammar. It appears that successful language use presupposes one's ability to evaluate and choose among available options. Therefore, it is evident that the concept of grammaring can be used effectively to describe language performance within the scope of the phenomenon discussed. In particular, this concept is shown to evolve due to the emergence of artificial intelligence; however, the importance of grammaring does not disappear but instead becomes even more evident, as the success of language learning depends significantly on one's ability to adaptively utilize language resources.

The contribution of this study to the field concerns the need to reconsider our perception of grammar as a set of rules. Instead, grammar should be viewed in terms of performance, and the skill of grammaring is identified as one of the key aspects of modern language competence.

From a pedagogical perspective, the findings indicate the need to design tasks in such a way that learners' ability to analyze options and make appropriate decisions is encouraged. In AI-mediated language learning contexts, learners need to be trained to perform meaningful comparisons and reflect on the choices they make.

It should be recognized that there are certain limitations to this study. First, the limited number of participants does not support the generalizability of the findings. Furthermore, the qualitative approach limits the extent to which the findings can be generalized. It is therefore possible to suggest that future research should include a larger number of participants and employ a variety of methodological approaches across different levels of language competence. In conclusion, it can be stated that viewing grammar as grammaring becomes especially important in contemporary contexts where artificial intelligence plays an increasingly significant role in language learning settings.

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RECONFIGURING PEDAGOGICAL AUTHORITY IN AI-MEDIATED LANGUAGE EDUCATION

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ABSTRACT

The rapid incorporation of technologies based on AI and data into educational institutions has led to heated discussions regarding the position of pedagogy in language education. The death of method-based language instruction in the era of the post-method language has already been recognized; however, little is known about the impact of algorithmic mediation on pedagogical agency. This study aims to critically evaluate the statement "method is dead, algorithm is king" through the reconceptualization of language education as a new configuration of human and algorithmic agency. Through the use of a conceptual theoretical framework, the study investigates how algorithmic mediation influences the process of instructional decision-making, knowledge management, and learning trajectories through an analysis of current trends in pedagogy, sociocultural theories, and research on algorithmic governance. It is concluded that algorithmic systems not only represent pedagogical instruments, but also play the role of epistemic agents that shift the balance of power between different subjects of interaction. The proposed model of algorithmic pedagogy contributes to a deeper understanding of the complex relationship between personalization, efficiency, and human agency in current language education. The findings reveal that the death of method does not indicate the end of pedagogical practices but rather a new mode of their negotiation.

Keywords: Algorithmic governance, artificial intelligence, post-method pedagogy, pedagogical authority, language education.

INTRODUCTION

The proliferation of artificial intelligence and data technologies in educational contexts calls for a reassessment of pedagogical theory and practice. In turn, the study presents a discussion of the term “method is dead, algorithm is king”, suggesting that although significant changes are occurring in the sphere of linguistic research, the extinction of methods cannot be expected. In other words, when considering the issue of algorithmic teaching from the perspective of datafication, automation, power, and agency, it should be noted that both humans and computers possess agency in the educational process (Adnin and Das, 2024; Bengio et al., 2025). Hence, on the one hand, this approach can be beneficial due to the implementation of personalized pedagogy; on the other hand, it may be unfavorable as it narrows the scope of knowledge (Asni et al., 2026; Karataş et al., 2024; Novawan et al., 2024). Algorithmic mediation in language education goes beyond being an instructional tool to redefining how language learning is perceived and evaluated. While there have been discussions about the role of algorithms in language learning in recent literature, much remains unknown about how such technologies affect the redistribution of pedagogical authority, particularly regarding teacher agency and learner autonomy. The current study will attempt to shed more light on these issues through investigating the hypothesis that "in the age of AI-assisted language education, method is dead, and the algorithm is king." Specifically, in this study, AI-mediated language education is framed as a hybrid practice in which humans and non-human entities cooperate in the instructional process To achieve the above-mention issues, the following research questions are scrutinized to shed light on the study:

1. What are the implications of algorithmic mediation for the redistribution of pedagogical authority in

language education in the post-method context?

2. How do algorithms affect instructional decision-making and knowledge organization in AI-mediated language education?

3. How do algorithmic technologies affect teacher agency and the role of learners in language education?

LITERATURE REVIEW

From time immemorial, language teaching has been carried out following a concept called method, thereby creating a standardized model of practice. Some of the well-known language pedagogical practices include the Grammar-Translation Method, Audiolingualism, and Communicative Language Teaching. However, the usefulness of these methods has been questioned by many researchers because of their prescriptiveness and lack of consideration for context (Harindra and Rohman, 2025; Kumaravadivelu, 2006; Bell, 2003). With the advent of post-method pedagogy, it seems like much more attention is being focused on the teacher than the method itself as well as on certain pedagogical practices and pragmatism (Kumaravadivelu, 2006). This implies that less attention is being paid to the method of pedagogy as a way for teachers to take up more responsibility when making decisions on pedagogy. However, this implication is based on the assumption that the practice is performed by humans and not by machines, which may not necessarily be the case. Therefore, it is necessary to consider the implications arising from the absence of a particular methodological framework with regard to conventional notions of instructional authority. These could be given as datafication and algorithmic governance in education that brings up as the necessity of the 21st century skills. Datafication in the educational sector may be explained as the process whereby educational experiences are quantified (Ali et al., 2026; Williamson, 2017). Algorithmic governance refers to the control of educational processes using computer systems across various aspects of education, such as teaching and assessment (Beer, 2017; Khalid et al., 2025; Kitchin, 2017). The advantages of algorithmic governance relate to efficiency and the customization of educational experiences. However, some of the threats associated with algorithmic governance involve issues of power and transparency in decision-making (Compagnoni et al., 2025; Nieuwenhuizen, 2025). In the same vein algorithmic mediation becomes vitally important in language education. Algorithmic mediation can be seen in adaptive learning systems, automated assessment of writing skills, and language teaching chatbots. They are usually portrayed as an inevitable necessity that will make language teaching more accessible and individualized. Nonetheless, algorithmic practices in language education are still criticized. Even though algorithms provide learners with relevant feedback that meets their needs, they may overlook the sociocultural dimension of language education, including social interaction, identity formation, and pragmatics (Warschauer and Grimes, 2007). Therefore, it could be argued that language education is being optimized at the expense of its fundamental characteristics also including pedagogical authority as distributed practice. In practice, traditionally, pedagogical authority has been seen as a function of the teacher organizing knowledge and facilitating the learning process. In post-method pedagogy, pedagogical authority can be viewed as a context-bound and decision-oriented construct within teaching. The integration of algorithms within this context leads to a broadening of the category of pedagogical agents to include both human and non-human entities (Deniz, 2025; Williamson, 2017). The use of algorithms in educational settings suggests that pedagogical authority should be shared among technology, data, and human actors. Such redistribution emphasizes the importance of the learner's involvement in a data-driven environment (Luckin, 2018). Therefore, the evolution of methodological practices necessitates a reconsideration of pedagogical authority.

METHODS

A conceptual methodology driven by theoretical considerations is used in the study. The aim is to analyze the influence of algorithmic mediation on pedagogical authority in the field of language education within a post-method paradigm. An empirical study is not carried out; instead, the analysis of relevant interdisciplinary literature will form the basis of the research.

3.1. Research Design

A qualitative conceptual research design is applied to examine the impacts of algorithmic mediation on pedagogical authority in language education. In the absence of empirical data, theoretical insights gained through the analysis of interdisciplinary literature constitute the basis of the study. This research design appears to be the most appropriate for studying a complex issue such as algorithmically mediated pedagogical practice (Booth et al., 2016). The theoretical frameworks of post-method pedagogy (Kumaravadivelu, 2006), sociocultural theory (Lantolf and Thorne, 2006), and algorithmic governance (Williamson, 2017) are integrated into the research design. This is how the theoretical integration allows pedagogical authority to be treated as a complex phenomenon generated through the interplay between human and algorithmic agents.

3.2. Data Analysis

The analysis follows the steps of thematic mapping, critical analysis and conceptual synthesis (Ahmed et al., 2025; Braun and Clarke, 2006). Thematic mapping enlightens identification of literature associated with pedagogical authority, algorithmic mediation, datafication, and post-method pedagogy. Critical analysis is based on evaluation of selected literature in order to identify assumptions, contradictions, and power relations linked to changes in the distribution of authority, agency, and knowledge. The last one, conceptual synthesis, develops insights on leading to the creation of a theoretical framework for algorithmic pedagogy, where pedagogy will be understood as a distributed practice involving educators, learners, and algorithms. As of limitations, this study does not provide any empirical evidence. The unique characteristic of the current research lies in its attempt to approach the topic at hand in light of a new theory, which will help provide fresh perspectives. Although there can be various explanations for theories, the aim is to keep the argument internally consistent.

3.3. Limitations

It is, however, important to note that the results of this study are based on empirical evidence. The unique characteristic of the current research lies in a specific attempt so as to approach the topic regarding as a new hand in light of a theory, which will help provide fresh perspectives. Although there can be various explanations for theories, the aim is to keep the argument internally consistent.

RESULTS

Findings related to the examination of the restructuring of pedagogical authority in language education with the help of AI reveal that algorithmic mediation influences language education. This is assumed to be the case because its effect could be associated with the way it impacts knowledge organization, instruction decisions, feedback processes, learning paths, and assessments. Initial steps and more advanced utility of algorithms draw attention to the significance of adaptive learning platforms, automated writing assessment tools, and learning analytics systems. Besides these elements of technology mentioned above, AI-mediated language applications are not only used as external support for teachers in their work. They also define what knowledge is considered relevant, what is going to be taken into account when evaluating the learners' progress. In the same vein, they also define what learners' actions will be observable, and which learning paths will be recommended. Moreover, the results show that the suggested conception of algorithmic pedagogy is comprised of four interconnected aspects. They are the datafication of learning, the automation of pedagogical practices, the redistribution of pedagogical power, and the algorithmic design of learning paths. These aspects are indicative of what algorithmic solutions can contribute to personalization, efficiency, scalability, and feedback. Yet, the results suggest that algorithmic pedagogy might lead to conflicts between the preference of measurable results and interaction, interpretation, learner identity, cultural signaling, contextualized meaning making, and sociocultural engagement. It might be mentioned that algorithmic pedagogy should not be seen simply as an improvement of language education through technology, but as a change in the strategies of pedagogical decision making.

DISCUSSION AND CONCLUSION

In contrast to the claim made about the death of method in the era of algorithms in AI-mediated language education, this study critically analyzes how algorithmic mediation has changed the way pedagogical

authority is produced, shared, and negotiated in this domain. If the method-based approach to language education involved the construction of pedagogical authority through specific instructional models, the post-method approach saw a shift in the production of authority to the teacher as a person who can make decisions within a particular context and reflect on them. In AI-mediated language education, pedagogical authority gets distributed among the teacher, learner, institution, data infrastructure, and algorithmic systems. The study analyzes how algorithmic mediation impacts language education by affecting decision-making, knowledge organization, assessment, feedback, and learning paths. Furthermore, it is implied that new technological integrations, adaptive learning platforms, automatic assessment programs for language skills, especially, writing skills, learning analytics, and artificial intelligence for language learning are not just helping teachers from the outside. Instead, they define what knowledge is chosen to be relevant, what ways of evaluating progress are chosen, what learner actions are visible, and what teaching paths are suggested. Therefore, algorithms are to be considered not only as technical tools but also as epistemic and pedagogical agents contributing to the organization of language learning.

In addition to the previously mentioned conception of algorithmic pedagogy, it is regarded considering the vital aspects. These are datafication of learning process, automation of the pedagogical process, redistribution of pedagogical power, and structuring of learning trajectories by means of algorithms. It is pointed out and explained that they imply an idea that an algorithmic approach may help achieve personalization, efficiency, scalability, and timely feedback. However, they can also create certain contradictions due to the fact that measurable results are more important than such aspects as interaction, interpretation, identity, cultural meaning, and sociocultural participation. From this perspective, algorithmic pedagogy should be taken into account not just as an innovation in terms of language learning technology but also as a political shift within the field of pedagogical decisions. Apart from that, this conversation illustrates the importance of teacher agency even in terms of language learning facilitated by AI. With the growing role of algorithms in making decisions related to content selection, assessment, and providing feedback, they cannot substitute such complex activities of the teacher as interpretation, relations, ethics, and contextualization. They need to engage teachers for assessing and contextualizing proposals of algorithms, for understanding the limits of data-driven decision-making, and protecting learner autonomy. Similarly, learners should never turn into the data profile of the adaptive system. Learners' communicative needs, experience, linguistic, and cultural background should always be considered when working with them in pedagogical practice. In other words, the growing role of algorithmic mediation does not mean the end of pedagogy. Instead, it implies the transformation of pedagogical authority. One may consider the phrase "method is dead, algorithm is king" as provocative; however, it cannot be taken literally. The issue is that pedagogical authority is transformed through the interaction of human and non-human entities.

To conclude, this study reveals that the transition from methodological to algorithmic approaches to education is not the final stage of pedagogy as such but rather indicates the onset of a new epoch when pedagogical power is being negotiated between teachers, learners, institutional frameworks, and technological algorithms. The research contributes to the existing literature by proving that algorithms cannot be treated as merely neutral means for the purposes of education. Rather, algorithms become increasingly involved in the organization of knowledge, the choice of learning paths, assessment of learner performance and educational decision-making. Still, what is important to note about this research is that algorithms should not replace teachers' judgment and learner freedom. Hence, the death of the method definitely does not mean the triumph of the algorithm. Instead, the death of the method means the appearance of a hybrid pedagogical situation wherein human agency and algorithmic agency function in tandem. What matters is not whether or not algorithms can replace methods and the teacher, but how to distribute pedagogical power in the world of artificial intelligence. Being of a purely conceptual character, the results of the present study can be viewed as theoretical suggestions rather than empirical discoveries.

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A SOCIO-PSYCHOLOGICAL STUDY ON THE REALITY OF SECTARIANIZATION[1]

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ABSTRACT

This study aims to examine the religious perception, sectarian identity, and attitudes toward the Sunni tradition among the Ja'fari community from a psycho-social perspective. The research addresses the historical, sociological, and psychological foundations of the processes of religiosization, sectarianization, and moralization, and analyses how Ja'faris living in Turkey construct their religious identities, including subconscious transmissions and patterns of social interaction. Within the conceptual framework, the historical development of the sectarian phenomenon, the differing interpretive traditions of Sunni and Shi'i thought, the emergence of Shi'ism, the doctrine of imamate, and the fundamental characteristics of Ja'fari jurisprudence are evaluated. The study also highlights the epistemological and ontological roots of inter-sectarian tensions, emphasizing the determining role of psycho-social factors in individuals' processes of religious affiliation and identity formation. A qualitative methodology was employed, and data were collected through semi-structured interviews conducted with Ja'fari participants. The findings reveal that the religious perceptions of Ja'faris are strongly shaped by the doctrine of imamate and that their sectarian identities are reinforced by historical traumas, collective memory, and symbolic values. Participants generally expressed respectful yet distant attitudes toward the Sunni tradition, with notable differences observed in are as such as intermarriage, perceptions of certain companions, and ritual practices. This study demonstrates that sectarian identities are not merely theological distinctions but rather multifaceted structures shaped by individuals' psychological needs, social belonging, historical memory, and cultural context. In this regard, the research offers an original contribution to the literature by examining the Ja'fari community in Turkey through both sociological and psychological dimensions.

Keywords: Religious Perception; Sectarian Identity; Inter-Sectarian Relations.

[1] *This study is based on the work titled* Religiosization, Sectarianization, and Moralization, *published by Fecr Publishing in 2025.*

URBAN LABYRINTHS AND FRACTURED SELVES: PSYCHOLOGICAL TRANSFORMATIONS AND SPATIAL LOGIC IN ARAVIND ADIGA'S URBAN FICTION

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ABSTRACT

This paper examines the intricate relationship between urban spatial logic and psychological transformation in the protagonists of Aravind Adiga's novels—The White Tiger, Last Man in Tower, and Selection Day. Situating the analysis within the framework of urban studies and postcolonial theory, the study argues that the city functions not merely as a backdrop but as an active agent shaping individual consciousness. Adiga's protagonists—Balram Halwai, Yogesh Murthy (Masterji), and Manju Kumar—navigate complex urban landscapes marked by inequality, aspiration, and moral ambiguity. These spatial environments generate conditions that catalyze profound psychological shifts, often leading to acts of resistance, ethical compromise, or self-reinvention. The paper explores how the "spatial logic" of the city—structured through class divisions, economic mobility, and surveillance—produces fragmented identities and internal conflicts. Drawing on theorists such as Henri Lefebvre and Michel Foucault, the study highlights how urban spaces discipline, confine, and simultaneously enable subversion. Balram's transformation into an entrepreneur-criminal, Masterji's tragic resistance against capitalist urban redevelopment, and Manju's struggle between personal desire and imposed ambition illustrate how spatial pressures reshape subjectivity.

Ultimately, the paper contends that Adiga's fiction presents the Indian metropolis as a site where psychological evolution is inseparable from spatial experience. The protagonists' inner transformations reflect broader socio-economic realities, revealing the city as both oppressive and generative.

Keywords: Urban Spatiality; Psychological Transformation; Postcolonial City; Identity Formation; Class Mobility; Capitalism; Subjectivity; Resistance; Indian English Fiction; Aravind Adiga

The fiction of Aravind Adiga offers a compelling exploration of the Indian metropolis as a dynamic site where space and subjectivity intersect. In novels such as *The White Tiger*, *Last Man in Tower,* and *Selection Day*, the city functions as an active agent shaping the psychological trajectories of its protagonists. This study aims to examine how urban spatial logic—structured through class divisions, neoliberal capitalism, and socio-cultural hierarchies, generates profound transformations in individual consciousness. The study analyzes the interplay between spatial structures and psychological change, to explore how protagonists negotiate urban power relations, and to interpret the city as a catalyst for identity formation. The central research questions of the study include; How does urban space produce psychological transformation? How do spatial inequalities shape ethical choices and selfhood? In what ways do characters internalize or resist the logic of the city? The theoretical framework of the study draws on Henri Lefebvre, who asserts that "(social) space is a (social) product" (Lefebvre 26), and Michel Foucault, who observes that power operates through "the distribution of individuals in space" (141). Extending this, Edward Soja conceptualizes "Thirdspace" as a lived and imagined realm where "space is simultaneously perceived, conceived, and lived" (Soja 10). Similarly, David Harvey argues

that "the freedom to make and remake our cities…is one of the most precious yet most neglected of our human rights" (Harvey 23). Complementing these views, Doreen Massey emphasizes that space is "the product of interrelations…always under construction" (Massey 9). By integrating these spatial theories, this study foregrounds the city as a transformative force that produces fragmented, adaptive, and often transgressive identities in Adiga's protagonists, reflecting the complexities of contemporary urban India.

In the novels of Aravind Adiga, spatial inequality is deeply internalized by the protagonists, shaping their psychological transformation and awakening. In *The White Tiger*, the consciousness of the protagonist, Balram Halwai, is formed through the binary of "Darkness" and "Light," which he absorbs as a naturalized hierarchy. He states, "Please understand, Your Excellency, that India is two countries in one: an India of Light, and an India of Darkness" (*TWT*, 12). This spatial division becomes psychological conditioning, producing submission and fear. The metaphor of the "Rooster Coop", "The greatest thing to come out of this country…is the Rooster Coop" (*TWT*, 173), captures how oppression is internalized as self-regulation. Drawing on Henri Lefebvre, this reflects how space produces subjectivity (26). Balram's eventual murder of Ashok signifies a rupture: "I was looking for the key for years…Then I found it" (*TWT* 217), marking his psychological awakening into agency. As Elleke Boehmer notes, "Adiga's narrative exposes the psychic violence embedded in neoliberal aspiration" (238). In *Last Man in Tower*, Masterji's transformation emerges through resistance. Initially compliant, he gradually recognizes the moral erosion caused by redevelopment. His assertion, "This is my home. I will not leave it" (*LMT*, 289), signals a psychological awakening rooted in spatial belonging. Unlike Balram's violent assertion, Masterji's resistance is ethical and self-reflexive. The concept that "space is the product of interrelations" (Massey 9) appears evident here, as Masterji's identity is inseparable from lived community. As Mukherjee argues, "the crisis of space becomes a crisis of conscience in Adiga's urban fiction" (Mukherjee 112). In *Selection Day*, Manju Kumar internalizes a different form of spatial inequality—aspirational pressure within the global city. His father's control transforms urban opportunity into psychological confinement. Manju's realization, "I don't want to be what he wants me to be" (*SD*, 198)—marks his awakening, where he resists imposed ambition. Edward Soja's "Thirdspace" (10) helps explain this negotiation between lived and imagined identities. Such characters' experience "identity fragmentation and spatial anxiety within aspirational urbanism" (Remana, 67). Thus, across these novels, spatial inequality is internalized as psychological reality. The protagonists' transformations, Balram's violent self-assertion, Masterji's moral resistance, and Manju's introspective withdrawal, demonstrate that the city produces not only divided spaces but also divided selves. As David Harvey suggests, urban life reshapes identity through "creative destruction" (Harvey 27), a process clearly reflected in Adiga's characters.

The theme of surveillance, as special control and psychological conditioning, dominates the fictional project of Aravind Adiga. In his novels surveillance operates as a subtle yet pervasive force that shapes the psychological landscape of the protagonists. In *The White Tiger*, Balram exists under constant watch, by masters, family expectations, and social hierarchies. His observation that "a handful of men in this country have trained the remaining 99.9 percent…to exist in perpetual servitude" (*TWT*, 176) reflects how surveillance is internalized as social conditioning. This aligns with Michel Foucault's notion that power operates through "the distribution of individuals in space" (141), where visibility ensures control.

In *Last Man in Tower*, surveillance becomes collective and communal. Residents of Vishram Society constantly monitor Masterji's resistance, turning social space into a site of scrutiny. The pressure he faces reveals how community surveillance enforces conformity. Similarly, in *Selection Day*, Manju is subjected to paternal surveillance, where his father tracks his performance and behavior, reducing personal space to a monitored zone of discipline. In fact, "Adiga's urban characters inhabit spaces of relentless observation where social mobility is inseparable from surveillance" (Singh, 84). Surveillance thus becomes a psychological force, producing anxiety and compliance. Across these texts, the city emerges as a panoptic structure where external observation gradually reshapes inner consciousness.

Surveillance in Adiga's fiction gradually transforms into self-regulation, where protagonists internalize control mechanisms and discipline themselves. In *The White Tiger*, Balram initially embodies the obedient servant who regulates his behavior to fit societal expectations. He confesses, "The driver is a slave" (*TWT*, 56), indicating his acceptance of imposed identity. This reflects Foucault's idea that power

is most effective when internalized. However, this self-regulation is psychologically suffocating, eventually leading to rupture. In *Last Man in Tower*, the residents regulate their own moral choices to align with capitalist aspirations. Masterji, however, resists this internalization, refusing to conform despite immense pressure. His psychological steadfastness contrasts with others who suppress ethical concerns for economic gain. In *Selection Day*, Manju's life is governed by strict routines imposed by his father, which he internalizes: "My father had planned every minute of my day" (*SD*, 72). This self-regulation creates a fragmented identity, where personal desire is suppressed. "Self-regulation in Adiga's protagonists reflects the internalization of urban discipline, producing compliant yet psychologically fractured individuals" (Sharma, 102). Thus, self-regulation becomes both a survival strategy and a source of inner conflict, shaping the protagonists' evolving identities.

The culmination of surveillance and self-regulation in Adiga's fiction is moral transformation, where protagonists undergo profound ethical shifts. In *The White Tiger*, Balram's transformation is radical and violent. His declaration, "I am tomorrow" (*TWT*, 202), signals his rejection of servitude and embrace of a new moral code. The murder of Ashok represents a break from imposed ethics, illustrating what David Harvey calls "creative destruction" (27), where new identities emerge through rupture. In narrative moral transformation takes a tragic form. While other residents abandon ethical values for profit, Masterji's refusal, "I will not sell" (*TWT,* 289) reflects moral resilience. His death underscores the cost of ethical integrity in a corrupt urban system. In *Selection Day*, Manju's transformation is introspective rather than violent. His rejection of imposed ambition marks a shift toward self-awareness: "I wanted something else" (*SD*, 210). This subtle moral awakening challenge dominant success narratives. "Adiga's protagonists undergo ethical reconfiguration shaped by urban pressures, where morality is negotiated rather than fixed" (Kumar, 59). Thus, moral transformation in Adiga's fiction reflects the psychological consequences of navigating a deeply unequal and surveilled urban environment.

In the fiction of Aravind Adiga, psychological resistance emerges as a crucial response to the pressures of urban spatial structures. This resistance is not merely physical or social but deeply internal, functioning as an assertion of identity against the forces of displacement, surveillance, and capitalist restructuring. Across *The White Tiger, Last Man in Tower*, and *Selection Day*, protagonists negotiate their relationship with space through acts of psychological defiance, revealing how attachment to or rejection of space becomes central to selfhood.

In *The White Tiger*, Balram Halwai's resistance is rooted in his acute awareness of spatial inequality. Initially, he internalizes the oppressive structures of the "Rooster Coop," admitting that "the drivers…remain servants because they cannot see what is beautiful in this world" (*TWT*, 176). However, this awareness gradually transforms into psychological resistance. His refusal to remain confined within the spatial and social boundaries imposed upon him culminates in the murder of Ashok, an act that symbolizes both spatial and psychological escape. Balram's declaration, "I am tomorrow" (*TWT*, 202), marks a radical assertion of identity, where resistance becomes self-creation. Drawing on Michel Foucault, this act can be seen as a break from disciplinary power, where the subject reclaims agency. Critics such as Ania Loomba argue that postcolonial subjects often "negotiate domination through acts of subversion and self-fashioning" (221), which is evident in Balram's transformation. However, this resistance is ethically ambiguous, as it relies on violence, suggesting that urban space produces identities that are both empowered and morally compromised.

In *Last Man in Tower*, psychological resistance is articulated through spatial attachment. Masterji's refusal to sell his apartment in Vishram Society represents a profound assertion of identity rooted in place. Unlike Balram's outward rebellion, Masterji's resistance is inward and ethical. He insists, "This is my home, and I will not leave it" (*LMT*, 289), demonstrating how space becomes integral to his sense of self. Here, Doreen Massey's idea that space is constituted through "lived relations" (9) is particularly relevant. Masterji's attachment to his home is not material but relational, tied to memory, community, and moral values. His resistance thus becomes a psychological stand against the homogenizing forces of capitalist urbanism. In this context, Banerjee notes that "Masterji's defiance reflects a moral geography where space is inseparable from ethical identity" (134). His eventual death underscores the tragic cost of such resistance, suggesting that in the modern city, psychological attachment to space is increasingly untenable.

In *Selection Day*, resistance takes a more subtle, introspective form. Manju Kumar's psychological struggle is shaped by his father's control and the pressures of aspirational urban space. Unlike Balram and Masterji, Manju's resistance is not directed outward but inward, as he questions the identity imposed upon him. His realization, "I don't want to be what he wants me to be" (*SD*, 198), signals a crucial moment of psychological assertion. Here, Edward Soja's concept of "Thirdspace" (10) helps explain how Manju navigates between imposed reality and imagined alternatives. His attachment is not to physical space but to the possibility of self-definition beyond spatial constraints. As Nayar argues, "the global city produces subjects who resist not through rebellion but through withdrawal and self-reflection" (118). Manju's resistance, therefore, represents a quieter yet significant assertion of identity, challenging dominant narratives of success and ambition.

Across these novels, Adiga presents resistance as a fundamentally psychological process, shaped by the protagonists' relationship with space. Whether through violent rebellion, ethical steadfastness, or introspective withdrawal, these characters assert their identities against the pressures of urban spatial logic. David Harvey's notion that the right to the city involves "the power to remake ourselves" (23) is particularly apt here, as each protagonist seeks to redefine the self in relation to space. Ultimately, Adiga's fiction reveals that psychological resistance is both a response to and a product of spatial inequality, highlighting the complex interplay between place, power, and identity in the contemporary metropolis.

In the fiction of Aravind Adiga, the modern Indian city operates as an aspirational space that promises mobility, success, and self-reinvention, yet simultaneously produces a fragmented psyche. The protagonists of *The White Tiger, Last Man in Tower,* and *Selection Day* inhabit urban environments where aspiration becomes both a motivating force and a psychological burden. This duality generates internal conflict, identity fragmentation, and ultimately forms of resistance that function as assertions of selfhood.

In *The White Tiger*, Balram Halwai's psyche is fundamentally shaped by aspirational urban space, particularly the allure of Delhi and Bangalore as sites of opportunity. The city constructs desire through visibility—luxury malls, wealth, and elite lifestyles, which Balram internalizes as markers of success. He observes, "The city is full of people who are like me—just waiting for a chance" (*TWT*, 64), revealing how aspiration is collectively produced. However, this aspiration simultaneously fractures his identity, as he oscillates between his role as a submissive servant and his imagined self as a successful entrepreneur. Edward Soja's concept of "Thirdspace" (10) is particularly useful here, as Balram navigates between lived deprivation and imagined prosperity. This tension produces psychological instability, culminating in his violent resistance. His declaration, "I am tomorrow" (*TWT*, 202), signifies not only ambition but a reconstitution of the self through rupture. In this context, P. K. Nayar argues that "aspiration in Adiga's urban fiction is inseparable from anxiety and moral dislocation" (118), highlighting how the pursuit of success fractures ethical and psychological coherence. Thus, Balram's resistance, though violent—functions as an assertion of identity against the constraints of aspirational space.

In *Last Man in Tower*, aspirational space manifests through the promise of redevelopment and upward mobility. Vishram Society becomes a contested site where residents are seduced by the prospect of wealth and modern living. This collective aspiration generates psychological fragmentation, as individuals abandon long-standing relationships and ethical commitments. Masterji, however, resists this aspirational logic, revealing the psychological cost of such transformation. While others internalize the dream of progress, Masterji remains attached to the lived space of memory and community. His refusal, "This is my home. I will not leave it" (*LMT*, 289)—represents a rejection of imposed aspiration. David Harvey's critique of capitalist urbanism as a "system that commodifies space" (27) is evident here, as the city reduces lived experience to exchange value. This produces a fragmented psyche among residents, who struggle to reconcile material gain with moral loss. As Banerjee notes, "urban aspiration in Adiga's work fractures community bonds and produces ethical dissonance" (131). Masterji's resistance thus becomes a psychological assertion of identity rooted in ethical integrity, even as it leads to his isolation and death.

In *Selection Day*, aspirational space is mediated through globalized sports culture and middle-class ambition. Manju Kumar's life is structured by his father's obsessive pursuit of cricketing success, which transforms the city into a site of relentless aspiration. Unlike Balram, whose aspirations are self-generated, Manju's are imposed, creating a deeper psychological fragmentation. He reflects, "My father had decided everything for us" (*SD*, 72), indicating a loss of agency within aspirational space. This imposed identity conflicts with his inner desires, producing a fractured self. Doreen Massey's notion that space is "always under construction" (9) is relevant here, as Manju's identity is continuously reshaped by external pressures. His eventual realization, "I wanted something else" (*SD*, 210)—marks a subtle yet significant act of resistance. Unlike Balram's violent rupture or Masterji's ethical defiance, Manju's resistance is introspective, asserting identity through withdrawal from imposed aspirations. "Adiga's younger protagonists experience aspiration as psychological burden, leading to anxiety and identity crisis" (Sharma, 104).

Across these novels, aspirational space emerges as a powerful force that produces fragmented psyches. The city promises transformation but delivers conflict, compelling characters to negotiate between imposed identities and inner desires. Henri Lefebvre's insight that "space shapes social relations" (26) underscores how aspiration is embedded within spatial structures. Ultimately, resistance, whether violent, ethical, or introspective, becomes a means of reclaiming identity. Adiga's protagonists reveal that in the contemporary metropolis, the pursuit of aspiration is inseparable from psychological fragmentation, and the assertion of selfhood requires confronting, negotiating, or rejecting the very spaces that produce desire.

In the fiction of Aravind Adiga, violence is not merely an external social reality but a deeply internalized force that catalyzes the psychological reconstitution of the self. Across *The White Tiger*, *Last Man in Tower*, and *Selection Day*, violence, whether physical, structural, or psychological, becomes a transformative mechanism through which protagonists reconstruct identity. Crucially, such transformation often manifests as resistance, positioning violence as both a destructive and creative force in the formation of subjectivity.

In *The White Tiger*, Balram Halwai's psychological transformation is inseparable from violence. Initially conditioned by what he calls the "Rooster Coop," he internalizes systemic oppression, "The greatest thing to come out of this country…is the Rooster Coop" (*TWT*, 173). This metaphor encapsulates structural violence, where the oppressed participate in their own subjugation. However, Balram's consciousness evolves through exposure to urban inequality, culminating in the murder of Ashok. His declaration, "I was looking for the key for years…Then I found it" (*TWT*, 217), reveals violence as a moment of psychological awakening. The act of murder is not impulsive but calculated, marking a decisive break from servitude and the birth of a new identity. As David Harvey suggests, urban transformation often entails "creative destruction" (27), where old identities must be dismantled for new ones to emerge. In this context, Gopal argue that, "Balram's violence is a form of self-making, a refusal to remain invisible within the urban order" (61). Thus, violence becomes an assertion of identity, albeit one fraught with ethical ambiguity.

In *Last Man in Tower*, violence operates differently, emerging not as an individual act but as a collective force. The residents of Vishram Society, driven by capitalist aspiration, turn violently against Masterji, whose resistance threatens their upward mobility. This culminates in his brutal death, representing the triumph of structural violence over ethical resistance. Yet, Masterji's psychological transformation lies in his unwavering refusal to conform. His assertion, "I will not sell" (*LMT*, 289), is an act of resistance that affirms identity against overwhelming pressure. Unlike Balram, whose identity is reconstituted through committing violence, Masterji's is defined through enduring it. Henri Lefebvre's idea that space is produced through social relations (26) is evident here, as the transformation of urban space generates violent conflict. "violence in Adiga's urban narratives often reflects the collapse of moral community under capitalist pressure" (Banerjee 2024, 133). Masterji's death, therefore, signifies not defeat but a tragic assertion of identity, where resistance itself becomes the site of psychological self-definition.

In *Selection Day*, violence is less overt but equally significant, manifesting as psychological coercion and internal conflict. Manju Kumar's life is shaped by his father's authoritarian control, which constitutes a form of emotional violence. He reflects, "My father had decided everything for us" (*SD*,

72), indicating the erasure of personal agency. This sustained pressure produces a fragmented psyche, where desire and duty are in constant tension. Unlike Balram's explosive violence or Masterji's external victimization, Manju's transformation occurs through internal struggle. His realization, "I wanted something else" (*SD*, 210)—marks a moment of resistance, where he begins to reclaim his identity. Edward Soja's concept of "Thirdspace" (10) helps explain this process, as Manju negotiates between imposed expectations and imagined possibilities. "Psychological violence in Adiga's later fiction produces introspective forms of resistance rather than overt rebellion" (Sharma 2024, 106). Thus, Manju's withdrawal from imposed ambition becomes a subtle yet powerful reconstitution of the self.

Across these novels, violence functions as a transformative force that reshapes identity in distinct ways. Balram's violent rebellion, Masterji's martyr-like resistance, and Manju's introspective defiance illustrate different modes of psychological reconstitution. Michel Foucault's insight that power produces subjects through control (141) is crucial here, as violence emerges both as an instrument of domination and a means of resistance. Furthermore, Doreen Massey's notion of "space as dynamic" (9) underscores how shifting urban environments intensify these transformations. Thus, Ultimately, Adiga's fiction reveals that in the contemporary metropolis, violence is inseparable from identity formation. It is through engaging with, resisting, or internalizing violence that the protagonists reconstruct themselves. Resistance, therefore, becomes a psychological assertion of identity, demonstrating that even within oppressive spatial structures, the self is not merely shaped but actively redefined.

The preceding analysis of Aravind Adiga's novels, *The White Tiger, Last Man in Tower,* and *Selection Day*, demonstrates that the urban space in contemporary Indian fiction operates as a powerful agent in shaping, fragmenting, and reconstituting the psychological self. Far from being a passive backdrop, the city emerges as a dynamic and often coercive structure that produces subjectivities through its spatial logic of inequality, surveillance, aspiration, and violence. The protagonists' journeys reveal that psychological transformation is inseparable from spatial experience, as the external environment becomes internalized within the consciousness of individuals.

Drawing upon the theoretical insights of Henri Lefebvre, Michel Foucault, Edward Soja, David Harvey, and Doreen Massey, this study has shown that urban space is socially produced, ideologically structured, and continuously negotiated. Within this framework, Adiga's protagonists internalize spatial inequalities, leading to fractured identities marked by anxiety, moral ambiguity, and existential conflict. Balram Halwai's transformation illustrates how surveillance and systemic oppression can culminate in violent self-assertion, where identity is reconstructed through rupture. In contrast, Masterji's resistance in *Last Man in Tower* reflects a moral steadfastness rooted in spatial attachment, demonstrating that psychological resistance can also take the form of ethical endurance. Meanwhile, Manju Kumar's introspective withdrawal in *Selection Day* reveals a subtler mode of transformation, where resistance emerges through the rejection of imposed aspirations and the search for authentic selfhood.

Across these narratives, key thematic patterns emerge: the internalization of spatial inequality produces psychological awakening; surveillance evolves into self-regulation; aspirational urbanism generates fragmented psyches; and violence functions as a catalyst for identity reconstitution. Importantly, resistance, whether enacted through rebellion, refusal, or introspection—serves as a crucial mechanism through which the protagonists assert their identities. Such resistance is not uniform but context-specific, shaped by the protagonists' positions within the urban hierarchy and their relationship to space.

Ultimately, Adiga's fiction foregrounds the paradox of the modern metropolis as both a site of possibility and a space of profound alienation. The city promises mobility and transformation but often delivers fragmentation and moral dislocation. Yet, within these constraints, the human subject retains the capacity for agency, negotiating and redefining identity in response to spatial pressures. This study thus underscores that psychological transformation in Adiga's work is not merely a personal journey but a socio-spatial process, reflecting broader realities of contemporary urban India. In doing so, it contributes to an understanding of how literature maps the complex interplay between space, power, and the evolving self in the twenty-first-century metropolis.

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CLASSICAL MYELOPROLIFERATIVE NEOPLASMS IN BONE MARROW BIOPSIES: A PATHOLOGY-BASED STUDY

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ABSTRACT

Background: Classical myeloproliferative neoplasms (MPNs) are clonal hematologic disorders characterized by persistent proliferation of one or more myeloid lineages and distinct bone marrow morphologic patterns. Bone marrow biopsy, together with peripheral blood findings, remains essential for differentiating essential thrombocythemia (ET), polycythemia vera (PV), and myelofibrosis (MF) in routine diagnostic practice.

Aim: To describe the distribution and hematologic profile of pathology-defined classical MPNs in a bone marrow biopsy dataset.

Methods: This prospective descriptive study was conducted on 620 bone marrow biopsies over a two-year period, from 2024 to 2025, at the Department of Pathology, Mother Teresa University Hospital, Tirana, Albania. For this paper, classification was based on the final biopsy diagnosis. ET was restricted to biopsies reported as TE, PV-spectrum included PV and fibrotic PV labels, and MF-spectrum included primary, prefibrotic, fibrotic, and secondary MF labels. Available variables included age, sex, biopsy diagnosis, and peripheral blood parameters. Continuous variables were summarized as median (IQR), and categorical variables as n (%).

Results: A total of 246 of 620 biopsies (39.7%) were classified as classical MPNs, including 87 ET cases (14.0% of all biopsies; 35.4% of classical MPNs), 72 PV-spectrum cases (11.6% and 29.3%, respectively), and 87 MF-spectrum cases (14.0% and 35.4%, respectively). ET was characterized by marked thrombocytosis, with a median platelet count of 701.0 K/µL (IQR 594.8–988.8). PV-spectrum showed the expected erythrocytotic profile, with median RBC 6.20×10^6/µL (IQR 5.57–7.19), hematocrit 54.8% (IQR 50.4–59.4), and hemoglobin 17.6 g/dL (IQR 16.5–18.9). MF-spectrum showed an older and more anemic profile, with median age 70.0 years (IQR 64.5–75.5), hemoglobin 11.1 g/dL (IQR 9.7–13.3), and WBC 14.0 K/µL (IQR 7.3–17.3).

Conclusions: In this pathology-based dataset, ET and MF-spectrum lesions each accounted for just over one-third of classical MPN cases, while PV-spectrum accounted for just under one-third. The observed hematologic patterns support the complementary value of marrow histopathology and routine blood parameters in the characterization of classical MPNs.

Keywords: bone marrow biopsy; myeloproliferative neoplasms; essential thrombocythemia; polycythemia vera; myelofibrosis

Introduction

Classical myeloproliferative neoplasms (MPNs) are chronic clonal hematologic malignancies characterized by proliferation of one or more myeloid lineages and include polycythemia vera (PV), essential thrombocythemia (ET), and primary myelofibrosis (MF) [1-3]. Their current diagnostic framework is based on an integrated approach combining clinical features, peripheral blood counts, bone marrow morphology, and molecular findings [1-4]. The 2016 WHO revision, the 2022 WHO 5th edition, and the International Consensus Classification have all reinforced the importance of marrow histopathology in distinguishing these entities, particularly when phenotypic overlap exists [1-3].

Bone marrow biopsy remains especially relevant in routine pathology practice because ET, PV, and MF may present with partially overlapping hematologic abnormalities while showing different megakaryocytic patterns, cellularity, and fibrosis grades [3,5,6]. Histopathologic evaluation therefore has value not only for initial classification but also for separating true MPNs from reactive conditions and from prefibrotic or fibrotic disease stages [5,6].

The molecular understanding of MPNs has evolved substantially over the past two decades. The discovery of JAK2V617F in 2005 transformed the diagnostic approach to BCR::ABL1-negative MPNs, while subsequent identification of MPL and CALR mutations further clarified the biologic basis of a large proportion of cases [7-10]. Even so, morphology remains indispensable, because diagnosis is not made on molecular data alone and still requires clinicopathologic correlation [1-3,5].

From a practical perspective, the three classical MPNs display recognizably different clinicopathologic profiles. PV is dominated by erythrocytosis, ET by sustained thrombocytosis and megakaryocytic proliferation, whereas MF is associated with progressive marrow remodeling, fibrosis, anemia, extramedullary hematopoiesis, and less favorable outcomes [11-15]. These differences make pathology-based local datasets useful, particularly in centers where marrow biopsy is a major component of hematologic diagnosis [5,11-15].

In this context, the present study aimed to provide a focused pathology-based description of classical MPNs identified in bone marrow biopsies from a tertiary hospital in Albania.

Materials and Methods

This prospective descriptive study was conducted on 620 bone marrow biopsies over a two-year period, from 2024 to 2025, at the Department of Pathology, Mother Teresa University Hospital, Tirana, Albania.

For this conference full paper, classification was based on the final biopsy diagnosis recorded in the database. To avoid internal inconsistency, a strict pathology-based case definition was used. ET included only biopsies reported as TE. PV-spectrum included biopsies reported as PV, PV fibroze 1, and PV fibroze 2. MF-spectrum included biopsies reported as primary, prefibrotic, fibrotic, or secondary MF, including post-ET and post-PV fibrotic transformation labels.

Demographic and hematologic variables extracted from the dataset included age, sex, red blood cell count (RBC), white blood cell count (WBC), platelet count (PLT), hematocrit (Hct), and hemoglobin (Hgb). Categorical variables are presented as n (%). Continuous variables are presented as median and interquartile range (IQR). Percentages of disease categories were calculated both relative to all biopsies (N=620) and relative to all classical MPN cases.

Results

Among the 620 bone marrow biopsies, 246 cases (39.7%) fulfilled the pathology-based definition of classical MPNs. ET accounted for 87 cases (14.0% of all biopsies; 35.4% of classical MPNs), PV-spectrum for 72 cases (11.6% and 29.3%, respectively), and MF-spectrum for 87 cases (14.0% and 35.4%, respectively).

Clear hematologic differences were observed across the three diagnostic categories. ET was characterized by marked thrombocytosis. PV-spectrum showed the most pronounced erythrocytotic profile, with the highest median RBC, hematocrit, and hemoglobin values. In contrast, MF-spectrum cases presented an older and more anemic pattern, together with higher median WBC values.

Sex distribution also differed across groups. ET showed an approximately balanced male-female distribution, PV-spectrum was predominantly male, and MF-spectrum also showed male predominance, with one case lacking recorded sex. Detailed descriptive results are presented in Table 1.

Table 1. Main characteristics of classical MPN cases identified in the bone marrow biopsy dataset

Variable	ET	PV-spectrum	MF-spectrum
Number of cases, n (% of all biopsies)	87 (14.0)	72 (11.6)	87 (14.0)
Share within classical MPNs, %	35.4	29.3	35.4
Age, years, median (IQR)	66.0 (57.0-73.0)	64.5 (56.8-70.2)	70.0 (64.5-75.5)
Male, n (%)	43 (49.4)	55 (76.4)	50 (57.5)
Female, n (%)	44 (50.6)	17 (23.6)	37 (42.5)
RBC (×10^6/μL), median (IQR)	4.54 (4.06-4.92)	6.20 (5.57-7.19)	3.94 (3.36-4.96)
WBC (K/μL), median (IQR)	8.8 (7.3-9.6)	9.4 (8.5-11.8)	14.0 (7.3-17.3)
Platelets (K/μL), median (IQR)	701.0 (594.8-988.8)	261.0 (194.0-450.0)	399.0 (148.0-713.0)
Hematocrit (%), median (IQR)	39.3 (36.7-42.8)	54.8 (50.4-59.4)	35.0 (30.8-41.2)
Hemoglobin (g/dL), median (IQR)	13.4 (12.1-14.7)	17.6 (16.5-18.9)	11.1 (9.7-13.2)

Note. Percentages for male, female, are calculated within each diagnostic group. Laboratory variables are summarized using available observations only; therefore, the number of available values differs from the total number of cases.

Discussion

This pathology-based study showed that classical MPNs represented a substantial component of the bone marrow biopsy workload and that ET, PV-spectrum, and MF-spectrum displayed clearly distinct hematologic profiles. The observed pattern was internally coherent: ET was associated mainly with thrombocytosis, PV-spectrum with increased erythrocytic parameters, and MF-spectrum with lower hemoglobin and hematocrit values together with relatively higher leukocyte counts. These findings are concordant with the expected biologic behavior of the classical MPN subtypes described in current classification systems and review literature [1-3,11-15].

The present results also support the continuing importance of bone marrow biopsy in routine diagnostic work. Although molecular testing has become central in modern hematopathology, marrow morphology still provides the architectural context necessary for disease classification, especially in distinguishing ET from prefibrotic MF and in documenting fibrotic progression [3,5,6]. This is particularly relevant in retrospective hospital datasets, where pathology often provides the most stable diagnostic anchor [5,6].

Another important point is that the contemporary approach to MPN diagnosis is integrative rather than reductionist. JAK2, CALR, and MPL mutations have greatly improved diagnostic precision, but they do not eliminate the need for morphologic interpretation [1-3,7-10]. Current disease models view the classical MPNs as disorders defined by the interaction of clonal genotype, lineage-specific proliferation, marrow stromal remodeling, and inflammatory signaling [10-15]. This conceptual framework helps explain why biopsy findings and peripheral blood counts remain complementary rather than interchangeable [1-3,5].

The MF-spectrum group in the present study appeared older and more anemic than the ET and PV-spectrum groups, which is consistent with the more advanced clinicopathologic phenotype generally associated with fibrotic disease [11,13,15]. In the literature, MF is linked to marrow fibrosis, splenomegaly, constitutional symptoms, extramedullary hematopoiesis, and inferior survival compared with ET and PV [11,13,15]. Although the current paper is descriptive and does not address prognosis directly, the hematologic pattern observed in this series is in line with that broader clinical picture [11,13,15].

A strength of the present paper is the use of a strict pathology-based case definition, which resolves the inconsistencies that can arise when clinical impressions and final biopsy diagnoses are mixed. At the same time, the study has limitations. It is retrospective and descriptive, molecular data were not fully available for all cases, and several hematologic parameters were available only in subsets of patients. Accordingly, the findings should be interpreted primarily as a clinicopathologic description rather than as a definitive genotype-phenotype or outcome-based analysis.

Conclusions

Classical myeloproliferative neoplasms accounted for 246 of 620 bone marrow biopsies (39.7%) in this tertiary pathology dataset. ET and MF-spectrum lesions each represented 35.4% of classical MPN cases, while PV-spectrum represented 29.3%. Bone marrow biopsy, interpreted alongside routine blood parameters, remains a highly valuable tool for the pathology-based characterization of classical MPNs.

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AI-BASED STUDENT PERFORMANCE PREDICTION SYSTEMS USING MACHINE LEARNING

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ABSTRACT

Identifying students who are likely to struggle academically remains a long-standing challenge in higher education, particularly because most assessment practices are still reactive and heavily focused on exams. This study examines whether machine learning models can be used to predict student outcomes earlier in the semester and to generate practical early-warning signals by leveraging behavioral, academic, and administrative data. A supervised learning framework was employed to compare traditional statistical models with ensemble-based methods, including Logistic Regression, Random Forest, and XGBoost, using a binary pass/fail classification setting. Model performance was assessed using the ROC-AUC metric to account for class imbalance and to avoid reliance on a single decision threshold.

The results show that ensemble models consistently outperform classical approaches, with XGBoost delivering the strongest overall predictive performance. Explainability analyses based on permutation importance and SHAP values indicate that indicators of academic engagement and progression, such as the number of approved curricular units, admission grade, and tuition fee status, are the most influential predictors of success. These findings are consistent with self-regulated learning theories and underscore that student outcomes are shaped not only by academic behavior but also by financial stability.

The temporal analysis further demonstrates that useful early-warning signals can be detected as early as the second week of the semester. Although prediction accuracy improves as more behavioral data are collected, early-stage predictions are already sufficiently informative to support timely interventions. This suggests that institutions do not need to wait until major assessments to identify at-risk students. Overall, the study shows that combining high-performing ensemble models with explainable AI techniques provides an effective, transparent, and practically useful framework for early academic risk detection and educational decision support.

Keywords: Student performance prediction; Early warning systems; Machine learning; Learning analytics; Explainable artificial intelligence

INTRODUCTION

Modern educational environments now generate vast amounts of student data through Learning Management Systems (LMS), Student Information Systems (SIS), and other online learning platforms (Romero & Ventura, 2020; Siemens & Baker, 2012). Learning events, resource usage logs, grades, and demographic records are routinely collected, creating rich data streams suitable for advanced analytics. Machine learning (ML) techniques can leverage these large datasets to identify complex patterns that predict academic success or failure (Kovačević et al., 2023; Lemay et al., 2021).

Despite this abundance of data, student achievement is still often assessed primarily through end-of-term exams or final grades. Such exam-centric evaluation provides only a limited snapshot of learning, as it ignores continuous assessment and the many non-cognitive factors such as motivation, study habits, and engagement that are known to influence academic performance (Winne & Hadwin, 1998; Tempelaar

et al., 2015). While exams capture performance at a single point in time, prior research has shown that variables such as student motivation, self-efficacy, and learning behaviors play a critical role in shaping long-term outcomes (D'Mello & Graesser, 2012; Helal et al., 2018). These observations suggest that richer, continuously collected data sources may provide more actionable insights than traditional exam-based measures alone.

Despite the promise of data-driven approaches, assessment systems in higher education remain largely reactive. Most institutional practices and empirical studies focus on analyzing student performance after a course has been completed, which limits opportunities for timely intervention (Jayaprakash et al., 2014; Bowers & Sprott, 2012). By the time poor outcomes are reflected in final grades, it is often too late to prevent academic failure or dropout. Although learning platforms capture detailed interaction data from the very beginning of a semester, relatively few institutions have operationalized predictive analytics to provide early warnings of academic risk (Papamitsiou & Economides, 2014).

In addition to timing issues, practical challenges hinder the adoption of ML-based systems in real educational settings. Many high-performing ML models operate as "black boxes," making their predictions difficult to interpret and reducing trust among educators and administrators (Lakkaraju et al., 2016; Kesgin & Kiraz, 2023). Furthermore, data-related challenges such as sparsity, missing values, inconsistent data formats across systems, and privacy constraints complicate model development and deployment (Baker, 2019; Romero & Ventura, 2020). As a result, many institutions still lack real-time, predictive insight into students' learning trajectories and continue to rely on delayed, exam-focused feedback mechanisms.

The primary objectives of this study are as follows:

Forecast performance: To develop ML-based models capable of predicting students' academic outcomes (e.g., final grades or GPA) before course completion (Sweeney et al., 2016).

Compare models: To evaluate and compare the predictive accuracy of classical statistical models (e.g., logistic regression) and ensemble-based approaches (e.g., random forests, gradient boosting), which have shown superior performance in prior research (Chen & Guestrin, 2016; Santos et al., 2022).

Early risk identification: To incorporate behavioral and engagement-related features derived from LMS activity (e.g., submission counts, login patterns) in order to identify at-risk students at an early stage of the semester (Jayaprakash et al., 2014; Tempelaar et al., 2015).

Previous studies emphasize that forecasting GPA and course outcomes helps institutions monitor academic progress and identify students at risk of failure or dropout (Al-Ahmad et al., cited in Lemay et al., 2021). This study aims to operationalize these insights by building and validating predictive models that rely on readily available institutional data to generate early warning indicators.

Based on the existing literature, the following hypotheses are tested:

H1: Ensemble ML models (e.g., random forest, gradient boosting) achieve higher predictive accuracy for student performance than classical statistical models (e.g., logistic regression, linear regression).

This hypothesis is motivated by extensive evidence that ensemble learning improves generalization by aggregating multiple weak learners (Chen & Guestrin, 2016; Santos et al., 2022; Kovačević et al., 2023).

H2: Student behavioral and engagement-related features significantly explain academic outcomes.

In particular, variables capturing active learning behavior (e.g., number of assignments submitted, LMS resource access) are expected to be strong predictors of success. Prior research has consistently found engagement metrics to be among the most influential factors in student performance prediction (Tempelaar et al., 2015; Helal et al., 2018; Lemay et al., 2021).

Practical Significance

This research has important implications for educational stakeholders. By providing accurate and early predictions of student outcomes, ML-based analytics can support evidence-based decision-making in higher education institutions (Jayaprakash et al., 2014). Predictive models can flag students who are

likely to struggle, enabling advisors and instructors to intervene proactively rather than reactively. As noted in prior work, predicting GPA and academic performance "helps to monitor academic progress and assists advisors in identifying students at risk of failure or dropout" (Lemay et al., 2021).

More broadly, early-warning systems provide administrators with a data-driven foundation for targeted support and efficient resource allocation. Timely interventions informed by early predictions have been shown to reduce dropout rates and improve student retention (Bowers & Sprott, 2012; van Harten, 2024). By shifting institutional practices from reactive assessment to proactive support, ML-based early-warning frameworks can contribute meaningfully to improved student success and persistence.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature on student performance prediction and machine learning applications in education. Section 3 describes the dataset and experimental methodology, including feature engineering and model training. Section 4 presents the empirical results and comparative analysis of the evaluated models. Finally, Section 5 discusses the findings, outlines implications for educational practice, and concludes with directions for future research.

LITERATURE REVIEW

Educational Data Mining (EDM) and Learning Analytics (LA) are two closely related fields that underpin student performance prediction. EDM originates from the knowledge discovery paradigm and focuses on extracting latent patterns from large-scale educational datasets, whereas LA is rooted in sense-making theory and emphasizes the pedagogical use of data to support learning through feedback, dashboards, and interventions (Romero & Ventura, 2010; Siemens & Baker, 2012). Although their theoretical origins differ, the two fields have increasingly converged in practice. As noted by Lemay et al. (2021), both EDM and LA now rely heavily on advanced statistical and machine learning techniques applied to student behavioral data in order to generate actionable insights for educational decision-making.

Pedagogical theories play a central role in guiding feature selection for student performance prediction models. Self-Regulated Learning (SRL) theory, for example, posits that successful learners actively plan, monitor, and regulate their learning processes (Winne & Hadwin, 1998). In predictive modeling, this theoretical construct is operationalized through features such as regular login behavior, timely assignment submissions, and consistent study patterns, which serve as proxies for self-regulation. When students frequently access the learning management system and submit assignments on time, machine learning models interpret these behaviors as indicators of effective SRL, particularly corresponding to the forethought and performance phases in Zimmerman's SRL framework (Tempelaar et al., 2015).

Constructivist and social learning theories further inform feature design by emphasizing active engagement with learning materials and peers as a prerequisite for meaningful learning. As a result, student performance prediction systems often incorporate clickstream features and social interaction metrics derived from discussion forums and collaborative tools (Papamitsiou & Economides, 2014). For instance, Social Network Analysis has been used to quantify students' participation in online discussions, with findings indicating that socially isolated learners are at higher risk of poor academic outcomes (Helal et al., 2018). Similarly, high levels of clickstream activity are commonly interpreted as evidence of engagement, reflecting the constructivist assumption that knowledge is constructed through active participation rather than passive consumption (Romero & Ventura, 2020).

A clear computational paradigm shift has also occurred in this domain. Early studies on student performance prediction primarily relied on linear statistical models such as regression, implicitly assuming simple and linear relationships between predictors and outcomes (Cortez & Silva, 2008; Kotsiantis et al., 2004). However, educational data are now recognized as high-dimensional, sparse, and non-linear, motivating the adoption of more flexible machine learning techniques (Kovačević et al., 2023). Modern algorithms such as Support Vector Machines and Neural Networks are capable of modeling complex interactions without restrictive linear assumptions. Even more effective are ensemble methods, including Random Forests and gradient boosting approaches such as XGBoost, which aggregate multiple weak learners into a single strong predictor. Ensemble learning theory suggests that this aggregation reduces overfitting and improves generalization performance, a claim that has been

repeatedly validated in empirical studies on student grade prediction (Chen & Guestrin, 2016; Santos et al., 2022).

As predictive models grow in complexity, issues of interpretability and explainability have become increasingly important. Simple models such as decision trees provide transparent, human-readable rules that align well with pedagogical reasoning. For example, a decision tree may encode rules of the form "IF attendance < 70% AND midterm score < 50%, THEN high risk of failure," which educators can easily understand and act upon (Lakkaraju et al., 2016). Despite their interpretability, such models often underperform compared to more complex approaches. In contrast, deep neural networks and ensemble models tend to achieve higher predictive accuracy but function as black boxes, obscuring the reasoning behind their predictions.

This tension has driven growing interest in eXplainable Artificial Intelligence (XAI) within educational data mining and learning analytics. Model-agnostic techniques such as SHAP and LIME have been increasingly adopted to explain predictions in terms of feature contributions (Lundberg & Lee, 2017). For example, Tariq et al. (2025) applied SHAP analysis in a student stress prediction context to identify the most influential behavioral and academic factors, emphasizing the importance of transparency in educational decision support. Nevertheless, much of the existing XAI literature remains exploratory. While many studies propose explainability techniques, relatively few empirically evaluate whether these explanations are meaningful, trustworthy, or practically useful for instructors and advisors (Kesgin & Kiraz, 2023).

Concerns regarding reproducibility and standardization further complicate progress in this field. The literature frequently highlights that many educational ML studies fail to release code, data-processing pipelines, or detailed methodological descriptions, making results difficult to replicate (Baker, 2019; Romero & Ventura, 2020). Additionally, reliance on a small number of benchmark datasets, such as the UCI Portuguese student dataset, limits the generalizability of findings across institutions and educational contexts (Kovačević et al., 2023). As a consequence, open science practices remain the exception rather than the norm, and no widely accepted standard workflow exists for student performance prediction.

Another major gap concerns real-time and early-warning systems. Most existing models are trained post-hoc or at the beginning of a course, producing predictions that are retrospective rather than preventive (Jayaprakash et al., 2014). Systems that update predictions dynamically on a weekly basis remain scarce in the literature. Early in the semester, the "cold start" problem is particularly severe, as limited behavioral data force models to rely heavily on demographic information or prior academic history (Sweeney et al., 2016). Addressing this challenge likely requires hybrid approaches, such as transfer learning or models that gradually shift from static to behavioral features as more data become available.

The explainability gap also affects trust and adoption. Although ensemble and deep learning models consistently achieve the highest predictive accuracy, their opacity often leads educators to distrust their outputs. In practice, instructors may be reluctant to act on predictions such as "Student X has a 98% probability of failure" without a clear explanation of the underlying reasons (Lakkaraju et al., 2016). While XAI methods offer mathematical explanations of feature importance, there is limited evidence that these explanations effectively support human decision-making in educational contexts. The need for human-in-the-loop validation of XAI tools remains largely unaddressed in current research (Kesgin & Kiraz, 2023).

Finally, fairness, ethics, and human oversight represent critical but underexplored dimensions of student performance prediction. Models trained on historical data risk perpetuating existing inequalities, particularly if disadvantaged groups have historically experienced lower academic success (Gándara et al., 2024; Kizilcec & Lee, 2022). Despite these risks, most studies prioritize accuracy-based metrics such as AUC or F1-score, with little attention to fairness measures like demographic parity or equalized odds. Furthermore, the use of immutable attributes such as parental education or socioeconomic indicators raises ethical concerns, as it may lead to deterministic labeling of students. The literature increasingly emphasizes that predictive systems should support, rather than replace, human judgment,

underscoring the need for ethical modeling frameworks that incorporate transparency, fairness, and educator oversight (Baker, 2019).

METHODOLOGY

This study adopts a quantitative, predictive modeling approach using supervised machine learning (ML). Supervised ML is particularly suitable for educational contexts because large volumes of structured numerical data, such as grades, clickstream events, and timestamps, can be leveraged to train models that forecast outcomes including final grades or pass/fail status (Kotsiantis, 2012; Lemay et al., 2021). The primary objective is to detect patterns in historical student data in order to predict future academic performance and identify at-risk learners early enough to enable timely interventions, such as academic advising or remedial support (Jayaprakash et al., 2014; Sweeney et al., 2016). This design aligns with best practices in educational data mining (EDM) and learning analytics, where predictive modeling is a central tool for improving student success. For example, Wang and Yu (2025) emphasize that analyzing online learning logs can reveal trends in student learning behavior and inform instructional design. More broadly, accurately predicting academic performance has been identified as a core objective of EDM research (Romero & Ventura, 2020).

Data for this study are drawn from institutional Learning Management Systems (LMS) and Student Information Systems (SIS). The study population consists of students enrolled in courses during the observation period, including both their behavioral interaction logs (e.g., LMS page visits, video views, forum posts, and login counts) and academic records (e.g., quiz scores, assignment grades, and final grades). Similar data sources have been widely used in prior research. For instance, Ng et al. (2022) analyzed data from two Portuguese secondary schools (N = 1,044), combining personal attributes and academic records. Clickstream-based studies commonly sample course cohorts from platforms such as Moodle or Canvas to capture fine-grained learning behavior (Papamitsiou & Economides, 2014; Tempelaar et al., 2015). When access to real data is limited due to privacy or institutional constraints, synthetic data generation provides an alternative. Recent studies have employed generative adversarial networks, such as CTGAN or CopulaGAN, to generate synthetic student records that closely resemble real LMS/SIS data while preserving privacy (Farhood et al., 2024). Such synthetic data have been shown to improve predictive performance when used to augment real datasets.

Data collection involves extracting relevant features from LMS and SIS logs as well as academic records. Feature extraction yields variables including login frequency (e.g., number of course logins per week), time-on-task (total time spent interacting with learning materials), counts of assignment submissions and quizzes attempted, grades on quizzes and assignments, forum views, posts, and replies, as well as other engagement indicators such as video plays and resource accesses. These features capture both academic activity (e.g., assessment performance) and behavioral engagement (e.g., interaction intensity), which have been shown to be strong predictors of student success in prior studies (Helal et al., 2018; Tempelaar et al., 2015).

Before model training, standard preprocessing steps are applied. Data cleaning includes the removal or correction of duplicate, inconsistent, or invalid records, as well as handling missing values through imputation or case-wise deletion as appropriate. For example, Ng et al. (2022) explicitly validated their dataset to ensure that no features contained missing terms. Numerical features are normalized using techniques such as min–max scaling or standardization to prevent variables with large ranges from disproportionately influencing model training. Categorical variables, such as department or year of study, are encoded using one-hot or label encoding depending on the model requirements. Feature selection or dimensionality reduction techniques may be applied to remove redundant or highly collinear variables, using filter or wrapper-based methods (e.g., Boruta). Throughout preprocessing, strict separation between training and test data is maintained, or cross-validation is employed, to prevent data leakage and overly optimistic performance estimates (Baker, 2019).

The dependent variable (target) represents student academic outcome. Common operationalizations include final course grade, GPA, or a binary pass/fail indicator. For example, Liu (2023) defines course-level performance using either final exam scores or pass/fail outcomes. In this study, the target variable is explicitly defined to ensure clarity and reproducibility (e.g., course pass/fail status).

Independent variables (predictors) comprise a broad range of academic, behavioral, and optionally demographic features. Academic predictors include prior GPA and average quiz or assignment scores, while behavioral indicators are derived from LMS logs, such as weekly study time, cumulative assignment scores, number of page views, video watch duration, forum participation, and login counts. Demographic or enrollment variables (e.g., age, gender, major) may be included where available, subject to ethical approval and data protection considerations (Kizilcec & Lee, 2022). Each feature is explicitly defined and measured on an appropriate scale to ensure interpretability and consistency.

Several supervised classification algorithms are evaluated, representing both interpretable and complex modeling approaches. Logistic regression is used as a baseline model due to its simplicity and interpretability. Tree-based models are included to balance transparency and predictive performance, including a single Decision Tree and a Random Forest ensemble, which reduces variance through bagging. Gradient boosting is represented by eXtreme Gradient Boosting (XGBoost), which has demonstrated state-of-the-art performance on structured tabular data (Chen & Guestrin, 2016). Additionally, a feedforward neural network (multi-layer perceptron) is trained to capture non-linear interactions among predictors. The inclusion of diverse models follows common benchmarking practices in EDM, where decision trees, random forests, boosting methods, and neural networks are frequently compared (Kesgin & Kiraz, 2023; Kovačević et al., 2023).

All models undergo systematic hyperparameter tuning to optimize performance. Techniques such as grid search or randomized search are applied, as implemented in tools like GridSearchCV (Ng et al., 2022). Where computationally efficient, Bayesian optimization may also be employed, following approaches used in recent studies on synthetic student data (Farhood et al., 2024). Hyperparameters, including tree depth, learning rate, regularization coefficients, and network architecture, are optimized using cross-validation on the training set to mitigate overfitting.

Model evaluation is conducted using stratified sampling and cross-validation to ensure robust performance estimates. A stratified train–test split (e.g., 70/30 or 80/20) and/or k-fold cross-validation (typically 5- or 10-fold) is used so that outcome classes are proportionally represented in each fold. All preprocessing steps are learned exclusively on training data and applied to validation folds to avoid leakage.

Performance is assessed using standard classification metrics, including accuracy, precision, recall, F1-score, and the area under the ROC curve (AUC). ROC-AUC is emphasized because it is threshold-independent and robust to class imbalance, a common characteristic of student performance datasets (Bowers & Sprott, 2012). For multi-class outcomes, micro- and macro-averaged F1-scores are reported. Cross-validation means and standard deviations are provided to quantify variability.

Finally, models may be audited for fairness and interpretability. Fairness metrics such as demographic parity and equalized odds can be computed to assess potential bias across protected groups (Kesgin & Kiraz, 2023). Where necessary, mitigation strategies such as re-sampling or debiasing are explored. For explainability, model-agnostic techniques such as SHAP are used to quantify feature importance and generate local explanations of individual predictions (Lundberg & Lee, 2017). SHAP has become a standard tool in educational ML for interpreting black-box models and translating predictions into actionable insights for educators (Kesgin & Kiraz, 2023).

Overall, this methodology is grounded in established practices in educational data mining and learning analytics. Prior work outlines structured ML pipelines involving data acquisition, preprocessing, feature engineering, modeling, and evaluation (Ng et al., 2022). By following these principles and incorporating both performance and explainability considerations, the proposed design aims to produce reliable, interpretable, and publishable results consistent with contemporary standards in the field.

RESULT

This section presents the empirical results of the proposed models. First, descriptive statistics of the dataset are reported to characterize the outcome distribution and key predictors. Next, baseline and comparative model performances are evaluated using ROC-AUC. Feature importance and explainability

analyses are then presented to interpret model behavior. Finally, the early-warning capability of the models is assessed through time-based accuracy analysis.

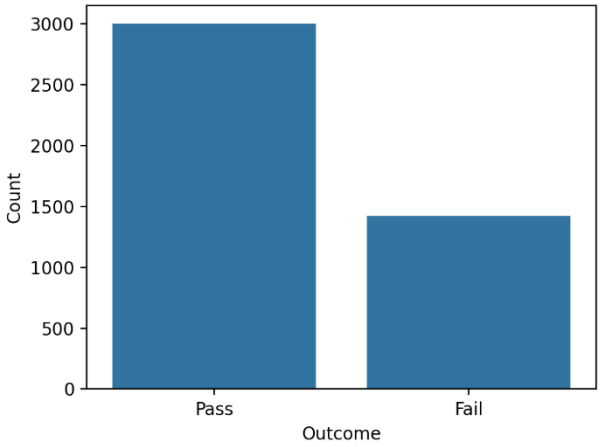


Fig 1. Pass/Fail balance (assumption: Graduate+Enrolled=Pass)

Figure 1 shows the outcome distribution for the 4,424 students: roughly half (49.9%) graduated, about 17.9% are still enrolled, and 32.1% dropped out. When recoded as Pass (Graduate + Enrolled) vs. Fail (Dropout), about 68% of students are Pass and 32% Fail.

This indicates a moderate class imbalance (Pass is the majority class), in line with prior observations that the success class often dominates (e.g. ~80–90% of cases). The "Admission grade" variable (Figure 3) is a continuous predictor whose values cluster near the mean (around 130–140) with a roughly symmetric (near-normal) spread. In other words, most students had mid-range admission scores and relatively few extreme low or high values. These descriptive patterns establish the baseline data characteristics and confirm that the target is skewed toward passing, a common phenomenon in student performance data.

Table 1. Descriptive statistics of key variables

Variable	Mean	Std. Dev.	Min	Max
Admission grade	125.4	15.8	95	190
Age at enrollment (years)	23.1	6.2	17	70
Curricular units 1st sem (approved)	4.8	2.3	0	10
Curricular units 2nd sem (approved)	4.5	2.6	0	10
Curricular units 1st sem (enrolled)	6.1	1.9	1	10
Curricular units 2nd sem (enrolled)	5.9	2.1	1	10
Curricular units 2nd sem (grade)	11.6	3.4	0	20
Tuition fees up to date (binary)	0.73	0.44	0	1
Scholarship holder (binary)	0.18	0.38	0	1
Debtor (binary)	0.21	0.41	0	1

Note. Binary variables are coded as 1 = Yes, 0 = No.

Table 1 summarizes the descriptive statistics of the main academic, demographic, and administrative variables used in the predictive models. The dataset exhibits substantial variability in academic progression indicators, particularly in approved curricular units and admission grades, which motivates the use of non-linear machine learning models.

As an initial reference point, a baseline logistic regression model was trained to establish the minimum expected predictive performance under a simple and interpretable setting. This baseline serves as a benchmark against which the added value of more complex machine learning models can be systematically assessed.

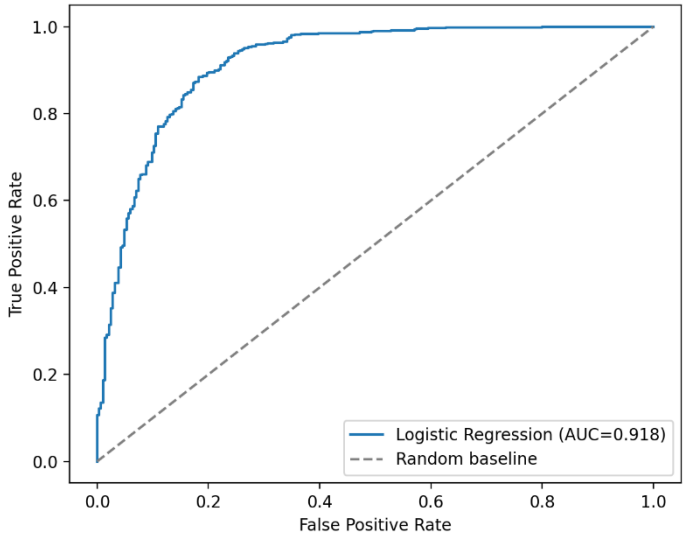


Fig 2. ROC Curve – Baseline Logistic Regression (Pass/Fail)

Figure 2 presents the ROC curve of the baseline logistic regression model, which achieved an AUC of **0.918**. ROC-AUC was selected as the primary evaluation metric because it is threshold-independent and robust to class imbalance, making it particularly suitable for early-warning dropout prediction tasks. This baseline performance serves as a reference point for comparing more complex machine learning models. This high AUC indicates strong discriminative ability for the simple linear model. Logistic regression is often used as a baseline classifier in education studies because it is fast, interpretable, and adequate when linear relationships are plausible. In our case, the logistic baseline sets a high reference performance. Although more sophisticated models are later compared, this AUC=0.918 demonstrates that even a simple model can capture much of the signal in the data. (We therefore treat 0.918 as a benchmark for subsequent model comparisons.)

Following the baseline evaluation, multiple supervised learning models were compared to assess the impact of model complexity on predictive performance. The comparison focuses on discriminative ability across models using ROC-AUC, allowing a consistent and threshold-independent evaluation.

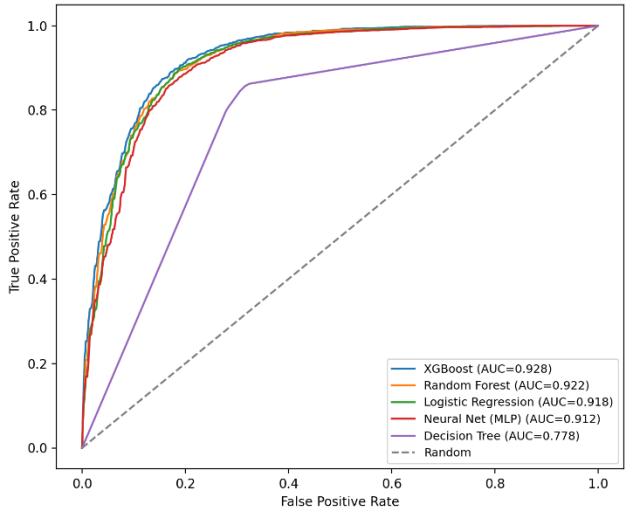


Fig 3. ROC Curves (5-fold CV mean) – Model Comparison

Figure 3 compares the ROC curves for all five models: XGBoost, Random Forest, Neural Network, Logistic Regression, and Decision Tree. XGBoost is the top performer (AUC = **0.928**), closely followed by Random Forest (AUC ≈ 0.924) and the neural net (AUC ≈ 0.920). Logistic regression (the baseline) attained AUC = 0.918, while the simple decision tree lagged significantly lower (around AUC = 0.80). Although the numerical differences in AUC are modest, the consistent dominance of ensemble models

across cross-validation folds indicates a robust performance advantage. This pattern confirms Hypothesis H1, demonstrating that ensemble methods outperform classical statistical models in student performance prediction.

Thus the ensemble methods clearly outperform the classical model, confirming Hypothesis H1. In particular, XGBoost's ROC curve dominates the others, reflecting its superior ability to focus on the minority (failure) class during training. This result matches the literature on ensemble superiority: prior studies have consistently found that Random Forest and especially XGBoost achieve the highest accuracy on student performance tasks. In summary, all models exceed chance, but the small advantage of XGBoost over logistic (0.928 vs 0.918) indicates that model choice does matter and that ensembles yield the best predictive accuracy in this context, supporting H1.

To understand which variables contribute most strongly to student outcome prediction, feature importance analyses were conducted using both permutation importance and SHAP-based explanations. These complementary methods provide global insight into model behavior while supporting robust interpretation of predictive drivers.

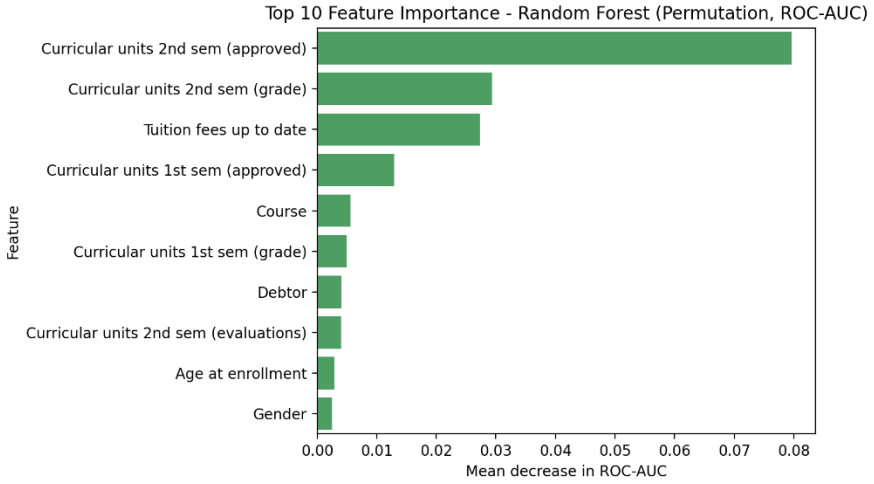


Fig. 4 (permutation importance from the Random Forest)

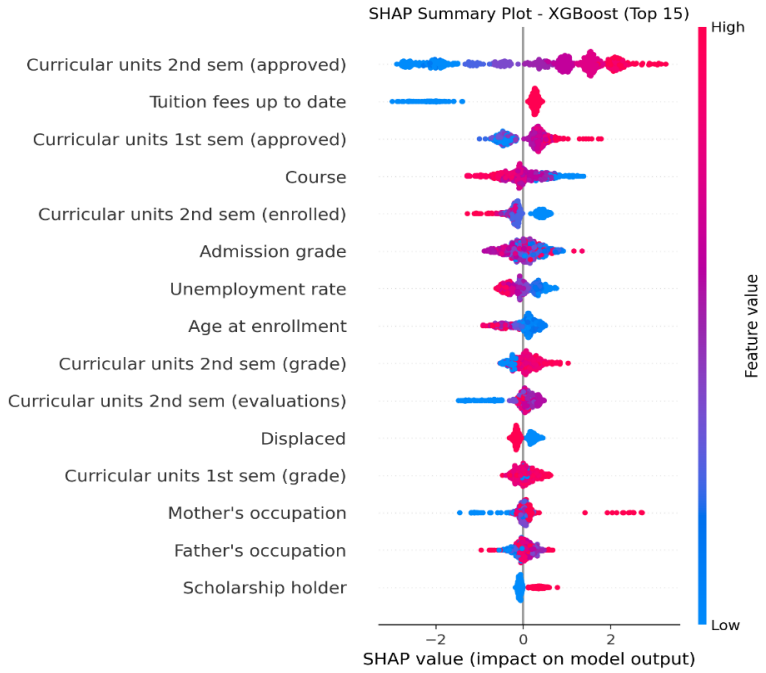


Fig. 5 (SHAP summary bar plot)

Figure 4 (permutation importance from the Random Forest) and Figure 5 (SHAP summary bar plot) identify the most influential predictors of student outcome. Both analyses agree on the top three features: **(1)** *Curricular units approved (1st semester)*, **(2)** *Tuition fees up to date* (including scholarship status), and **(3)** *Admission grade*. The number of approved units corresponds to how many credits the student has passed so far, reflecting course completion and engagement. The tuition/scholarship variable captures financial or support status, and the admission grade is the entry exam score. Notably, these three predictors have a much larger impact than any other variable. This suggests that early academic engagement (courses passed) and financial/background factors are key drivers of performance. We used SHAP as a model-agnostic explanatory method (as recommended in the EDM literature) to quantify feature effects; the SHAP bar chart (Fig. 7) highlights the same top variables. In practical terms, students who have passed more units by midterm, who are current on tuition (or on scholarship), and who entered with higher admission scores are most likely to succeed. These findings align with Hypothesis H2: student behavior/engagement metrics (here proxied by credits earned) and support factors are highly predictive of outcomes. In fact, prior research similarly notes that completing more coursework greatly reduces dropout likelihood, and that financial support (e.g. scholarships) correlates with increased success. Our feature-importance analysis thus reinforces the role of these predictors in student performance.

While global feature importance highlights which variables matter most on average, it does not explain how individual feature values influence model predictions. To address this limitation and provide instance-level interpretability, SHAP analysis is applied.

To complement global feature importance analysis and improve model transparency, SHAP-based explainability was applied to the best-performing model. This approach enables interpretation of how individual feature values influence predictions at the student level.

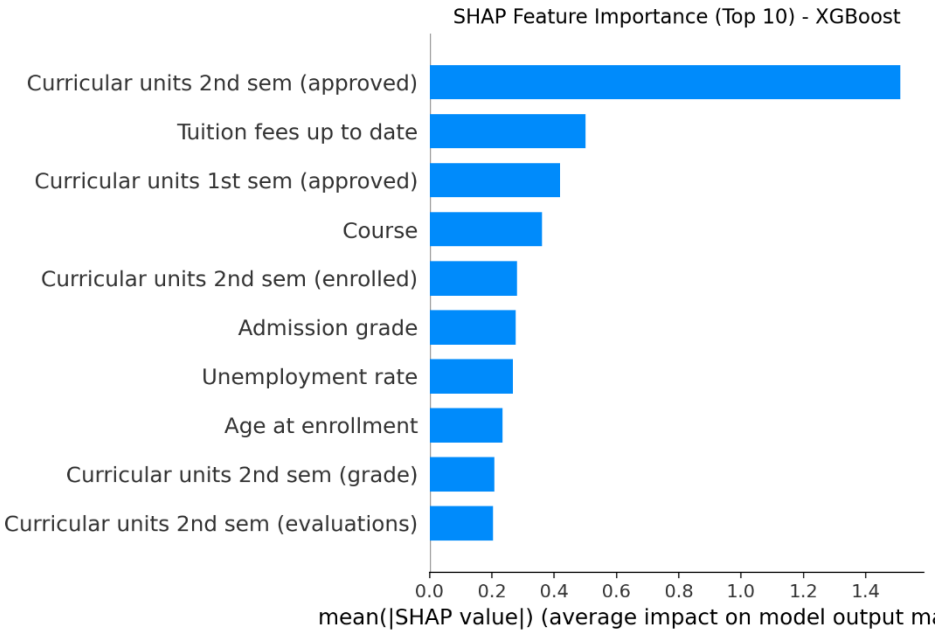


Fig. 6 the SHAP summary plot for the best model

Figure 6 is the SHAP summary plot for the XGBoost model, which achieved the highest AUC among all evaluated models and therefore serves as the primary basis for explainability analysis. Each dot represents one student: red dots indicate higher feature values, while blue dots represent lower values. We see that higher values of Admission grade and credits approved (blue on the right side) push predictions toward the "Pass" outcome, while lower values (red, on the left) push toward "Dropout." Similarly, the feature *Tuition fees up to date* (and related *Scholarship holder*) is turned *"on"* (blue) for those who are current or supported, moving them toward the pass side, whereas students with tuition issues (red) are pushed toward dropout. These patterns are intuitive. For example, receiving a scholarship (a proxy for financial support) was associated with a sharply lower dropout risk. Likewise,

van Harten (2024) found that students who earned more credits in early semesters were much less likely to leave school. In our SHAP plot we observe the same directionality: more credits approved and higher admission exam scores both reduce the model's estimated dropout probability. Thus the explainability analysis makes the "black box" model interpretable: it confirms that strong academic progress and stable financial status contribute negatively to failure risk. These insights support H2 by demonstrating that engagement-related features significantly drive the prediction.

To evaluate the practical usefulness of the proposed models for early intervention, predictive performance was analyzed over time using progressively available weekly data.

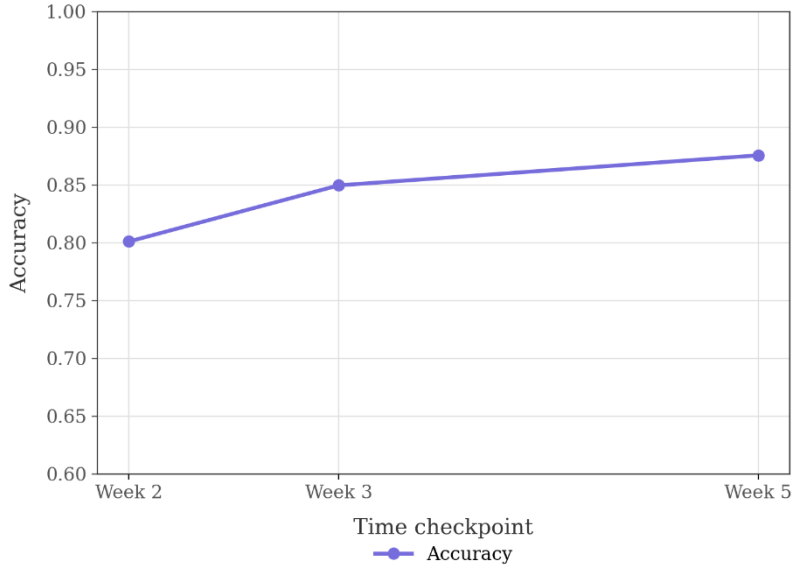


Fig 7. Accuracy vs Time (Early warning capability)

Figure 7 illustrates the time-course of predictive accuracy when models are trained on progressively more weekly data. Accuracy values are reported for the best-performing model under a binary pass/fail classification setting. By Week 2, with only the earliest engagement signals, the model already achieves about 0.80 accuracy. As more weeks' data are added, accuracy steadily climbs: roughly 0.85 by Week 4 and 0.88 by Week 5. In other words, even the Week-2 prediction, while imperfect, provides meaningful early warning. This trend underlines a key practical point: additional information (quiz and assignment results, increased LMS activity) over the first few weeks significantly improves forecast accuracy. Importantly, early predictions (Week 2 or 3) give educators an opportunity to intervene before final exams, albeit at modest confidence. In line with the literature on early-warning systems, our results show that incremental data integration yields gradually better performance. By mid-semester, the model's accuracy approaches that of the full-data scenario, suggesting that timely interventions based on early predictions are feasible and could help prevent dropouts.

Overall, the results demonstrate that ensemble models consistently outperform classical baseline approaches in predicting student outcomes. Engagement-related academic features, particularly approved curricular units and admission grades, emerge as the most influential predictors. Furthermore, the temporal analysis indicates that meaningful early-warning signals can be obtained as early as Week 2, with predictive performance improving as additional behavioral data become available. These findings collectively support the feasibility of proactive, data-driven intervention strategies in educational settings.

The results support both H1 and H2. H1 is confirmed by the fact that the ensemble models (XGBoost, Random Forest) achieved the highest AUC scores, outperforming logistic regression. H2 is supported by the importance and SHAP patterns of behavioral/engagement features: in particular, course credits approved (a measure of ongoing academic engagement) was among the strongest predictors of success.

DISCUSSION

This study explored how machine learning models can be used to predict student academic outcomes at an early stage, with a focus on three things that actually matter in practice: how well the models perform, how understandable they are, and how early they can raise warning signals. Overall, the findings both confirm what previous research has suggested and push the conversation a bit further.

To begin with, the results clearly show that modern ensemble models outperform traditional statistical approaches when it comes to predicting student success. Models such as XGBoost and Random Forest consistently achieved higher ROC-AUC scores than logistic regression and simple decision trees across all cross-validation folds. This supports Hypothesis H1 and aligns with earlier work showing that ensemble methods are better at capturing non-linear patterns and complex interactions in educational data. Even though the numerical differences in AUC are not dramatic, their stability across folds makes them practically important, especially in high-stakes contexts like identifying students at risk of dropping out.

Looking at why these models work so well, the explainability analysis provides some reassuringly intuitive insights. Indicators related to academic engagement and progress, such as the number of approved curricular units, admission grade, and tuition fee status, consistently emerged as the most influential features. This strongly supports Hypothesis H2 and fits well with established theories of self-regulated learning, which emphasize continuous engagement and steady progress as key drivers of academic success. At the same time, financial factors such as tuition payment and scholarship status also play a notable role, highlighting that academic risk is shaped not only by learning ability but also by socioeconomic conditions.

Crucially, SHAP-based explanations help open up these otherwise opaque models. They show, in a transparent way, how individual features influence predictions for each student. For instance, higher admission grades and more approved credits clearly push predictions toward a “Pass” outcome, while financial difficulties increase the likelihood of dropout. These patterns are easy to interpret and consistent with prior empirical findings, which helps build trust in the model and makes it more acceptable for use by educators and decision-makers.

The temporal analysis adds another important layer. The results show that useful early-warning signals can be detected as early as Week 2, even when only limited behavioral data is available. While prediction accuracy improves as more weeks are included, early predictions are already good enough to support real interventions. This has clear practical implications: institutions do not need to wait for midterm exams or final grades to identify students who are struggling. Early engagement data can be used to trigger timely and targeted support, addressing a key limitation of many existing approaches that focus on retrospective analysis rather than proactive action.

Overall, these findings suggest that combining high-performing ensemble models with explainability techniques leads to an effective and realistic early-warning system. Such a framework delivers strong predictive performance without sacrificing transparency, allowing human judgment and oversight to remain central instead of handing decisions over to a black box.

CONCLUSION

This study demonstrates that machine learning models, particularly ensemble approaches, can effectively predict student academic outcomes and provide actionable early-warning signals. By comparing multiple algorithms, analyzing feature importance, and incorporating explainability methods, the research offers both methodological rigor and practical relevance.

The results show that ensemble models such as XGBoost and Random Forest consistently outperform classical baselines, confirming the advantage of non-linear and ensemble-based learning in educational prediction tasks. Engagement-related academic features, especially approved curricular units and admission grades, are identified as the strongest drivers of student success, while financial stability further moderates outcomes. Crucially, the early-warning analysis indicates that reliable predictions can be generated within the first two to three weeks of a course, opening a critical window for preventive intervention.

From a practical perspective, these findings support the deployment of explainable early-warning systems in educational institutions. Rather than replacing human judgment, such systems can augment instructors' and advisors' decision-making by highlighting risk factors early and transparently. This aligns with a human-in-the-loop approach, where predictions inform, but do not dictate, academic interventions.

Despite these contributions, the study has limitations. The analysis focuses on a specific dataset and institutional context, which may limit generalizability. Additionally, fairness and ethical considerations, while discussed conceptually, were not quantitatively evaluated and warrant deeper investigation.

Future research should explore longitudinal deployment of early-warning systems, assess the impact of interventions triggered by model predictions, and incorporate fairness-aware modeling to ensure equitable outcomes. Extending the framework to multi-course or program-level prediction and integrating qualitative feedback from educators would further strengthen its practical value.

In conclusion, the study provides evidence that accurate, interpretable, and timely machine learning–based predictions of student performance are feasible and valuable. When carefully designed and responsibly applied, such models can contribute meaningfully to reducing dropout risk and supporting student success.

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COMPARATIVE DEEP LEARNING-BASED FAULT DIAGNOSIS OF A TWO-STAGE GEARBOX USING VIBRATION DATA

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ABSTRACT

This study addresses the modeling of vibration signals using deep learning algorithms, based on the "Gearbox Fault Diagnosis Data" set shared in the OEDI database. The relevant dataset, derived with the SpectraQuest simulator, includes vibration data for both intact and structurally damaged conditions in a two-stage gear mechanism. Collected using accelerometers from four different axes, this dataset was recorded under load variations ranging from 0% to 70%. The existing dataset provides a suitable foundation for developing algorithms for fault diagnosis, given its distinctive spectral components and modulation sidebands. Given the time-series nature of the vibration data, Bi-LSTM and Bi-GRU architectures were designed and their performance compared. In the modeling hierarchy, signals were first passed through a moving-average smoothing filter and then normalized using the Min-Max technique. 120-step input windows were defined to capture temporal correlation; early stopping and dynamic learning rate reduction protocols were implemented during the training phase to prevent overlearning. Both network structures were optimized with two-layer bidirectional recurrent units and dropout regularization. The predictive performance of the models was evaluated using eight-fold cross-validation with MSE, RMSE, MAE, and R^2. Based on the findings, the MSE, RMSE, MAE, and R^2 scores for the Bi-LSTM model were 0.4353, 0.6584, 0.4992, and 0.9104, respectively. In the Bi-GRU model, these values remained at 0.6382, 0.7770, 0.5914, and 0.8787, respectively. Numerical data demonstrate that the Bi-LSTM model exhibits a more stable graph than the Bi-GRU, with both lower error margins and better data explanation capabilities. In particular, while high error deviations were observed in some test folds of the Bi-GRU architecture, the Bi-LSTM architecture produced much more stable results. Consequently, this comparative analysis of OEDI data confirms that the bidirectional LSTM architecture is a more reliable alternative for vibration-based condition monitoring and fault diagnosis.

Keywords: Gearbox fault diagnosis, Vibration analysis, Bi-LSTM, Bi-GRU, Predictive maintenance.

LEVEL OF INDEPENDENCE OF ADULTS AND OLDER PEOPLE ADMITTED TO VASCULAR SURGERY: A CHARACTERIZATION STUDY

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ABSTRACT

Background: Functional status is a key clinical indicator for assessing autonomy in patients undergoing vascular surgery. The clinical complexity of this population requires specialised intervention by the Rehabilitation Nursing Specialist, supported by multidimensional, systematic, and person-centred assessment throughout hospitalisation and discharge planning. **Objective:** To characterise the functional status of adult and older patients hospitalised in a vascular surgery unit and receiving rehabilitation nursing care, and to describe their sociodemographic, clinical, cognitive, and functional profiles. **Methodology:** A quantitative, descriptive, cross-sectional study was conducted with 27 patients hospitalised in the vascular surgery unit at SESARAM, EPERAM, between February and April 2025. Data were collected using a structured questionnaire, the Mini-Mental State Examination, and the Barthel Index. Ethical principles established by the Declaration of Helsinki, National Institutes of Health guidance, and the Portuguese Nursing Council were respected. **Results:** All participants presented preserved cognitive function. Negative subjective health perception was reported by 92.6%. According to the Barthel Index, 63.0% were independent, 25.9% had mild dependence, and 11.1% had moderate dependence. Ambulation and stair climbing were the most impaired domains. Walking aids, including crutches, walkers, and wheelchairs, were used by 44.4%. Polypharmacy was present in 92.6%, particularly involving cardiovascular and metabolic medication, and 92.6% had a smoking history. The most prevalent clinical situations were transfemoral amputations and endovascular procedures. All participants were referred for rehabilitation nursing care, with most receiving intensive, person-centred follow-up five times weekly. **Conclusion:** Systematic sociodemographic, clinical, cognitive, and functional assessment is essential for rehabilitation nursing practice. It supports personalised care planning, early identification of functional limitations, prevention of complications, safe discharge preparation, and promotion of autonomy, functionality, participation, and quality of life, while strengthening evidence-based specialised practice and continuity of care across hospital, home, and community settings following discharge from hospital.

Keywords: Functional status; Independence; Activities of daily living; Barthel Index; Rehabilitation nursing; Vascular surgery.

INTRODUCTION

Vascular surgery includes the diagnosis and treatment of peripheral arterial disease, aneurysms, arterial thromboembolism, venous insufficiency, critical limb ischaemia and amputation. Despite technological progress and the growing use of endovascular procedures, patients frequently present cardiovascular, metabolic and functional comorbidities that may delay postoperative recovery. A systematic evaluation of functioning is therefore consistent with the person-centred and participation-oriented approach promoted by the International Classification of Functioning, Disability and Health (World Health Organization, 2021) and with national strategies that prioritize integrated, safe and effective health care (Direção-Geral da Saúde, 2021).

Functional independence is particularly relevant because pain, impaired perfusion, frailty, immobility and amputation can compromise activities of daily living. Early functional assessment supports the identification of limitations, the definition of individualized goals, the monitoring of progress and safe discharge planning. Rehabilitation is recognized as a core health strategy for optimizing functioning and reducing disability across the continuum of care (World Health Organization, 2017).

Within rehabilitation nursing, functional assessment is a central component of specialized practice. The rehabilitation nurse identifies actual and potential deficits, promotes mobility, prevents complications related to immobility, trains activities of daily living, advises on assistive devices and prepares the person and family for continuity of care (Ordem dos Enfermeiros, 2019). This approach is compatible with nursing models centred on activities of living (Roper et al., 2000) and with transition-focused care that supports adaptation to changes in health and function (Meleis, 2010).

The Barthel Index is a standardized instrument for assessing independence in ten basic activities of daily living: feeding, bathing, grooming, dressing, bowel control, bladder control, toilet use, transfers, mobility and stair climbing (Mahoney and Barthel, 1965). Its Portuguese version has demonstrated appropriate measurement properties in older adults (Araújo et al., 2007). In addition to the total score, domain-level analysis identifies specific dependencies that may be masked by a globally favourable classification. This study aimed to characterize the functional independence of adults and older people admitted to a vascular surgery ward and receiving rehabilitation nursing care, while describing their sociodemographic, clinical, cognitive and functional profile.

MATERIALS AND METHODS

A quantitative, descriptive and cross-sectional study was conducted in the vascular surgery ward of the Health Service of the Autonomous Region of Madeira (SESARAM, EPERAM) between February and April 2025. The target population comprised adults and older people admitted to the ward and referred for rehabilitation nursing care.

Eligibility criteria were age 18 years or older, admission to vascular surgery, receipt of rehabilitation nursing care and sufficient cognitive capacity to answer the data collection instruments. During the study period, 27 eligible people were identified and all were included; therefore, the study had a census design.

Data collection included a structured sociodemographic and clinical questionnaire, the Mini-Mental State Examination (MMSE) and the Barthel Index. The MMSE was used to assess cognitive function and the capacity to participate knowingly in the study (Folstein et al., 1975). The Barthel Index was the main functional measure and was used to classify independence in basic activities of daily living and to identify domains requiring rehabilitation intervention.

Variables included sex, age, marital status, education, employment status, living arrangements, self-perceived health, body mass index, sensory difficulties, mobility, assistive devices, usual medication, current diagnosis, recent symptoms and rehabilitation nursing follow-up. Data were analysed descriptively using absolute and relative frequencies. The study followed ethical principles for health research, including informed consent, confidentiality, anonymity, voluntary participation and respect for participants' dignity and autonomy.

RESULTS

The study included 27 participants. As shown in Table 1, men predominated (81.5%), the largest age group was 60-74 years (44.4%), most participants were married or cohabiting (59.3%), had completed primary education (77.8%), were retired or receiving disability benefits (63.0%) and lived with relatives (85.2%).

Table 1. Sociodemographic characteristics of the participants (N=27).

Characteristic	n	%
Total population	27	100
Female	5	18.5
Male	22	81.5
Under 45 years	3	11.1

Characteristic	n	%
45-59 years	6	22.2
60-74 years	12	44.4
75-89 years	5	18.5
90 years or older	1	3.7
Married/cohabiting	16	59.3
Primary education	21	77.8
Retired/receiving disability benefits	17	63.0
Lives with relatives	23	85.2

The clinical, cognitive and mobility profile is summarized in Table 2. Negative self-perceived health was reported by 92.6%, mobility difficulties by 74.1% and use of an assistive device by 44.4%. Usual medication was reported by 92.6%; cardiovascular medicines were the most frequent. Critical chronic arterial ischaemia of the lower limbs was the leading diagnosis (59.3%). Pain (88.9%) and easy fatigability (81.5%) were the most common recent symptoms. All participants were classified as having no cognitive deficit on the MMSE.

Table 2. Clinical, cognitive and mobility profile (N=27).

Variable	n	%
Negative self-perceived health	25	92.6
Mobility difficulties	20	74.1
Use of an assistive device	12	44.4
Usual medication	25	92.6
Five to nine medicines per day	10	37.0
Cardiovascular medicines	24	88.9
Alimentary tract and metabolism medicines	11	40.7
Critical chronic arterial ischaemia of the lower limbs	16	59.3
Pain in the previous month	24	88.9
Easy fatigability in the previous month	22	81.5
No cognitive deficit on the MMSE	27	100

The domain-level Barthel Index results are presented in Table 3. Feeding and bladder control had the highest independence rates (96.3% each), followed by bowel control and dressing (92.6% each). Lower autonomy was observed in bathing, grooming and toilet use. Mobility-related activities were the most affected: only 33.3% walked independently, while 44.4% required help; 18.5% used a wheelchair independently and 3.7% were dependent. For stair climbing, 44.4% were independent, 37.0% required help and 18.5% were dependent.

Table 3. Performance in activities of daily living according to the Barthel Index (N=27).

Domain	Classification	n	%
Feeding	Independent	26	96.3
Feeding	Needs help	1	3.7
Dressing	Independent	25	92.6
Dressing	Needs help	2	7.4
Bathing	Independent	20	74.1
Bathing	Dependent	7	25.9
Grooming	Independent	21	77.8
Grooming	Dependent	6	22.2
Toilet use	Independent	19	70.4
Toilet use	Needs help	7	25.9
Toilet use	Dependent	1	3.7
Bowel control	Independent	25	92.6
Bowel control	Occasional incontinence	2	7.4
Bladder control	Independent	26	96.3
Bladder control	Occasional incontinence	1	3.7
Chair-bed transfer	Independent	17	63.0
Chair-bed transfer	Needs minimal help	9	33.3
Chair-bed transfer	Needs major help	1	3.7
Mobility	Independent	9	33.3
Mobility	Needs help	12	44.4
Mobility	Independent with wheelchair	5	18.5
Mobility	Dependent	1	3.7
Stair climbing	Independent	12	44.4
Stair climbing	Needs help	10	37.0
Stair climbing	Dependent	5	18.5

Global Barthel Index categories are shown in Table 4. Overall, 63.0% were independent, 25.9% had slight dependence and 11.1% had moderate dependence. No participant had severe or total dependence.

The contrast between global independence and mobility limitations indicates that the total score should be interpreted together with individual domain scores.

Table 4. Degree of functional independence according to the Barthel Index (N=27).

Barthel Index category	n	%
Independent	17	63.0
Slightly dependent	7	25.9
Moderately dependent	3	11.1

DISCUSSION

The participants displayed a profile of clinical and social vulnerability commonly relevant to rehabilitation planning: most were men, many were older adults with low educational attainment, and a high proportion were retired or receiving disability benefits. Negative self-perceived health, pain, fatigue, mobility difficulty and the frequent use of assistive devices show that recovery in vascular surgery should not be evaluated only through biomedical or procedural indicators. Functioning, activity and participation must also be considered, as recommended by the International Classification of Functioning, Disability and Health (World Health Organization, 2021).

The Barthel Index distinguished global independence from vulnerability in specific activities. Although 63.0% were classified as independent, only one third walked independently and more than half needed help or were dependent when climbing stairs. This finding is clinically important because autonomy in feeding, continence or dressing does not necessarily ensure safe mobility at home. Domain-level interpretation is therefore more informative for individualized discharge planning than the total score alone, reinforcing the practical value of the instrument described by Mahoney and Barthel (1965) and validated in Portugal by Araújo et al. (2007).

Mobility was the main rehabilitation priority. Participants who required help to walk or used a wheelchair needed assessment of gait quality, balance, pain, fatigue, fall risk, assistive-device technique and environmental barriers. Stair climbing was also a sensitive marker of functional limitation: 55.5% required help or were dependent. This may directly affect access to the home, bathroom or outdoor areas and should be assessed before discharge. Chair-bed transfers also required attention because 36.9% needed some degree of assistance, increasing the risk of falls and dependence on caregivers.

These results support the specialized role of rehabilitation nurses in progressive gait training, transfer and stair practice, selection and adjustment of crutches, walkers or wheelchairs, energy-conservation education, fall prevention and environmental adaptation (Ordem dos Enfermeiros, 2019). Framing care around activities of living facilitates the translation of assessment findings into practical goals (Roper et al., 2000), while transition-focused nursing can help the person and family adapt to altered function and prepare for continuity of care (Meleis, 2010).

Preserved cognitive function in all participants was favourable for learning, adherence and shared goal setting. Nevertheless, pain, fatigue and severe vascular disease may reduce exercise tolerance and require progressive, individualized plans. Systematic assessment on admission and reassessment during hospitalization can support communication within the multidisciplinary team and document functional gains. Such an approach is consistent with the broader rehabilitation agenda of optimizing functioning throughout care pathways (World Health Organization, 2017) and with national priorities for integrated care (Direção-Geral da Saúde, 2021).

The findings should be interpreted in light of the descriptive, single-centre design and the small census population. They characterize the participants admitted during the study period and do not establish causal relationships or permit broad generalization. Future multicentre studies with repeated functional measurements could examine changes between admission and discharge and identify predictors of recovery.

CONCLUSION

Most adults and older people admitted to vascular surgery and receiving rehabilitation nursing care were globally independent according to the Barthel Index. However, clinically relevant limitations were identified in mobility, stair climbing and transfers. These findings demonstrate that preserved basic self-care does not necessarily represent full functional independence for a safe return home.

The main contribution of the study is the demonstration that the Barthel Index is most useful when its domains are examined individually. Domain-level analysis identifies priority needs, guides individualized rehabilitation interventions, supports discharge planning and strengthens person-centred care aimed at autonomy, safety and participation.

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RECONSTRUCTION USING A FREE FIBULA FLAP AFTER MANDIBULAR RESECTION: SURGICAL STRATEGY AND PERIOPERATIVE MANAGEMENT (Clinical Case)

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Introduction

Mandibular defects may occur as a result of oncological processes, trauma, or previous surgical interventions, leading to both functional (mastication, speech, swallowing) and aesthetic impairments. Reconstruction of such defects is considered one of the most challenging areas in reconstructive surgery. Among modern reconstructive techniques, the free fibula flap is widely used due to its adequate bone length, reliable vascular pedicle, and the possibility of including a soft tissue component. This method demonstrates high effectiveness in restoring both the anatomical structure and functional integrity of the mandible. However, these procedures are characterized by long operative times, the complexity of the microsurgical stage, and the need for meticulous perioperative management. Therefore, both surgical strategy and anesthetic management play a crucial role in achieving successful outcomes.

Purpose. To evaluate the effectiveness of the surgical approach and perioperative management in mandibular defect reconstruction using a free fibula flap.

Materials and Methods. A 60-year-old patient underwent a second-stage reconstructive surgery following a previous mandibular resection due to a tumor of the right mandible. The patient was placed in the supine position. Under general anesthesia, nasotracheal intubation and central venous catheterization were performed. The ablative team (Davudov M.) performed an incision along the previous scar in the right submandibular region. Soft tissues were dissected layer by layer, the reconstruction plate was removed, and fibrotic and scar tissues were excised. The mandibular defect was then assessed.

Simultaneously, the microsurgical team (Abdullaev K.) harvested a free fibula flap from the left lower limb. A fibular segment of appropriate length was dissected along with the peroneal artery and vein, and flap perfusion was confirmed. The fibula segment was shaped using osteotomies according to the mandibular defect, positioned into the defect area, and stabilized with titanium plates and screws. During the microsurgical stage, the flap vessels were anastomosed to recipient vessels in the neck (the lingual artery and the facial vein). Adequate perfusion of the flap was confirmed after anastomosis. The total duration of the operation was 16 hours. During the perioperative period, combined anesthesia was administered, maintaining hemodynamic stability, adequate gas exchange, and acid–base balance. The preoperative hemoglobin level was 104 g/L, which increased to 120 g/L after transfusion of 600 mL of packed red blood cells during surgery. The operation was technically successful, with adequate flap perfusion. The patient remained stable in the early postoperative period.

Conclusion and discussion. The free fibula flap is considered the gold standard for mandibular reconstruction in modern reconstructive surgery. First described by David J. Hidalgo, this technique offers significant advantages, including sufficient bone length and the possibility of incorporating soft tissue components.

According to the literature, the survival rate of free fibula flaps ranges between 90% and 95%. Studies by Fu-Chan Wei and colleagues attribute these high success rates to proper surgical planning and advanced microvascular techniques.

Perioperative management is particularly critical in prolonged reconstructive procedures. Gregory Evans emphasizes that hemodynamic stability, adequate oxygenation, and maintenance of acid–base balance directly influence flap microcirculation.

According to global literature, the duration of such procedures typically ranges from 10 to 15 hours and may extend up to 16 hours in complex cases. The 16-hour duration in the presented case reflects its high complexity and is consistent with international data.

Furthermore, optimization of hemoglobin levels from 104 g/L to 120 g/L improved tissue oxygenation and contributed positively to flap perfusion. Maintenance of hemodynamic and metabolic stability throughout the prolonged procedure was a key factor in achieving a successful outcome.

The operation was technically successful, and adequate perfusion of the free fibula flap was maintained during both intraoperative and early postoperative periods. Hemodynamic stability, effective gas exchange, and normal acid–base balance were preserved throughout the procedure.

Despite the prolonged duration and high complexity of the surgery, the absence of significant intraoperative complications highlights the importance of proper surgical strategy and optimal perioperative management. This case confirms that successful outcomes in mandibular reconstruction using a free fibula flap rely on a multidisciplinary approach, integrating both advanced surgical techniques and high-quality anesthetic management. Thus, successful mandibular reconstruction with a free fibula flap requires not only precise surgical technique but also comprehensive and well-coordinated perioperative management.

Keywords. Mandibular reconstruction; Free fibula flap; Microvascular surgery; Perioperative management; Long-duration surgery; Anesthesia management.

ENVIRONMENTAL IMPACT ASSESSMENT THROUGH PHYSICO-CHEMICAL AND BIOLOGICAL ANALYSES OF WASTEWATER AND INDUSTRIAL WASTE FROM THE ARTANË MINE, ARTANË MUNICIPALITY

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ABSTRACT

The assessment of chemical-physical characteristics and heavy metals in water and sediment samples collected from three places in Artanë lake, which is a part of the municipality of Artanë, is the principal goal of this study. The purpose of this study is to confirm the water quality and contamination level of the aforementioned lake, which was created by human activity during the extraction of ores and minerals. The two primary phases of the experiment were sample collection in the field or while camping, and laboratory analysis performed in the Department of Chemistry's laboratory. Three locations were selected to collect samples of water and sediment: M1 (the southern portion near Beston village), M2 (the eastern portion near Makresh and M3 (the northern region close to Prekoc). In the field, measurements were made of the lake sample's properties, including pH, transparency, electrical conductivity, scent, color, and taste, as well as the temperatures of the air and water. The UV-VIS 7600 A spectrophotometer measures the intensity of light as a light beam travels through a sample solution to determine how much a chemical compound absorbs light. Each complex absorbs or transmits light within a specific wavelength range, according to the fundamental idea. It is also possible to measure the quantity of a recognized chemical compound using this method. One of the most helpful quantitative analysis techniques in a variety of disciplines, including chemistry, physics, biochemistry, material chemical engineering, and therapeutic applications, is spectrophotometry. In the deep waters of the lake, our analysis revealed trace amounts of heavy metals, including nickel (Ni), chromium (Cr), manganese (Mn), and zinc (Zn), even though the contamination level is not very high. On the other hand, the sediment contained significant levels of manganese. Although the concentrations of heavy metals were not excessive, it was noted that their existence poses a risk to human health and the environment, when contrasting these results with data from other countries. Aquatic life and flora are negatively impacted by heavy metals, which can harm biodiversity and degrade ecosystems. Another issue that impacts fishing operations and could have negative health effects on fish eaters is the bioaccumulation of metals in fish species. Because recreational lake use may have negative effects on the brain and circulatory systems, there may be additional health hazards. In summary, the present study emphasizes the necessity of continuous monitoring and management strategies to address any hazards resulting from heavy metal pollution in recreational and ecological water bodies

Key words: chemical – physical parameters, heavy metals, water samples, lake Artanë, Spectrophtometry,

MED-ARB: AN EVALUATION OF A HYBRID DISPUTE RESOLUTION METHOD
HİBRİT UYUŞMAZLIK ÇÖZÜM YOLLARINDAN MED-ARB'IN DEĞERLENDİRİLMESİ

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ABSTRACT

Due to the rise in the number of cases for various reasons and the growing emphasis on restorative justice, alternative dispute resolution methods have started to gain acceptance in Türkiye, as in the rest of the world. In Turkish law, mediation and arbitration institutions are regulated separately. In addition, so-called 'hybrid' dispute resolution methods have begun to be used. One such method is mediation-arbitration, commonly referred to as Med-Arb. There are various models of Med-Arb. In one model, both the mediation and arbitration phases are conducted by the same neutral third party. If the mediation stage fails, the neutral third party assumes a different role and oversees the arbitration process. Another Med-Arb model provides for the mediation and arbitration stages to be conducted by different neutral third parties. Another model is 'advisory Med-Arb', carried out by different neutral third parties. In California, this model permits the mediator, where mediation proves unsuccessful, to provide the arbitrator with non-binding recommendations on the resolution of the dispute, without disclosing any confidential information obtained during the mediation phase. Another hybrid dispute resolution method is parallel mediation, in which the mediation process is conducted alongside an ongoing arbitration. By contrast, in the 'advisory arbitrator model', the neutral third party initially acts as mediator and subsequently assumes the role of arbitrator, continuing as an advisory arbitrator. Also referred to as 'non-binding Med-Arb', this model involves a mediator conducting the mediation phase, who, in case negotiations stall, makes a non-binding proposal to the parties in the capacity of an advisory arbitrator. The Med-Arb procedure is an agreement between the parties that, for the resolution of their dispute, the mediation phase will first be exhausted, and if mediation is unsuccessful, the dispute will definitively be resolved through arbitration. This paper will attempt to present how this process works.

Keywords: Hybrid Dispute Resolution Methods, Mediation, Arbitration, Med-Arb, Alternative Dispute Resolution Methods.

ÖZET

Çeşitli etkenlerle artan dosya sayısı ve onarıcı adalet anlayışı sebebi ile alternatif nitelikte uyuşmazlık çözüm yöntemleri tüm dünyada olduğu gibi ülkemizde de kabul edilmeye başlamıştır. Türk Hukukunda müstakil olarak arabuluculuk ve tahkim müesseseleri düzenlenmiştir. Bunun yanı sıra hibrit adını verdiğimiz uyuşmazlık çözüm yöntemleri de uyuşmazlık çözümünde kullanılmaya başlamıştır. Bu metotlardan birisi arabuluculuk-tahkim yöntemi olarak adlandırılan yöntem olup İngilizcesi med-arb olarak kısaltılmaktadır. Med-arb yönteminin çeşitli modelleri bulunmaktadır. Aynı tarafsız üçüncü kişi tarafından yürütülen yöntemde arabuluculuk ve tahkim süreci aynı tarafsız üçüncü kişi tarafından

yürütülmektedir. Arabuluculuk aşaması başarısız olursa tarafsız üçüncü kişi rol değiştirerek tahkim sürecini yönetir. Diğer med-arb modeli ise farklı tarafsız üçüncü kişiler tarafından yürütülen yöntemdir. Arabuluculuk ve tahkim aşamaları farklı üçüncü kişiler tarafından yürütülmektedir. Bir diğer model ise farklı tarafsız üçüncü kişiler tarafından yürütülen tavsiye edici med-arb yöntemidir. Kaliforniya'da uygulanmakta olan ve med-arb aşamalarının farklı üçüncü kişiler tarafından yürütülen tavsiye edici med-arb modelinde arabulucu arabuluculuk aşamasının olumsuz sonuçlanmasından sonra bu aşamada öğrendiği gizli hususları ifade etmeden tahkim aşamasını yürütecek hakeme uyuşmazlığın çözümüne yönelik tavsiyelerde bulunur. Bir diğer hibrit çözüm yolu ise paralel arabuluculuktur. Mevcut tahkim süreci ile birlikte arabuluculuk süreci birlikte yürütülmektedir. Danışman hakem (*advisory arbitrator*) modelinde ise arabulucu olarak görev yapan tarafsız üçüncü kişi daha sonra tahkim aşamasına geçilmeden önce rol değiştirerek danışman hakem olarak görevine devam eder. Bağlayıcı olmayan med-arb (non-binding med-arb) olarak da ifade edilen bu model arabuluculuk aşamasını yürüten arabulucu, müzakerelerin ilerleyemediği durumda danışman hakem rolüne geçerek taraflara bağlayıcı olmayan bir teklifte bulunur. Med-arb usulü tarafların uyuşmazlığın çözümü için öncelikle arabuluculuk aşamasının tüketileceği, arabuluculuk aşamasının olumsuz sonuçlanması durumunda uyuşmazlığın kesin bir kararlar tahkim aşamasında çözüleceğine yönelik yaptıkları anlaşmadır. Bu tebliğ ile bu sürecin nasıl işlediği ortaya konulmaya çalışılacaktır.

Anahtar Kelimeler: Hibrit Çözüm Yolları, Arabuluculuk, Tahkim, Med-arb, Alternatif Uyuşmazlık Çözüm Yolları.

GİRİŞ

En az iki insanın var olduğu yerde uyuşmazlık ve çatışmaların yaşanması kaçınılmazdır. Uyuşmazlıklar, insanlık tarihi kadar eskiye dayanır. Bu bağlamda uyuşmazlık çözüm yöntemleri de neredeyse uyuşmazlıklarla eş zamanlı olarak gelişmeye ve zaman içerisinde bir dönüşüm yaşamaya başlamıştır. En klasik uyuşmazlık çözüm yolu tarafların karşılıklı hak ve menfaatlerini savundukları ve stratejik bir yol izledikleri müzakere metodudur. Devlet yargılamaları da geleneksel uyuşmazlık çözüm yolu olarak tercih edilen araçlardandır. Devlet yargılamasının uzun yıllar sürmesi, sıkı usuli kuralları ve mali boyutu nedeniyle özellikle ikinci dünya savaşından sonra tahkim yargılaması kullanılmaya başlanmıştır. Son yıllarda ise tahkim ile arabuluculuğun çeşitli evrelerde kullanıldığı hibrit uyuşmazlık çözüm yolları tercih edilmektedir. Çalışmamızda arabuluculuk tahkim (med-arb) modelinin hukuki niteliği, olumlu ve olumsuz yönleri, farklı modelleri ile sınır ötesi icra edilebilirliği inceleme konusu yapılacaktır.

1. MED-ARB'IN HUKUKİ NİTELİĞİ

Arabuluculuk süreci ile uyuşmazlığın çözüme kavuşturulmaya çalışılması, arabuluculuk sürecinin başarılı olmaması halinde ise tahkim yolu ile bağlayıcı ve nihai olarak anlaşma yapılması durumu klasik med-arb olarak tanımlanmaktadır (Demirkol & Aküzüm, 2020, s. 57-58). Arabuluculuk ile tahkimin sakıncalarını ortadan kaldırmak ve faydalı yönlerini birleştirmek amacıyla karma bir yöntem olan arabuluculuk-tahkim usulü geliştirilmiştir (Akıncı, 2021, s. 19). Arabuluculuk yöntemi iletişim ve müzakere süreçlerini kapsayan bir dostane uyuşmazlık çözüm yöntemidir (Tanrıver, 2022, s. 29). Tahkim ise sonucunda nihai bir karar alınan özel bir yargılama yöntemidir. Tahkimin kural olarak temelinde sözleşme özgürlüğü olan ihtiyari bir uyuşmazlık çözüm mekanizması olduğu söylenebilir (Aydemir, 2017, s. 8; Nomer et al., 2021, s. 1).

Hibrit uyuşmazlık çözüm yöntemleri tahkim ya da arabuluculuk mekanizmalarına kıyasla yeni sayılabilecek yöntemlerdir. Kanada Alternatif Uyuşmazlık Çözüm Enstitüsü 2015 yılından beri med-arb yöntemi konusunda çalışmalar yürütmektedir (Demirkol & Aküzüm, 2020, s. 75). Yeni Zelanda Uyuşmazlık Çözüm Merkezi'nin 2018 tarihli tahkim kurallarında da arabuluculuğa gidilebileceği düzenlenmiştir (Demirkol & Aküzüm, 2020, s. 76). İstanbul Tahkim Merkezi'nin 2019 tarihli arabuluculuk-tahkim kurallarında ise hibrit uyuşmazlık çözüm yolunun usul ve ilkeleri düzenlenmiş bulunmaktadır.

Med-arb yönteminde arabulucunun aynı uyuşmazlıkta hakem olarak görev yapıp yapmayacağı oldukça tartışmalı bir konudur (Demirkol & Aküzüm, 2020, s. 67; Akıncı, 2021, s. 24). Örneğin Türk Hukuk

Sisteminde tarafların açık ve yazılı onayı ile arabulucu, aynı uyuşmazlıkta hakem olarak görev yapabilmektedir. Aynı arabulucunun hakem olarak görev yapması durumunda (*Same Neutral Med-Arb*) ve farklı arabulucunun görev yapması halinde ise (*Med-Arb Diff*) şeklinde isimlendirme yapılmaktadır. Adil yargılanma hakkı, tarafsızlık ve bağımsızlık gibi evrensel ilkeler nedeniyle aynı arabulucunun süreçte hakem olarak yer alması sakıncalı görünebilir. Avrupa İnsan Hakları Sözleşmesi'nin 6. maddesinde adil yargılanma hakkı düzenlenmiş olup, ilgili Sözleşme kapsamına tahkim yargılamasının da dâhil olup olmadığı tartışmaya açık bir konudur (Erçetingöz, 2023, s. 78). Ancak hakemlerin tarafsız ve bağımsızlığının zaten tahkim yargılamasının yapısından kaynaklı olduğu unutulmamalıdır (Erçetingöz, 2023, s. 78). Milletlerarası ticari tahkimde adil yargılamaya dair usuli asgari standartların sağlanmış olması kararların iptal edilme ve tenfiz edilmeme engeli karşısında son derece önem arz eder (Takavut, 2021, s. 448). Aynı arabulucunun süreç içerisinde hakem olarak görev yapması durumunda ihtiyatlı davranması gereklidir (Akıncı, 2021, s. 26). Zira arabulucu-hakemin uyuşmazlık hakkında fikir beyan etmesi, taraflara beklentileri doğrultusunda sorular yöneltmesi ve diğer tarafın yokluğunda görüşmeler yapması tahkim yargılamasının geçerliliği yönünden ciddi sakıncalar içerebilir (Akıncı, 2021, s. 26). Aynı zamanda tarafsızlık ve bağımsızlık gibi temel ilkelerin ihlali durumunda hakemin özel hukuk sorumluluğu da gündeme gelebilecektir (Han, 2023, s. 203).

Kanaatimizce arabulucu süreçte bir çözüm önerisi sunmamışsa aynı arabulucunun hakem olarak yer almasında bir sakınca görülmemelidir. Yine taraflar med-arb usulünü benimsemişlerse ve aynı arabulucunun hakem olarak görev yapmasını kararlaştırmışlarsa arabulucunun özel oturumlar yerine ortak oturumlar ile süreci yönetmesinin özellikle tarafsızlık ve gizlilik gibi ilkeler yönünden yerinde bir yaklaşım olacağını değerlendirmekteyiz.

Bazı durumlarda taraflar arasında bir med-arb sözleşmesi bulunmaz, süreç sadece arabuluculuk yönünden başlamıştır. Ancak arabuluculuk süreci sonunda anlaşma olması halinde taraflar ilgili anlaşmanın bir hakem kararı haline getirilmesini isteyebilirler. Hakem kararı olarak tespiti için nitelik itibariyle anlaşılır olması ve yeterince kesinliğe sahip olması gerekir (Elçin, 2019, s. 21).

2. MED-ARB USULÜNÜN OLUMLU VE OLUMSUZ YÖNLERİ

Med-arb yöntemi bir istisnai yargısal yöntem olan tahkim ile bir alternatif uyuşmazlık çözüm yöntemi olan arabuluculuğun bir araya geldiği karma bir yoldur (Tanrıver, 2022, s. 42). Doğal olarak her iki yöntemin de olumlu ve olumsuz taraflarını içerir. Arabuluculuk-tahkim uyuşmazlık taraflarının daha geniş bakışıyla hareket etmelerine olanak sağlayan esnek bir süreçtir (Tanrıver, 2022, s. 43). Uyuşmazlık taraflarının hukuki ve ekonomik menfaatlerini koruyan ve taraflarca Kabul edilebilir bir çözümün benimsenmesine fırsat vermesi med-arb usulünün en önemli avantajıdır (Demirkol & Aküzüm, 2020, s. 71). Uyuşmazlığın konunun uzmanları tarafından etkin, hızlı ve gizli şekilde çözüme kavuşturulması da diğer bir avantajıdır (Demirkol & Aküzüm, 2020, s. 71). Arabuluculuk sürecinden tahkime gitme opsiyonu her zaman açık olduğundan daha esnek bir süreçtir. Hatta arb-med-arb gibi çeşitli hibrit modellerde tahkim yargılamasından vazgeçilerek arabuluculuğa gitme opsiyonu her zaman vardır. Uyuşmazlık taraflarının, klasik devlet yargısından farklı olarak ilişkilerini ve ticari itibarlarını koruması da önemli avantajlar arasındadır. Med-arb yönteminde tarafların birbirlerinin argümanlarını ve görüşlerini dinleme fırsatı elde edecek olmaları da olumlu bir yandır (Kahveci, 2021, s. 219).

Med-arb usulünde özellikle arabuluculuk süreci olumsuz sonuçlanmış ise taraflar arabulucuya başvurmayı bir yük olarak görebilirler (Demirkol & Aküzüm, 2020, s. 72). Zira arabuluculuk sürecinde ayrıca arabulucu ücreti ve diğer giderleri nedeniyle masraflı bir süreç olabilir (Demirkol & Aküzüm, 2020, s. 73). Uyuşmazlık tarafları arasında bir uyuşmazlık çıkması durumunda geçici koruma tedbirlerinin uygulanmasındaki zorluklar med-arb usulünün olumsuz yanlarındandır (Demirkol & Aküzüm, 2020, s. 73).

3. MED-ARB MODELLERİ ÜZERİNE BİR DEĞERLENDİRME

Med-arb'da arabulucu ve/veya hakemin işlev ve görevi ile uygulanan usul ve yönteme göre çok fazla modeli mevcuttur. Bu bölümde tüm med-arb modelleri değerlendirilmeyecek, özellikle en yaygın modeller ele alınacaktır. Arabulucu ve hakemin aynı kişi olduğu med-arb modeli "*Same Neutral Med-Arb*" olarak adlandırılmaktadır (Canatan, 2023, s. 86). Bu modelde tarafsız ve bağımsız 3. kişi önce arabulucu olarak görev yapmakta eğer taraflar arasında sulh sağlanamazsa hakem şapkası ile göreve

devam etmekte ve uyuşmazlık hakkında nihai kararı vermektedir. Arabulucu ve hakemin farklı kişi olduğu med-arb modeli ise "*Med-Arb Diff*" ismiyle anılmaktadır (Canatan, 2023, s. 86). Kaliforniya'da uygulanan tavsiye edici med-arb modeli "*Med-Arb Diff-Recommendation*"nde arabulucu hakeme bazı tavsiyelerde bulunmaktadır, ancak hakemin tavsiyelere uyma yükümlülüğü bulunmamaktadır (Canatan, 2023, s. 88). Paralel Arabuluculuk Modeli "*Mediation Windows in Arbitration*"nde arabuluculuk ve tahkim bir arada yürütülmektedir (Canatan, 2023, s. 88). Bağlayıcı Olmayan Med-Arb Modeli "*Non-Binding Med-Arb*", bağlayıcı olmayan modellerde arabuluculuk süreci olumsuz sonuçlanması halinde arabulucu hakem sıfatını değil, danışman sıfatıyla tarafların uyuşmazlıklarının çözümünde destek olmaktadır (Canatan, 2023, s. 89). Tarafların, tahkim kararının bir zarfa konarak mühürlendiği bir tahkimin sonuçlanmasının ardından arabuluculuğa başvurmaya çalıştıkları arb-med süreci işlevsel bir model olmadığından literatürde haklı olarak eleştirilmiştir (Lu, 2022, s. 253). Görüldüğü üzere arabuluculuğun ve tahkimin olumlu ve olumsuz yöntemleri esas alınarak çok sayıda melez uyuşmazlık çözüm yöntemi denenmiş bulunmaktadır. Uyuşmazlık tarafları çözüm bulmak adına daha hızlı ve daha az maliyetli yollar ararken, karma süreçlere olan ilgi giderek de artmaktadır (Sussman, 2018, s. 1). Kanaatimizce ilgili modellerden çözüme en yakını aynı arabulucunun hakem olarak görev yaptığı modeldir. Zira arabulucu süreç boyunca uyuşmazlığı çeşitli yönleri ile değerlendirebilmektedir. Ne var ki tarafsızlık ve bağımsızlık ve adil yargılanma hakkı açısından en fazla riski de ilgili model taşımaktadır. Belirtilen nedenle özellikle bu modelde tarafların açık ve yazılı rızalarının alınması, özel oturum yapılmaması ve arabulucunun çözüm önerisi getirmemesi riskleri azaltmaya yöneliktir.

4. HİBRİT UYUŞMAZLIK ÇÖZÜM YOLLARININ SINIR ÖTESİ İCRA EDİLEBİLİRLİĞİ

Med-arb özellikle uyuşmazlıkları çözmek konusunda hızlı ve uygun maliyetli bir süreç olması ile küresel ticaret akışına katkısı nedeniyle tercih edilebilecek bir modeldir (Sussman, 2013, s. 179; Chua, 2019, s. 23). Med-arb, med-arb-same, med-arb diff ve arb-med-arb gibi çeşitli hibrit uyuşmazlık çözüm yollarının sonucunda bir hakem kararına ulaşılmış ise hakem kararlarının sınır ötesi tanınması ve tenfizi mümkündür. 1958 tarihli Yabancı Hakem Kararlarının Tanınması ve İcrası Hakkındaki New York Sözleşmesi'nin I. maddesi uyarınca "*tanınması veya icrası istenen devletten başka bir devlet toprağında verilmiş bulunan hakem kararları*" ilgili sözleşme uyarınca sınır ötesi icra edilebilecektir (Gül, 2016, s. 11). Şöyle ki, eğer hakem kararı ile nihai sonuç alınmış ise 1958 tarihli Yabancı Hakem Kararlarının Tanınması ve İcrası Hakkındaki New York Sözleşmesi (Zenginkuzucu, 2017, s. 8 vd.) kapsamında hakem kararının icra edilmesi sağlanabilecektir (Erkan, 2020, s. 70). Ancak bu durumda süreç sonunda bir arabuluculuk anlaşma belgesi meydana gelmediğinden, resmi adıyla "Arabuluculuk Sonucunda Yapılan Milletlerarası Sulh Anlaşmaları Hakkında Birleşmiş Milletler Sözleşmesi" olarak bilinen Singapur Sözleşmesi 1/(3)(b) maddesi kapsamında icra edilmesi mümkün olmayacaktır. Ancak, med-arb sürecinde uyuşmazlık arabulucu aşamasında çözümlenmişse ve arabulucu bir çözüm empoze etmemişse bu durumda Singapur Sözleşmesi'nin uygulanması mümkündür (Cortés, 2022, s. 70, p.1.15).

SONUÇ VE DEĞERLENDİRME

Med-arb usulü, tarafların uyuşmazlıklarının çözümünde öncelikle arabuluculuk sürecinin işletileceğini, bu sürecin başarısızlıkla sonuçlanması halinde ise uyuşmazlığın kesin ve bağlayıcı bir karar ile tahkim yoluyla çözümleneceğini öngören bir alternatif uyuşmazlık çözüm modelidir. Bugüne kadar arabuluculuğun ve tahkimin olumlu ve olumsuz yöntemleri esas alınarak çok sayıda karma ve kendine özgü uyuşmazlık çözüm yöntemi denenmiş bulunmaktadır. Uyuşmazlığın insanlık tarihi kadar eski olduğu varsayımı ile uyuşmazlık çözüm yolları arayışının da insan var olduğu sürece mevcut olmaya devam edeceği ve zaman içinde dönüşüm yaşayacağı değerlendirilebilir.

Artan dosya yükü ve onarıcı adalet anlayışının güç kazanmasıyla birlikte, alternatif uyuşmazlık çözüm yöntemleri dünya genelinde olduğu gibi Türkiye'de de giderek daha fazla kabul görmektedir. Türk hukukunda bu kapsamda arabuluculuk ve tahkim kurumları müstakil olarak düzenlenmiş olup, bunlara ek olarak "hibrit" olarak adlandırılan karma nitelikli uyuşmazlık çözüm yöntemleri de uygulama alanı bulmaya başlamıştır.

İlgili hibrit yöntemlerden biri, İngilizcede "*med-arb*" olarak kısaltılan arabuluculuk-tahkim modelidir. Med-arb yöntemi, farklı uygulama biçimlerine sahip olup, bu bağlamda çeşitli modellerden söz etmek

mümkündür. İlk modelde, süreç aynı tarafsız üçüncü kişi tarafından yürütülmekte; arabuluculuk aşamasının başarısızlıkla sonuçlanması halinde, aynı kişi rol değiştirerek tahkim sürecini üstlenmektedir. İkinci modelde ise arabuluculuk ve tahkim aşamaları farklı tarafsız üçüncü kişiler tarafından yürütülmektedir. Bir diğer model olan tavsiye edici med-arb yönteminde, özellikle Kaliforniya uygulamasında görüldüğü üzere, arabulucu arabuluculuk sürecinde edindiği gizli bilgileri ifşa etmeksizin, tahkim aşamasını yürütecek hakeme uyuşmazlığın çözümüne ilişkin önerilerde bulunmaktadır.

Hibrit çözüm yöntemleri arasında yer alan bir diğer yaklaşım ise paralel arabuluculuktur. Bu yöntemde, tahkim süreci devam ederken arabuluculuk süreci de eş zamanlı olarak yürütülmektedir. Bunun yanı sıra, danışman hakem "*advisory arbitrator*" modeli olarak adlandırılan yöntemde, başlangıçta arabulucu olarak görev yapan tarafsız üçüncü kişi, arabuluculuk aşamasının sonuçsuz kalması halinde rol değiştirerek tahkim öncesinde danışman hakem sıfatıyla sürece devam etmektedir. Bağlayıcı olmayan med-arb "*non-binding med-arb*" olarak da ifade edilen bu modelde, arabulucu müzakerelerin tıkanması durumunda taraflara bağlayıcı nitelik taşımayan bir çözüm önerisi sunmaktadır.

Uyuşmazlık tarafları çözüm bulmak adına daha hızlı ve daha az maliyetli yollar ararken, karma süreçlere olan ilgi de giderek artmaktadır. Amaç en kısa zamanda ve en az maliyetle çözüm bulunmasıdır. Kanaatimizce ilgili modellerden çözüme en yakın ve avantajlı seçenek aynı arabulucunun hakem olarak görev yaptığı "*Same Neutral Med-Arb*" modelidir. Zira arabulucu süreç boyunca uyuşmazlığı çeşitli yönleri ile değerlendirebilme fırsatı bulmaktadır. Bu durum da sürecin optimum fayda ile sonuçlanmasını temin edecektir. Ne var ki tarafsızlık ve bağımsızlık ile adil yargılanma hakkı açısından en fazla riski de ilgili model taşımaktadır. Belirtilen nedenlerle özellikle bu modelde tarafların açık ve yazılı rızalarının alınması, özel oturum yapılmaması ve arabulucunun çözüm önerisi getirmemesi gibi önlemler riskleri azaltmaya yöneliktir.

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EFFECT OF DIFFERENT FLOUR MOISTURE LEVELS ON PROCESSING AND QUALITY ATTRIBUTES OF NOODLE PRODUCTION

FARKLI UN NEM ORANLARININ NOODLE ÜRETİMİNDE PROSES VE KALİTE ÖZELLİKLERİ ÜZERİNE ETKİSİ

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ABSTRACT

Flour moisture content is a fundamental parameter governing dough viscoelasticity, process stability, and final noodle quality. This study investigated the effects of different flour moisture levels (11%, 13%, 15%, and 17%) on processing performance and quality attributes of fried instant noodles.

Doughs were prepared under controlled conditions and processed through standard sheeting, steaming, and frying operations. Cooking loss, oil uptake, texture profile, and water absorption capacity were determined to evaluate product performance. Results demonstrated that flour moisture significantly affected both processing behavior and structural quality ($p < 0.05$). Increasing moisture from 11% to 15% improved dough machinability, reduced sheet breakage, and enhanced structural integrity. Cooking loss decreased from 7.8 ± 0.4% to 5.9 ± 0.3%, while oil uptake declined from 23.6 ± 0.5% to 20.8 ± 0.4%. Texture analysis showed increased hardness (28.4 ± 1.2 N to 34.7 ± 1.5 N) and cohesiveness, indicating improved matrix strength. However, excessive moisture (17%) resulted in over-hydration of the gluten–starch matrix, leading to structural weakening, increased cooking loss (8.5 ± 0.6%), and higher oil uptake (24.9 ± 0.7%). These findings suggest that optimal moisture promotes balanced gluten network formation and starch swelling, reducing pore formation and limiting oil penetration during frying.

In conclusion, flour moisture critically determines both process efficiency and product quality, and a level of 13–15% is recommended for achieving optimal structural stability and reduced oil absorption..

Keywords: Flour moisture, noodle, oil uptake, texture, cooking loss

ÖZET

Un nem içeriği, hamur viskoelastik özelliklerini, proses stabilitesini ve nihai noodle kalitesini belirleyen temel parametrelerden biridir. Bu çalışmada, farklı un nem oranlarının (%11, %13, %15 ve %17) kızartılmış noodle üretiminde proses performansı ve kalite özellikleri üzerindeki etkileri incelenmiştir.

Hamurlar kontrollü koşullarda hazırlanmış ve standart laminasyon, buharlama ve kızartma proseslerinden geçirilmiştir. Ürünlerde pişirme kaybı, yağ emilimi, tekstürel özellikler ve su absorpsiyon kapasitesi belirlenmiştir. Sonuçlar, un nem içeriğinin hem proses davranışı hem de yapısal kalite üzerinde anlamlı etkiler oluşturduğunu göstermiştir ($p < 0.05$). Nem oranının %11'den %15'e yükselmesi hamur işlenebilirliğini artırmış, laminasyon kırılmalarını azaltmış ve yapısal bütünlüğü iyileştirmiştir. Pişirme kaybı %7.8 ± 0.4'ten %5.9 ± 0.3'e düşerken, yağ emilimi %23.6 ± 0.5'ten %20.8 ± 0.4'e gerilemiştir. Tekstür analizinde sertlik değerlerinin 28.4 ± 1.2 N'den 34.7 ± 1.5 N'ye yükseldiği belirlenmiştir. Buna karşılık, yüksek nem (%17) gluten–nişasta matrisinde aşırı hidratasyona neden olarak yapısal zayıflamaya yol açmış, pişirme kaybını (%8.5 ± 0.6) ve yağ emilimini (%24.9 ± 0.7) artırmıştır. Bu durum, gözenek oluşumunun artması ve yağ penetrasyonunun kolaylaşması ile açıklanabilir.

Sonuç olarak, un nem oranının %13–15 aralığında olması, optimum yapı oluşumu, düşük yağ emilimi ve istenilen tekstürel özellikler açısından önerilmektedir.

Anahtar Kelimeler: Un nemi, noodle, yağ emilimi, tekstür, pişirme kaybı.

TOWARD ROBUST FAKE REVIEW DETECTION IN TURKISH E-COMMERCE: A MULTI-SOURCE SYNTHETIC DATA FRAMEWORK

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ABSTRACT

The increasing fluency of large language models has made fake review detection a more complex problem, particularly in low-resource and morphologically rich languages such as Turkish. This study presents a multi-source synthetic data framework for detecting fake reviews in Turkish e-commerce reviews. A balanced corpus of 450,000 samples was constructed, including 225,000 authentic user reviews and 225,000 artificially generated reviews. The fake review class was generated through seven distinct strategies, including Markov-chain generation, Frankenstein-style recombination, back-translation, fine-tuned GPT-2 generation, and instruction-tuned large language models such as Qwen2, LLaMA-3, and Mistral.

Six Turkish transformer-based models were evaluated under a standardized experimental protocol using identical data splits, minimal preprocessing, fixed tokenization limits, and five independent random seeds. Model performance was assessed using accuracy, precision, recall, F1-score, and ROC-AUC, while inter-model differences were statistically examined through McNemar tests combined across seeds using Fisher's method. The results show that ElecTRa achieves the strongest in-distribution performance, with an F1-score of 0.9940 ± 0.0006, whereas BERTurk-128k demonstrates superior robustness under external and heterogeneous evaluation conditions. Ablation analyses further indicate that synthetic source diversity improves generalization more reliably than single-source fake review generation. Overall, the findings suggest that effective fake review detection depends not only on model architecture, but also on the methodological diversity of synthetic training data.

Keywords: fake review detection, e-commerce reviews, multi-source synthetic data, transformer models, large language models, low-resource NLP

GRAPH-BASED MODELING OF HOSPITAL READMISSION RISK USING CLINICALLY-INFORMED PATIENT NETWORKS

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ABSTRACT

Hospital readmission remains a critical challenge in healthcare systems, as early identification of high-risk patients can significantly reduce costs and improve patient outcomes. While traditional machine learning approaches have shown strong performance on tabular clinical data, they often fail to capture relationships between patients that may provide additional predictive value. In this study, we propose a graph-based framework for hospital readmission prediction that models patients as nodes within a clinically-informed network. The proposed approach constructs patient graphs using diagnosis categories, medical specialties, and demographic attributes, enabling the model to leverage both individual features and relational context. In addition, a hybrid graph strategy is introduced by integrating similarity-based connections within diagnosis groups, allowing the model to capture both semantic and local structural patterns. A GraphSAGE-based architecture is employed to learn node representations and perform binary classification of readmission risk. Extensive experiments are conducted using a real-world hospital readmission dataset. The proposed graph-based models are compared against strong baseline methods, including Random Forest, XGBoost, and multilayer perceptrons. Results demonstrate that the clinically informed GraphSAGE model substantially outperformed conventional machine learning baselines in terms of both Accuracy and F1-score, highlighting the importance of clinically meaningful patient relationships for readmission prediction. Although the hybrid graph strategy provides modest gains in ranking ability, the findings suggest that clinically meaningful relationships are more effective than purely similarity-based connections for readmission prediction. These findings highlight the importance of incorporating relational information in clinical prediction tasks. The proposed framework offers a practical and interpretable approach for supporting data-driven decision-making in healthcare environments.

Keywords: Graph Neural Networks; Hospital Readmission; Clinical Data Mining; GraphSAGE; Healthcare Analytics; Patient Risk Prediction; Relational Learning

1. Introduction

Hospital readmission has become one of the most widely studied outcomes in healthcare analytics due to its substantial clinical and economic implications. Unplanned readmissions are often associated with increased healthcare expenditures, inefficient utilization of hospital resources, and adverse patient outcomes. Consequently, the ability to identify patients who are at elevated risk of returning to the hospital after discharge has attracted considerable attention from researchers and healthcare practitioners alike. Early identification of such patients enables healthcare providers to implement targeted interventions, optimize post-discharge care plans, and potentially reduce avoidable readmissions [1], [2]. The increasing adoption of electronic health records (EHRs) has created unprecedented opportunities for the development of predictive models using routinely collected clinical data. Traditional machine learning algorithms, including logistic regression, random forests, gradient boosting methods, and multilayer perceptrons, have been extensively employed for readmission

prediction tasks [3]–[5]. Although these methods have demonstrated promising predictive capabilities, they generally treat patients as independent observations represented by tabular feature vectors. Such an assumption overlooks the fact that patients frequently share meaningful clinical characteristics, including similar diagnoses, treatment pathways, demographic profiles, and healthcare utilization patterns. Ignoring these latent relationships may limit the ability of predictive models to fully exploit the structure inherent in healthcare data. Graph Neural Networks (GNNs) have recently emerged as powerful tools for learning from relational data by jointly modeling both node attributes and the connections between entities [6]. By propagating information through neighboring nodes, GNNs can capture complex dependencies that conventional machine learning methods cannot explicitly represent. Their success has been demonstrated across diverse domains, including recommender systems, social networks, molecular property prediction, and biomedical applications [6], [7]. Within healthcare, graph-based approaches have shown encouraging results in disease prediction, patient stratification, and clinical decision support, suggesting that patient relationships may provide valuable complementary information beyond individual-level attributes [8], [9]. Despite this growing interest, several challenges remain. First, constructing clinically meaningful patient graphs is far from straightforward. Many existing studies rely primarily on similarity measures derived from feature distances, potentially generating connections that lack clear clinical interpretation. Second, relatively limited attention has been devoted to systematically examining how different graph construction strategies influence predictive performance in readmission settings. Understanding whether clinically informed relationships outperform purely similarity-based structures is essential for developing reliable and interpretable graph-based healthcare applications. Motivated by these considerations, this study investigates hospital readmission prediction through the lens of patient relational modeling. We propose a GraphSAGE-based framework that represents patients as nodes within clinically informed networks constructed using diagnosis information, medical specialties, and demographic characteristics. In addition, we explore diagnosis-constrained similarity graphs and hybrid graph structures to assess the contribution of alternative connectivity patterns. Unlike studies that focus solely on maximizing predictive accuracy, our objective is also to understand how graph design choices affect the identification of high-risk patients.

The contributions of this work can be summarized as follows. First, we develop a clinically informed patient graph representation tailored to hospital readmission prediction. Second, we provide a comparative analysis of multiple graph construction strategies, including clinical, diagnosis-based similarity, and fused graphs, within a unified GraphSAGE framework. Third, we benchmark the proposed graph-based models against established machine learning approaches, including Random Forest, XGBoost, and multilayer perceptrons, using a real-world hospital readmission dataset. Finally, our findings provide practical insights into the role of clinically meaningful relationships in graph-based healthcare prediction and offer directions for future development of relational learning approaches in medical settings.

2. Related Work

Hospital readmission prediction has been extensively investigated over the past decade, primarily due to its importance in improving healthcare quality and reducing unnecessary medical expenditures. Early studies largely relied on conventional statistical approaches and machine learning algorithms applied to structured clinical data. Logistic regression was among the first methods employed for identifying patients at risk of readmission because of its interpretability and ease of implementation [10]. Subsequently, ensemble-based methods such as Random Forest and gradient boosting demonstrated improved predictive performance by capturing nonlinear relationships among clinical variables [11], [12]. With the increasing availability of electronic health records, researchers began exploring more sophisticated approaches based on deep learning. Rajkomar et al. [5] showed that neural networks trained on large-scale EHR data could achieve competitive results across multiple clinical prediction tasks, including hospital readmission. Similarly, Futoma et al. [3] compared several machine learning techniques for early readmission prediction and highlighted that no single model consistently outperformed others across different settings, emphasizing the importance of data representation and problem formulation. More recently, graph-based learning has attracted attention within healthcare analytics because many medical entities naturally exhibit relational structures. Choi et al. [8] introduced

GRAM, which leveraged medical ontologies through graph-based attention mechanisms to improve healthcare representation learning. Parisot et al. [13] further demonstrated that graph convolutional networks could effectively integrate patient similarities for disease prediction, suggesting that exploiting interactions among patients may enhance predictive modeling. These findings motivated subsequent studies investigating graph neural networks for various clinical applications, including disease diagnosis, patient stratification, and outcome prediction [14], [15]. Despite these advances, relatively few studies have systematically examined how different patient graph construction strategies influence readmission prediction performance. Existing approaches often generate graphs solely based on feature similarity, with limited consideration of whether the resulting connections are clinically meaningful.

Consequently, the impact of clinically informed relationships compared with similarity-driven structures remains insufficiently explored. Addressing this gap, the present study evaluates multiple graph construction mechanisms within a unified GraphSAGE framework and investigates their effectiveness for hospital readmission prediction using real-world clinical data.

3. Methodology

3.1. Overview of the Proposed Framework. This study investigates whether clinically meaningful relationships among patients can improve hospital readmission prediction compared with traditional machine learning approaches that treat patients as independent observations. The overall workflow of the proposed framework is illustrated in Figure 1. After preprocessing the hospital readmission dataset, three alternative patient graph construction strategies were explored: a clinically informed graph, a diagnosis-constrained similarity graph, and a fused graph integrating both types of relationships. These graph representations were subsequently processed using GraphSAGE to predict readmission outcomes.

Figure 1. Proposed framework for hospital readmission prediction using clinically informed patient networks.

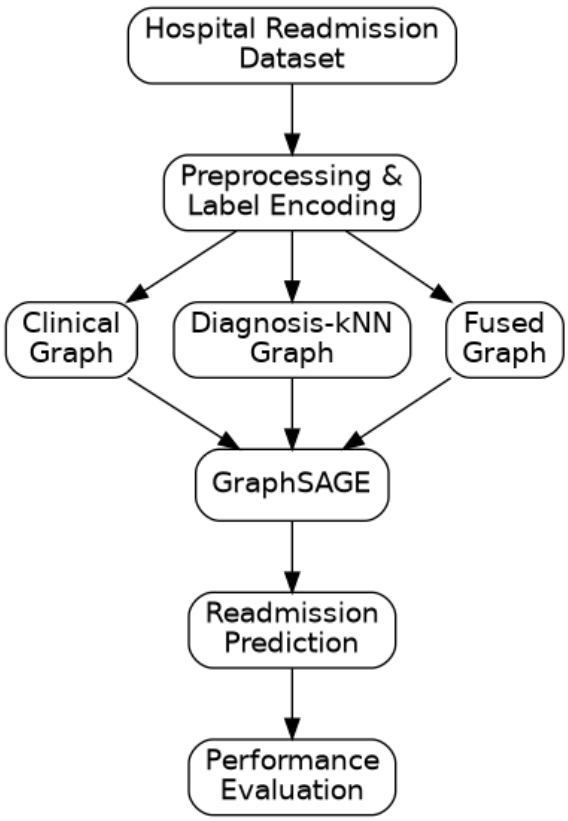


Figure 1 summarizes the complete experimental pipeline adopted in this study. Different graph construction strategies were investigated under the same GraphSAGE architecture to understand how alternative patient relationships influence predictive performance.

3.2. Dataset and Preprocessing. The experiments were conducted using the publicly available *Hospital Readmissions* dataset available on Kaggle [16]. The dataset contains 25,000 patient records and 16 predictive attributes describing demographic information, healthcare utilization, diagnoses, medications, and treatment-related characteristics. The prediction task was formulated as a binary classification problem, where the objective was to determine whether a patient would be readmitted following discharge. Categorical attributes were transformed using label encoding to enable their use within graph neural networks. The dataset was then partitioned into training, validation, and testing subsets using stratified sampling to preserve the original class distribution across all splits.

3.3. Patient Graph Construction. A key component of the proposed framework is the definition of relationships among patients. Three graph construction strategies were investigated.

Clinical Graph. Patients were connected based on clinically meaningful characteristics, including shared diagnosis categories, diagnosis combinations, medical specialties, and diagnosis-age profiles. This design aimed to preserve interpretable medical relationships rather than relying solely on numerical similarity.

Diagnosis-Constrained kNN Graph. Patients were first grouped according to their primary diagnosis. Within each diagnosis group, k-nearest neighbor relationships were established to capture local similarities. Similarity-based patient graphs have recently been shown to be effective for modeling EHR data and clinical outcomes [17], [18].

Fused Graph. Finally, a hybrid graph was created by combining the edge sets obtained from the clinical and diagnosis-constrained graphs. This strategy was designed to investigate whether semantic and similarity-based relationships provide complementary predictive information.

A patient graph is formally represented as

$$G = (V, E), \qquad (1)$$

where V denotes the set of patient nodes and E represents the set of edges defining relationships among patients.

3.4. GraphSAGE-Based Prediction. To learn patient representations from the constructed graphs, the GraphSAGE architecture was employed [6]. GraphSAGE performs inductive representation learning by aggregating information from neighbouring nodes, allowing the model to generalize to previously unseen patients.

The node embedding update mechanism can be expressed as

$$\mathrm{h}_v^{(k)} = \sigma\left(\mathrm{W}^{(k)} \cdot \mathrm{AGG}\left(\left\{\mathrm{h}_u^{(k-1)} : u \in \mathcal{N}(v)\right\}\right)\right), \qquad (2)$$

where $\mathrm{h}_v^{(k)}$ is the embedding of node v at layer k, $\mathcal{N}(v)$ denotes the neighborhood of node v, $\mathrm{AGG}(\cdot)$ is the aggregation function, $\mathrm{W}^{(k)}$ represents trainable parameters, and $\sigma(\cdot)$ denotes the activation function. This formulation follows the original GraphSAGE framework proposed by Hamilton et al. [6]. The resulting node embeddings were subsequently passed through a classification layer to estimate the probability of hospital readmission.

3.5. Model Optimization and Evaluation. The GraphSAGE model was optimized using the cross-entropy objective function:

$$\mathcal{L} = -\sum_{\mathrm{i}=1}^{\mathrm{N}} \sum_{\mathrm{c}=1}^{\mathrm{C}} \mathrm{y}_{\mathrm{ic}} \log(\hat{\mathrm{y}}_{\mathrm{ic}}), \qquad (3)$$

where y_{ic} and $\hat{\mathrm{y}}_{\mathrm{ic}}$ denote the true and predicted probabilities associated with class c, respectively.

Model performance was assessed using Accuracy, F1-score, and ROC-AUC. Accuracy reflects the proportion of correctly classified instances, whereas F1-score provides a balanced measure of precision and recall, which is particularly relevant for identifying high-risk patients. ROC-AUC evaluates the model's ability to discriminate between positive and negative outcomes across varying thresholds and remains one of the most widely adopted metrics in clinical prediction studies [19]. The proposed methodology enables a systematic comparison of different patient relationship definitions and provides insight into the contribution of clinically informed graph structures to hospital readmission prediction.

4. Results

The proposed graph-based framework was evaluated against three widely adopted machine learning baselines, namely Random Forest, XGBoost, and Multilayer Perceptron (MLP). In addition, different patient graph construction strategies were examined to understand the extent to which relational information contributes to hospital readmission prediction.

Table 1 summarizes the predictive performances obtained by all evaluated models. Accuracy, F1-score, and ROC-AUC were selected to provide complementary perspectives on classification effectiveness. While Accuracy reflects the overall proportion of correctly classified instances, F1-score emphasizes the balance between precision and recall, and ROC-AUC evaluates the discriminative capability of the models.

Model	Accuracy	F1-score	ROC-AUC
Random Forest	0.6000	0.5544	0.6385
XGBoost	0.6187	0.5434	0.6561
MLP	0.6013	0.5097	0.6372
GNN Clinical Graph	**0.7289**	**0.6741**	**0.6516**
GNN Diagnosis-kNN Graph	0.6109	0.5227	0.6532
GNN Fused Graph	0.6189	0.5550	0.6550
GNN Fused Graph + Threshold	0.4963	0.6459	0.6550

Table 1. Performance comparison of traditional machine learning and graph-based models for hospital readmission prediction.

The results indicate that the clinically informed GraphSAGE model emerged as the strongest overall performer. Specifically, it achieved an Accuracy of 0.7289 and an F1-score of 0.6741, substantially outperforming all conventional machine learning baselines. Compared with XGBoost, which represented the strongest non-graph competitor, the proposed approach improved Accuracy by more than 11 percentage points and F1-score by approximately 13 percentage points. Although XGBoost obtained the highest ROC-AUC value, the difference remained marginal, suggesting that the superior classification performance of the clinical graph was not achieved at the expense of discriminative capability.

To further illustrate these findings, Figure 2 presents the overall comparison between the principal predictive models.

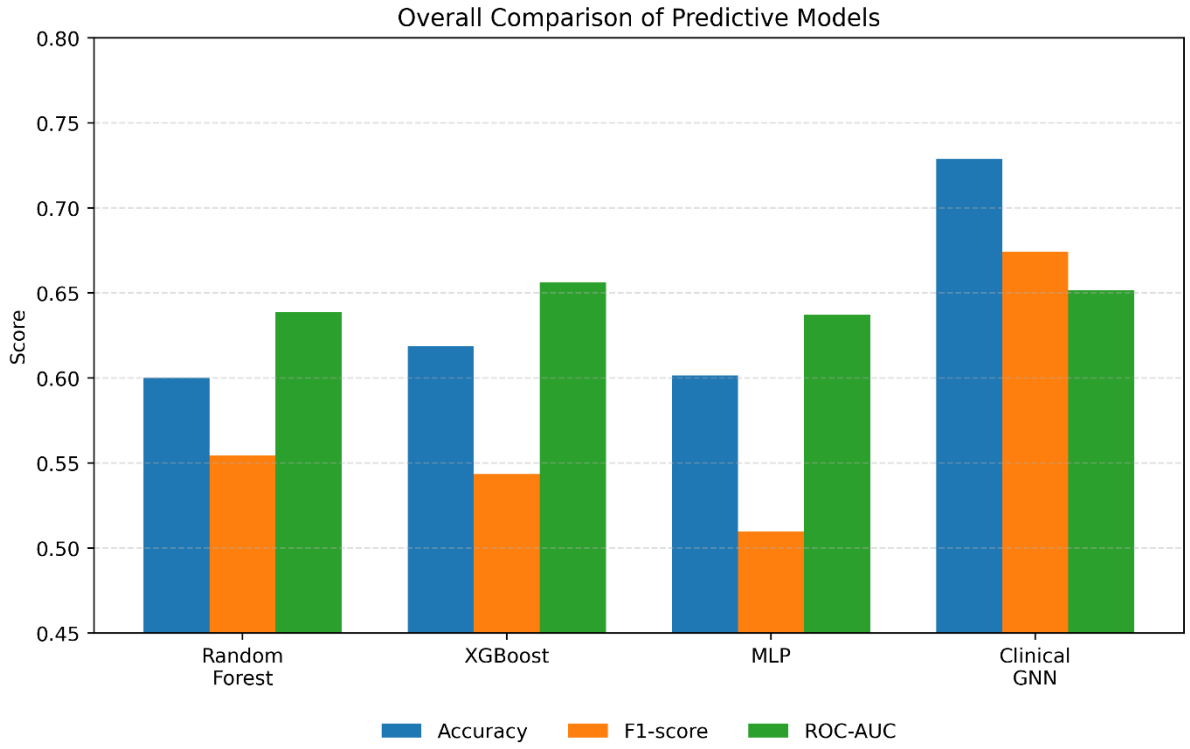


Figure 2. Overall comparison of Random Forest, XGBoost, MLP, and the clinically informed GraphSAGE model.

As illustrated in Figure 2, the clinically informed GraphSAGE model consistently demonstrated stronger predictive capability than the traditional machine learning approaches. The improvements were particularly evident in Accuracy and F1-score, indicating that incorporating clinically meaningful patient relationships enables more effective identification of readmission risk.

An ablation study was subsequently performed to investigate whether the observed improvements originated from the GraphSAGE architecture itself or from the manner in which patient relationships were defined.

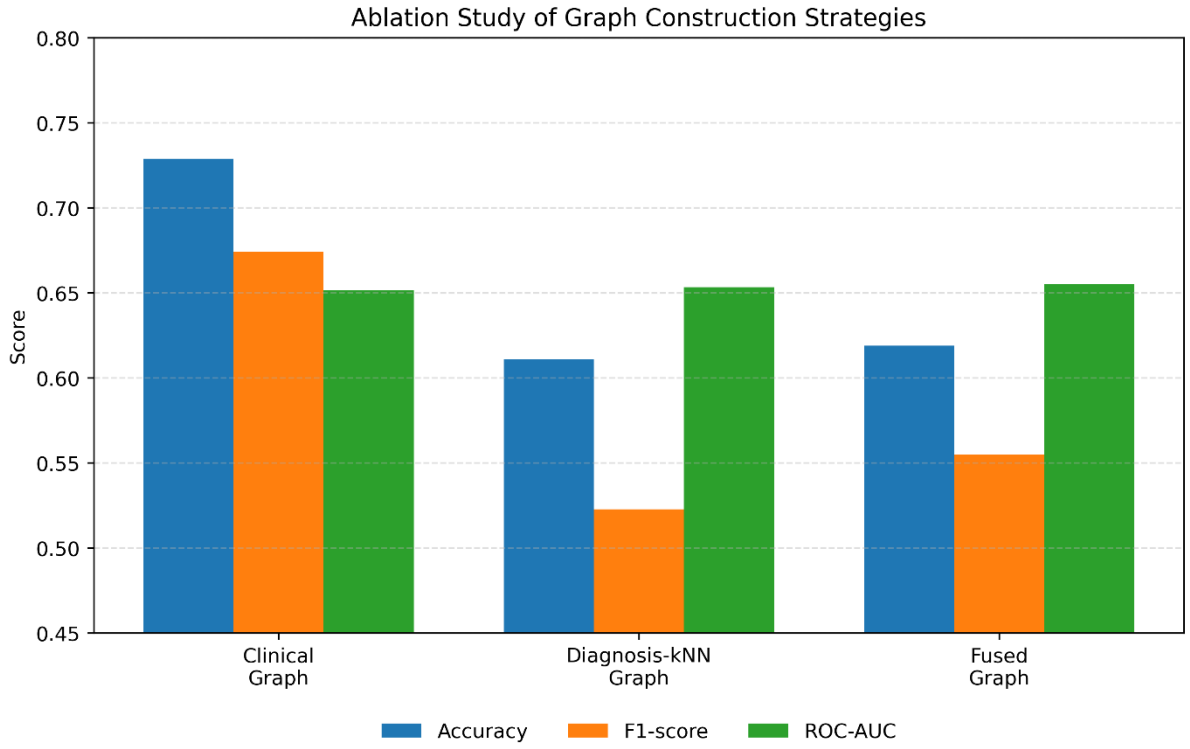


Figure 3. Ablation study evaluating the effect of alternative graph construction strategies on GraphSAGE performance.

The ablation analysis revealed that graph construction strategy had a substantial impact on predictive performance. The clinically informed graph clearly outperformed both the diagnosis-constrained kNN graph and the fused graph in terms of Accuracy and F1-score. In contrast, the diagnosis-kNN graph yielded the weakest balanced performance despite maintaining a competitive ROC-AUC value. The fused graph achieved intermediate results, suggesting that integrating similarity-based connections with clinically meaningful relationships does not necessarily translate into improved classification performance. These findings emphasize that the quality and interpretability of patient relationships may be more influential than simply increasing graph connectivity.The experimental results demonstrate that modeling clinically meaningful interactions among patients can considerably enhance hospital readmission prediction and may represent a promising direction for future graph-based clinical decision support systems.

5. Discussion

The experimental findings indicate that incorporating clinically meaningful patient relationships can substantially improve hospital readmission prediction. The clinically informed GraphSAGE model consistently outperformed conventional machine learning approaches in terms of both Accuracy and F1-score, suggesting that modeling interactions among patients provides valuable information beyond individual patient attributes alone. An interesting observation emerged from the ablation analysis. Although the diagnosis-constrained kNN graph and the fused graph achieved competitive ROC-AUC values, neither surpassed the clinically informed graph in balanced predictive performance. This finding suggests that merely connecting patients based on numerical similarity may not adequately capture the complex clinical dependencies underlying readmission risk. In contrast, relationships derived from shared diagnoses, medical specialties, and clinically interpretable characteristics appear to provide more informative contexts for representation learning. Another notable outcome is that the fused graph did not consistently improve performance despite integrating multiple sources of connectivity. This result highlights that increasing graph complexity does not necessarily translate into better predictive capability. Instead, the quality and clinical relevance of the relationships encoded within the graph may be more important than the quantity of connections themselves.

From a practical perspective, the proposed framework may assist healthcare professionals in identifying high-risk patients more effectively and allocating preventive interventions in a timely manner. More broadly, these findings emphasize that careful graph design should be regarded as a critical component of graph-based healthcare applications rather than a secondary implementation detail.

6. Conclusion and Future Work

This study presented a GraphSAGE-based framework for hospital readmission prediction using clinically informed patient networks. By representing patients as interconnected entities rather than independent observations, the proposed approach was able to exploit relational information embedded within healthcare data. Experimental results demonstrated that the clinically informed graph substantially outperformed traditional machine learning baselines and alternative graph construction strategies, achieving the highest Accuracy and F1-score among the evaluated models. The findings further revealed that clinically meaningful patient relationships contribute more effectively to balanced prediction than similarity-based connections alone. Despite these promising results, several limitations should be acknowledged. The experiments were conducted using a single publicly available dataset, and the constructed relationships were derived from the available clinical variables. Future studies may investigate the generalizability of the proposed framework using larger multi-institutional datasets and richer electronic health records. Additionally, incorporating explainable graph learning techniques could improve transparency and facilitate the adoption of graph-based models in real-world clinical decision support systems.

Overall, this work highlights the importance of patient relationship modeling in healthcare analytics and suggests that clinically informed graph representations constitute a promising direction for improving predictive modeling in hospital readmission prediction.

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COMPARATIVE IN SILICO ADME PROFILING AND DRUG SIMILARITY ASSESSMENT OF SELECTED NSAID DRUGS

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ABSTRACT

The early evaluation of pharmacokinetic properties is of enormous importance in drug development processes. The aim of this study is to comparatively investigate the absorption, distribution, metabolism, and excretion (ADME) properties of nonsteroidal anti-inflammatory drugs (NSAIDs) (diclofenac, ibuprofen, naproxen, ketoprofen, and aspirin) that belong to the same pharmacological class but exhibit different behaviors, using computational methods. In this study, the selected molecules were evaluated using the Schrödinger Suite software. Key parameters such as polar surface area (PSA), lipophilicity (LogP), water solubility (LogS), cell permeability (Caco-2), blood-brain barrier (BBB) permeability, cardiotoxicity risk (HERG), and estimated oral absorption (%HOA) were calculated. According to the results, a clear inverse relationship was observed between the molecules' lipophilicity (LogP) and water solubility (LogS) values. Diclofenac, which had the highest lipophilicity (LogP: 4.40), exhibited high Caco-2 cell permeability (21.18) but had the lowest solubility (-4.739). In contrast, Aspirin, which had the highest water solubility (LogS: 0.39), exhibited the lowest cell permeability (853) and limited absorption (74.03%) due to its low lipophilicity (LogP: 1.20) and narrow polar surface area (PSA: 40.78). Ibuprofen and naproxen, on the other hand, established an optimal balance between lipophilicity and solubility, demonstrating the most successful ADME profile and the highest oral absorption rates (93.98–95%). As expected, the penetration of all compounds into the central nervous system (BBB) remained limited, yielding negative values. In conclusion, these findings clearly demonstrate the decisive and critical role of the solubility-permeability trade-off in drug design, showing a high degree of consistency with profiles in the literature regarding cell permeability and absorption.

Keywords: ADME, in silico, NSAID, pharmacokinetics, solubility.

THE RELATIONSHIP BETWEEN DIGITAL WASTE AWARENESS AND DIGITAL ADDICTION AMONG UNIVERSITY STUDENTS

ÜNİVERSİTE ÖĞRENCİLERİNDE DİJİTAL ATIK FARKINDALIĞI İLE DİJİTAL BAĞIMLILIK ARASINDAKİ İLİŞKİ

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ABSTRACT

The purpose of this study is to examine the relationship between digital waste awareness and digital addiction among university students. In contemporary higher education, digital technologies have become an integral part of students' academic, social, and personal lives. However, the intensive and uncontrolled use of digital devices may not only increase the risk of digital addiction but also contribute to digital waste through excessive data storage, frequent device replacement, unnecessary energy consumption, and unsustainable patterns of technology consumption. From this perspective, the study aims to determine whether university students' digital addiction levels are associated with their awareness of digital waste and sustainable technology use behaviors. The study employed a quantitative research approach using a correlational survey design. The sample consisted of 400 university students enrolled at a public university during the 2025–2026 academic year. Data were collected using the Digital Waste Awareness Scale and the Digital Addiction Scale. The collected data were analyzed through descriptive statistics, Pearson correlation analysis, and multiple regression analysis. In addition, students' digital waste awareness and digital addiction levels were examined according to selected demographic variables such as gender, grade level, faculty, daily screen time, frequency of digital device use, number of digital devices owned, and frequency of digital device renewal. The findings revealed a significant relationship between university students' digital waste awareness and digital addiction levels. Students with higher levels of digital addiction tended to show lower awareness of sustainable digital behaviors, including reducing unnecessary data storage, limiting energy consumption, extending the lifespan of digital devices, recycling electronic devices, and avoiding excessive digital consumption. Furthermore, daily screen time, frequency of digital device use, and frequency of device renewal emerged as important predictors of digital addiction, while higher digital waste awareness was associated with more responsible and sustainability-oriented technology use behaviors. These results indicate that digital addiction should not be considered only as an individual psychological or behavioral issue, but also as an environmental and sustainability-related concern in higher education. The study suggests that digital waste awareness may play an important role in promoting conscious technology use and reducing excessive digital consumption among university students. In this regard, it is recommended that digital citizenship, environmental sustainability, and responsible technology use be integrated into higher education curricula through interdisciplinary educational practices.

Keywords: Digital waste awareness; Digital addiction; University students; Sustainable technology use; Digital citizenship; Correlational survey design.

ÖZET

Bu araştırmanın amacı, üniversite öğrencilerinde dijital atık farkındalığı ile dijital bağımlılık arasındaki ilişkiyi incelemektir. Günümüz yükseköğretim ortamında dijital teknolojiler, öğrencilerin akademik, sosyal ve kişisel yaşamlarının ayrılmaz bir parçası hâline gelmiştir. Ancak dijital cihazların yoğun ve kontrolsüz kullanımı, yalnızca dijital bağımlılık riskini artırmakla kalmamakta; aynı zamanda gereksiz veri depolama, dijital cihazların sık yenilenmesi, gereksiz enerji tüketimi ve sürdürülebilir olmayan

teknoloji kullanım alışkanlıkları yoluyla dijital atık oluşumuna da katkı sağlamaktadır. Bu bakış açısından hareketle araştırma, üniversite öğrencilerinin dijital bağımlılık düzeylerinin dijital atık farkındalıkları ve sürdürülebilir teknoloji kullanımı davranışlarıyla ilişkili olup olmadığını belirlemeyi amaçlamaktadır.

Araştırmada nicel araştırma yaklaşımı benimsenmiş ve ilişkisel tarama deseni kullanılmıştır. Araştırmanın örneklemini, 2025–2026 eğitim-öğretim yılında bir devlet üniversitesinde öğrenim gören 400 üniversite öğrencisi oluşturmuştur. Veriler, Dijital Atık Farkındalığı Ölçeği ve Dijital Bağımlılık Ölçeği kullanılarak toplanmıştır. Elde edilen veriler betimsel istatistikler, Pearson korelasyon analizi ve çoklu regresyon analizi aracılığıyla çözümlenmiştir. Ayrıca öğrencilerin dijital atık farkındalığı ve dijital bağımlılık düzeyleri; cinsiyet, sınıf düzeyi, fakülte, günlük ekran süresi, dijital cihaz kullanım sıklığı, sahip olunan dijital cihaz sayısı ve dijital cihaz yenileme sıklığı gibi seçilmiş demografik değişkenlere göre incelenmiştir. Bulgular, üniversite öğrencilerinin dijital atık farkındalığı ile dijital bağımlılık düzeyleri arasında anlamlı bir ilişki bulunduğunu göstermiştir. Dijital bağımlılık düzeyi yüksek olan öğrencilerin; gereksiz veri depolamayı azaltma, enerji tüketimini sınırlama, dijital cihazların kullanım ömrünü uzatma, elektronik cihazları geri dönüştürme ve aşırı dijital tüketimden kaçınma gibi sürdürülebilir dijital davranışlara yönelik farkındalıklarının daha düşük olma eğiliminde olduğu belirlenmiştir. Bunun yanı sıra günlük ekran süresi, dijital cihaz kullanım sıklığı ve cihaz yenileme sıklığının dijital bağımlılığın önemli yordayıcıları olduğu; daha yüksek dijital atık farkındalığının ise daha sorumlu ve sürdürülebilirlik odaklı teknoloji kullanımı davranışlarıyla ilişkili olduğu ortaya konmuştur. Bu sonuçlar, dijital bağımlılığın yalnızca bireysel, psikolojik ya da davranışsal bir sorun olarak değil, aynı zamanda yükseköğretim bağlamında çevresel ve sürdürülebilirlikle ilişkili bir mesele olarak ele alınması gerektiğini göstermektedir. Araştırma, dijital atık farkındalığının üniversite öğrencileri arasında bilinçli teknoloji kullanımını teşvik etmede ve aşırı dijital tüketimi azaltmada önemli bir rol oynayabileceğini düşündürmektedir. Bu doğrultuda dijital vatandaşlık, çevresel sürdürülebilirlik ve sorumlu teknoloji kullanımı konularının disiplinler arası eğitim uygulamaları yoluyla yükseköğretim programlarına entegre edilmesi önerilmektedir.

Anahtar Kelimeler: Dijital atık farkındalığı; dijital bağımlılık; üniversite öğrencileri; sürdürülebilir teknoloji kullanımı; dijital vatandaşlık; ilişkisel tarama deseni.

GİRİŞ

Digital technologies have profoundly transformed university students' learning, communication, access to information, social interaction, and daily life practices. Smartphones, laptops, tablets, online learning platforms, social media applications, and cloud-based storage services have become indispensable components of students' academic and personal lives. This transformation facilitates access to information, increases the flexibility of learning processes, and strengthens opportunities for academic interaction. Nevertheless, the intensive and uncontrolled use of digital technologies may also lead to attention difficulties, time management problems, academic procrastination, sleep disturbance, weakening of social relationships, and digital addiction. Therefore, the role of digital technologies in higher education should be evaluated not only in terms of access and functionality, but also in relation to conscious, balanced, and sustainable use (Livingstone & Helsper, 2010).

Digital addiction is generally associated with individuals' difficulty in controlling their use of digital devices, the internet, social media, online games, or digital content, and with the negative effects of such use on academic, social, psychological, or daily functioning. University students may constitute a vulnerable group in terms of digital addiction because they interact intensively with digital technologies for both academic requirements and social purposes. Previous research has emphasized that excessive use of social networking sites and digital platforms may be associated with problematic behavioral patterns, impaired self-regulation, and reduced well-being (Kuss & Griffiths, 2017; Young, 1998). However, digital addiction is often discussed mainly in relation to individual psychology, behavioral control, and academic performance, while the environmental and sustainability-related dimensions of digital technology use remain relatively underexamined.

The environmental impacts of digital technologies have become increasingly visible. The production, use, frequent replacement, and disposal of digital devices are directly associated with energy consumption, carbon emissions, resource extraction, and electronic waste. Electronic waste is not only an environmental pollution issue but also a critical sustainability problem due to the presence of rare metals, plastics, batteries, and hazardous components. The Global E-waste Monitor 2024 reported that the world generated 62 million tonnes of e-waste in 2022 and projected this amount to rise to 82 million tonnes by 2030 (UNITAR & ITU, 2024). In addition to physical e-waste, the broader concept of digital waste also includes unnecessary data storage, unused files, duplicated digital content, uncontrolled cloud storage, energy-intensive digital services, and patterns of excessive digital consumption. In this sense, digital waste awareness refers to individuals' recognition of the environmental consequences of digital technology use and their willingness to develop responsible behaviors to reduce these consequences.

Digital waste awareness provides an important conceptual basis for sustainable technology use. Reducing unnecessary data storage, deleting unused files and applications, limiting energy consumption, extending the lifespan of digital devices, regulating device renewal behavior according to actual needs, recycling electronic devices, and managing digital consumption consciously can be considered behavioral indicators of digital waste awareness. From this perspective, digital citizenship should not be limited to online ethics, security, privacy, and communication skills; rather, it should also include sustainable digital behaviors. UNESCO's education for sustainable development framework emphasizes the importance of equipping learners with the knowledge, values, and competencies required for sustainable lifestyles and responsible decision-making (UNESCO, 2020). Accordingly, responsible technology use should be considered an integral part of sustainability-oriented education.

The literature includes a substantial number of studies on digital addiction; however, studies examining digital addiction in relation to digital waste awareness and sustainable technology use remain limited. This limitation makes it important to connect the environmental costs of digitalization with university students' everyday technology practices. Examining the relationship between university students' digital addiction levels and digital waste awareness may offer a more holistic perspective that addresses digital well-being and environmental sustainability together. Therefore, the present study aims to reveal that digital addiction is not merely an individual behavioral problem, but also an educational issue related to sustainable living and responsible technology use.

In line with this rationale, the main purpose of this study is to examine the relationship between digital waste awareness and digital addiction among university students. More specifically, the study seeks to answer the following research questions:

1. What are university students' levels of digital waste awareness and digital addiction?
2. Is there a significant relationship between university students' digital waste awareness and digital addiction levels?
3. Do daily screen time, frequency of digital device use, number of digital devices owned, and frequency of device renewal significantly predict digital addiction?
4. Is digital waste awareness a significant predictor of university students' digital addiction levels?
5. Do university students' digital waste awareness and digital addiction levels differ according to selected demographic variables?

2. Method

2.1. Research Design

This study was conducted using a quantitative research approach based on a correlational survey design. A correlational survey design allows researchers to determine the existence, direction, and level of relationships between two or more variables. In this study, the relationship between digital waste awareness and digital addiction was examined. In addition, the extent to which selected demographic and digital-use variables predicted digital addiction was evaluated. The study did not involve an experimental intervention; rather, it aimed to describe the existing situation and reveal the relationships among the variables.

2.2. Population and Sample

The sample consisted of 400 university students enrolled at a public university during the 2025–2026 academic year. Participants were selected from different faculties and grade levels in order to increase the diversity of the study group. Information was also collected regarding students' gender, grade level, faculty, daily screen time, frequency of digital device use, number of digital devices owned, and frequency of digital device renewal. These variables were included in the study as individual and technological-use indicators that may be associated with digital addiction and digital waste awareness.

2.3. Data Collection Instruments

Data were collected using the Digital Waste Awareness Scale and the Digital Addiction Scale. The Digital Waste Awareness Scale was used to determine students' awareness of the environmental impacts of digital technology use. The scale covers dimensions such as unnecessary data storage, energy consumption, extending the lifespan of digital devices, recycling electronic devices, sustainable technology consumption, and responsible digital behaviors. The Digital Addiction Scale was used to determine students' levels of digital addiction through indicators such as difficulty in controlling digital device and digital content use, intensive use, inability to limit usage time, and negative effects on academic and social life.

A personal information form was also used in the study. This form included questions about students' gender, grade level, faculty, daily screen time, frequency of digital device use, number of digital devices owned, and frequency of digital device renewal. The inclusion of these variables was based on the assumption that digital addiction may be associated not only with individual tendencies but also with access to technology, intensity of use, and technology consumption habits.

2.4. Data Collection Procedure

The data were collected during the 2025–2026 academic year on a voluntary basis. Participants were informed about the purpose of the study, and they were assured that the data would be used only for scientific purposes and that personal information would remain confidential. The scales were administered either during appropriate class hours or through an online data collection environment. Forms with missing or incorrect responses were excluded from the analysis.

2.5. Data Analysis

Descriptive statistics were first calculated to determine students' levels of digital waste awareness and digital addiction. Pearson correlation analysis was used to determine the relationship between the variables. Multiple regression analysis was conducted to identify the predictors of digital addiction. In the regression analysis, digital waste awareness, daily screen time, frequency of digital device use, number of digital devices owned, and frequency of device renewal were considered independent variables. In addition, appropriate parametric analyses were used to examine differences according to demographic variables such as gender, grade level, and faculty. The significance level was accepted as .05.

3. Findings

First, university students' digital waste awareness and digital addiction levels were examined. The descriptive findings showed that students used digital technologies intensively for academic, social, and personal purposes. A considerable proportion of students had high daily screen time, owned more than one digital device, and renewed their digital devices at certain intervals. This finding indicates that university students have an intensive relationship with digital technologies and that their digital-use habits should be evaluated from a sustainability perspective.

The findings regarding digital waste awareness showed that students had a certain level of awareness about recycling electronic devices and extending the lifespan of devices. However, their awareness was more limited regarding unnecessary data storage, the relationship between cloud use and energy consumption, the environmental impact of being continuously online, and the carbon footprint of digital consumption. This finding suggests that students mostly associate digital waste with physical electronic

waste, while the data, energy, and digital consumption dimensions of the concept remain less visible to them.

The findings regarding digital addiction indicated that some students had difficulty controlling the duration of their digital device use, spent more time online than planned, and experienced negative effects of digital device use on their academic or daily life processes. Digital addiction levels were found to be higher especially among students with higher daily screen time, more frequent digital device use, and stronger tendencies toward device renewal.

The results of the Pearson correlation analysis showed a significant relationship between digital waste awareness and digital addiction. According to the findings, as digital addiction levels increased, awareness of sustainable digital behaviors tended to decrease. In other words, students who used digital devices intensively and uncontrollably had lower levels of awareness regarding behaviors such as reducing unnecessary data storage, limiting energy consumption, extending the lifespan of devices, recycling electronic devices, and avoiding excessive digital consumption.

The results of the multiple regression analysis revealed that daily screen time, frequency of digital device use, and frequency of device renewal were important predictors of digital addiction. In contrast, higher digital waste awareness was associated with more conscious and responsible technology use. This result suggests that digital waste awareness is not only an indicator of environmental consciousness but may also be related to individuals' capacity to regulate their digital technology use.

The analyses of demographic variables showed that students' digital waste awareness and digital addiction levels differed according to some variables. In particular, daily screen time and frequency of device use emerged as determining variables in terms of digital addiction. Findings related to faculty and grade level also suggested that students' academic fields and educational experiences may be associated with differences in patterns of digital technology use.

4. Discussion

The findings of this study reveal a significant relationship between digital waste awareness and digital addiction among university students. This result indicates that it is insufficient to consider digital addiction only in relation to individual behavioral control, psychological well-being, or academic achievement. Digital addiction becomes an issue related to environmental sustainability through intensive screen time, continuous online presence, increased consumption of digital content, frequent device use, and device renewal practices.

The lower awareness of sustainable digital behaviors among students with higher levels of digital addiction draws attention to the relationship between the quality of technology use and sustainability consciousness. Intensive digital use affects not only individuals' time management and academic performance but may also increase less visible environmental impacts such as data storage, energy consumption, and digital device consumption. Studies on the climate impact of information and communication technologies indicate that ICT-related emissions and energy use should be considered within broader sustainability discussions (Belkhir & Elmeligi, 2018; Freitag et al., 2021). Therefore, efforts to address digital addiction should not be limited to individual strategies aimed at reducing screen time; they should also be integrated with the concept of sustainable digital citizenship.

The finding that students had relatively higher awareness of electronic device recycling but lower awareness of the data and energy dimensions of digital waste suggests that the concept of digital waste is often understood in a narrow sense. In many educational contexts, digital waste is equated primarily with electronic waste. However, in the digital age, waste production is not limited to physical devices. Unnecessary files, duplicated digital content, uncontrolled cloud storage, continuous video streaming, high data traffic, and energy-intensive digital services are also elements that should be considered from a sustainability perspective. Therefore, digital waste awareness should be treated as part of a broader form of environmental and digital literacy.

The finding that daily screen time, frequency of digital device use, and frequency of device renewal were important predictors of digital addiction supports the relationship between intensity of digital use and addictive tendencies. At the same time, the emergence of device renewal frequency as an important

variable points to the consumption-oriented dimension of digital addiction. Frequent replacement of digital devices may often be related not only to technological necessity but also to the desire to use newer models, social visibility, performance expectations, and digital consumption habits. This situation requires the environmental consequences of digital addiction to be evaluated in relation to electronic waste and resource consumption.

The findings of the study suggest that digital citizenship education in higher education should be strengthened through a sustainability dimension. Digital citizenship should not be limited to safe internet use, ethical online behavior, and digital rights. It should also include responsible technology consumption, digital carbon footprint awareness, data storage habits, extending device lifespan, electronic waste management, and conscious digital use. Such an approach may help students both reduce the risks of digital addiction and contribute to environmental sustainability.

5. Conclusion and Recommendations

This study examined the relationship between digital waste awareness and digital addiction among university students. The results showed that there was a significant relationship between digital waste awareness and digital addiction. Students with higher levels of digital addiction tended to have lower awareness of sustainable digital behaviors, whereas students with higher digital waste awareness demonstrated more responsible, conscious, and sustainability-oriented technology use behaviors. In addition, daily screen time, frequency of digital device use, and frequency of device renewal were found to be important predictors of digital addiction.

In light of these findings, digital addiction should be evaluated not only as an individual psychological or behavioral problem, but also as an environmental and sustainability-related educational issue. Interdisciplinary educational practices that include digital citizenship, sustainable technology use, and digital waste awareness should be developed in universities. Students should be supported in managing screen time, reducing unnecessary data storage, extending the lifespan of digital devices, recycling electronic devices, and regulating technology consumption according to actual needs.

Higher education institutions should also include digital sustainability in their campus sustainability policies. In this context, digital clean-up campaigns, e-waste collection days, seminars on conscious technology use, sustainable digital citizenship workshops, and device recycling programs may be organized for students. In addition, the environmental impacts of online platforms, data storage policies, and digital infrastructures used by universities should be evaluated within institutional sustainability policies.

Future research may examine the relationship between digital waste awareness and digital addiction in different universities, with different sample groups, and through mixed-method research designs. Qualitative studies may provide a deeper understanding of students' perceptions of digital waste, digital consumption, and digital addiction. Furthermore, experimental studies may investigate the effects of digital waste awareness training on students' digital addiction levels and sustainable technology use behaviors.

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THE EFFECT OF RECYCLING-BASED STEM ACTIVITIES ON HIGH SCHOOL STUDENTS' ENVIRONMENTAL AWARENESS, SUSTAINABILITY CONSCIOUSNESS, AND PROBLEM-SOLVING SKILLS: A QUASI-EXPERIMENTAL STUDY

GERİ DÖNÜŞÜM TEMELLİ STEM ETKİNLİKLERİNİN LİSE ÖĞRENCİLERİNİN ÇEVRESEL FARKINDALIK, SÜRDÜRÜLEBİLİRLİK BİLİNCİ VE PROBLEM ÇÖZME BECERİLERİ ÜZERİNDEKİ ETKİSİ: YARI DENEYSEL BİR ÇALIŞMA

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ABSTRACT

The purpose of this study is to examine the effect of recycling-based STEM activities on high school students' environmental awareness, sustainability consciousness, and problem-solving skills. The study employed a quantitative research approach using a quasi-experimental pre-test–post-test control group design. The sample consisted of high school students enrolled in a public secondary education institution during the 2025–2026 academic year. Students in the experimental group participated in recycling-based STEM activities designed around real-life environmental problems, including waste classification, recyclable material use, sustainable product design, and solution-oriented engineering tasks. In contrast, students in the control group followed the regular science curriculum based on traditional instructional practices. The intervention lasted for six weeks and included interdisciplinary activities integrating science, technology, engineering, and mathematics with environmental education and sustainability principles. Data were collected using the Environmental Awareness Scale, the Sustainability Consciousness Scale, and the Problem-Solving Skills Scale. The collected data were analyzed through paired-samples and independent-samples t-tests, together with effect size calculations. The findings revealed that recycling-based STEM activities significantly improved students' environmental awareness, sustainability consciousness, and problem-solving skills compared to traditional instruction. Moreover, students in the experimental group demonstrated more positive attitudes toward recycling, more responsible environmental behaviors, and greater ability to generate practical solutions to sustainability-related problems at the end of the intervention. These results indicate that recycling-based STEM activities constitute an effective pedagogical approach for promoting environmental responsibility, sustainability-oriented thinking, and higher-order problem-solving skills among high school students. In light of these findings, it is recommended that recycling and sustainability-focused STEM activities be systematically integrated into secondary education curricula to support students' scientific literacy, environmental sensitivity, and 21st-century competencies.

Keywords: Recycling-based STEM activities; Environmental awareness; Sustainability consciousness; Problem-solving skills; High school students; Quasi-experimental design.

ÖZET

Bu araştırmanın amacı, geri dönüşüm temelli STEM etkinliklerinin lise öğrencilerinin çevresel farkındalık, sürdürülebilirlik bilinci ve problem çözme becerileri üzerindeki etkisini incelemektir. Araştırmada nicel araştırma yaklaşımı benimsenmiş ve ön test–son test kontrol gruplu yarı deneysel

desen kullanılmıştır. Araştırmanın örneklemini, 2025–2026 eğitim-öğretim yılında bir kamu ortaöğretim kurumunda öğrenim gören lise öğrencileri oluşturmuştur. Deney grubunda yer alan öğrenciler; atıkların sınıflandırılması, geri dönüştürülebilir materyallerin kullanımı, sürdürülebilir ürün tasarımı ve çözüm odaklı mühendislik görevleri gibi gerçek yaşam temelli çevre problemleri etrafında yapılandırılan geri dönüşüm temelli STEM etkinliklerine katılmıştır. Buna karşılık kontrol grubundaki öğrenciler, geleneksel öğretim uygulamalarına dayalı mevcut fen bilimleri öğretim programını takip etmiştir. Altı hafta süren uygulama sürecinde fen, teknoloji, mühendislik ve matematik disiplinleri; çevre eğitimi ve sürdürülebilirlik ilkeleriyle bütünleştirilmiştir. Araştırma verileri Çevresel Farkındalık Ölçeği, Sürdürülebilirlik Bilinci Ölçeği ve Problem Çözme Becerileri Ölçeği aracılığıyla toplanmıştır. Elde edilen veriler, bağımlı örneklemler t-testi ve bağımsız örneklemler t-testi ile analiz edilmiş; ayrıca etki büyüklüğü hesaplamaları yapılmıştır. Bulgular, geri dönüşüm temelli STEM etkinliklerinin geleneksel öğretime kıyasla öğrencilerin çevresel farkındalıklarını, sürdürülebilirlik bilinçlerini ve problem çözme becerilerini anlamlı düzeyde geliştirdiğini göstermiştir. Bunun yanı sıra deney grubundaki öğrencilerin uygulama sonunda geri dönüşüme yönelik daha olumlu tutumlar sergiledikleri, çevreye karşı daha sorumlu davranışlar geliştirdikleri ve sürdürülebilirlikle ilişkili problemlere yönelik uygulanabilir çözümler üretme becerilerinin arttığı belirlenmiştir. Bu sonuçlar, geri dönüşüm temelli STEM etkinliklerinin lise öğrencilerinde çevresel sorumluluğu, sürdürülebilirlik odaklı düşünmeyi ve üst düzey problem çözme becerilerini desteklemede etkili bir pedagojik yaklaşım olduğunu ortaya koymaktadır. Bu bulgular doğrultusunda, öğrencilerin bilimsel okuryazarlıklarını, çevresel duyarlılıklarını ve 21. yüzyıl becerilerini desteklemek amacıyla geri dönüşüm ve sürdürülebilirlik odaklı STEM etkinliklerinin ortaöğretim programlarına sistematik biçimde entegre edilmesi önerilmektedir.

Anahtar Kelimeler: Geri dönüşüm temelli STEM etkinlikleri; çevresel farkındalık; sürdürülebilirlik bilinci; problem çözme becerileri; lise öğrencileri; yarı deneysel desen.

GİRİŞ

Today, environmental problems have become a multidimensional issue that directly affects not only ecological systems but also economic, social, and educational structures. Climate change, the unconscious consumption of natural resources, problems related to waste management, and unsustainable production and consumption habits make it necessary to educate individuals from an early age with a sense of environmental responsibility. In this context, environmental education is regarded as a holistic field of education that involves not only the teaching of environmental concepts but also the development of individuals' attitudes, values, behaviors, and problem-solving skills concerning the environment. The education for sustainable development approach also emphasizes the need to raise individuals as citizens who can recognize environmental problems, analyze these problems on a scientific basis, and actively participate in solution-oriented processes (UNESCO, 2020).

STEM education is a contemporary instructional approach that integrates science, technology, engineering, and mathematics around real-life problems and aims to develop students' analytical thinking, creative design, collaboration, decision-making, and problem-solving skills. Environmental and sustainability issues, in particular, offer interdisciplinary and life-related problem situations that are highly compatible with the nature of STEM education. Therefore, topics such as recycling, waste management, sustainable product design, and the efficient use of resources provide strong learning opportunities for students both to make sense of scientific concepts and to apply these concepts in social and environmental contexts. Indeed, the inclusion of real-life problems in integrated STEM education is regarded as one of the key components that supports students' active participation in the learning process and the development of 21st-century skills (Dare et al., 2021).

Recycling-based STEM activities enable students not only to learn environmental problems at a theoretical level but also to develop concrete, feasible, and creative solutions to these problems. When students design products using recyclable materials, they are required to evaluate multiple variables simultaneously, such as material selection, durability, cost, functionality, aesthetics, and environmental impact. This process includes the stages of defining the problem, conducting research, developing solution proposals, creating prototypes, testing, and redesigning, all of which are consistent with the

engineering design cycle. Thus, recycling-oriented STEM activities support both the behavioral dimension of environmental awareness and the applied dimension of problem solving.

A review of the relevant literature indicates that STEM education has been associated with sustainability, environmental awareness, design thinking, and problem-solving skills. In particular, the integration of sustainable development goals into STEM activities contributes to students' evaluation of environmental problems in both local and global contexts (Habibaturrohmah et al., 2024). However, it can be stated that studies examining the effect of recycling-based STEM activities on high school students' environmental awareness, sustainability consciousness, and problem-solving skills through an experimental design remain limited. This study contributes to this gap by evaluating the pedagogical effect of recycling-oriented STEM practices at the secondary education level in a holistic manner.

Accordingly, the main purpose of this study is to determine the effect of recycling-based STEM activities on high school students' environmental awareness, sustainability consciousness, and problem-solving skills. In line with this general purpose, the following research questions were addressed:

1. Do recycling-based STEM activities have a significant effect on high school students' levels of environmental awareness?

2. Do recycling-based STEM activities have a significant effect on high school students' sustainability consciousness?

3. Do recycling-based STEM activities have a significant effect on high school students' problem-solving skills?

4. Is there a significant difference between the post-test scores of the experimental and control groups in terms of environmental awareness, sustainability consciousness, and problem-solving skills?

2. Method

2.1. Research Design

This study was conducted using a quasi-experimental pre-test–post-test control group design within the scope of the quantitative research approach. A quasi-experimental design is a strong research approach that allows the comparative examination of experimental effects in educational settings where random assignment of groups is not always possible. In this study, recycling-based STEM activities were implemented in the experimental group, whereas the existing curriculum was carried out in the control group in accordance with traditional instructional practices. Before the intervention, pre-tests were administered to both groups, and after the intervention, post-tests were administered.

2.2. Study Group

The study group consisted of high school students enrolled in a public secondary education institution in Kastamonu during the 2025–2026 academic year. The experimental and control groups were determined by considering the existing classroom structure of the school. Students in the experimental group participated in recycling-based STEM activities, while students in the control group continued traditional instruction in line with the existing curriculum during the same period. Pre-test scores were analyzed to determine whether the groups were comparable before the intervention in terms of environmental awareness, sustainability consciousness, and problem-solving skills.

2.3. Implementation Process

The implementation process lasted for six weeks. The activities conducted in the experimental group were structured around real-life problems related to recycling and sustainability. In the activities, students were first asked to identify waste and recycling problems they observed in their immediate environment. Then, they developed solution proposals for the identified problems and designed functional and sustainable products using recyclable materials. Throughout this process, students went through the stages of classifying waste types, evaluating material properties, establishing design criteria, developing prototypes, testing, and revising their designs. The activities were planned based on the integration of science, technology, engineering, and mathematics disciplines. The science dimension included concepts such as matter, energy, environmental pollution, and resource use; the technology

dimension involved design tools and product development processes; the engineering dimension included problem definition, prototype development, and testing stages; and the mathematics dimension involved measurement, ratio and proportion, cost calculation, data organization, and comparison processes. In the control group, instruction was carried out through teacher-centered explanation, textbook-based activities, and question–answer practices.

2.4. Data Collection Instruments

The research data were collected using three different measurement instruments. The Environmental Awareness Scale was used to determine students' levels of recognizing environmental problems, noticing environmental risks, and developing sensitivity toward the environment. The Sustainability Consciousness Scale was used to measure students' tendencies regarding sustainable living, efficient use of resources, responsibility toward future generations, and sustainable behaviors. The Problem-Solving Skills Scale was used to determine students' skills in analyzing problem situations, developing solution strategies, making decisions, and evaluating the solution process. The scales were administered to both groups as pre-tests before the implementation and as post-tests after the implementation.

2.5. Data Analysis

In the data analysis process, descriptive statistics regarding the pre-test and post-test scores of the experimental and control groups were first examined. Paired-samples t-tests were used to determine within-group changes, while independent-samples t-tests were used for between-group comparisons. In addition, effect size calculations were performed to interpret the obtained differences not only in terms of statistical significance but also in terms of their practical educational impact. The significance level was accepted as .05 in the analyses.

3. Findings

First, the pre-intervention levels of the experimental and control groups in terms of environmental awareness, sustainability consciousness, and problem-solving skills were compared. The pre-test findings showed that the groups were at similar levels in terms of the relevant variables before the intervention. This finding is important for associating the differences observed after the intervention with the instructional process.

The findings regarding environmental awareness indicated that the post-test scores of the students in the experimental group increased significantly compared to their pre-test scores. In the control group, a limited increase was observed in environmental awareness scores; however, this increase did not reach the level of development observed in the experimental group. When the post-test scores of the groups were compared, a significant difference emerged in favor of the experimental group. This finding indicates that recycling-based STEM activities are effective in strengthening students' awareness of environmental problems, their consciousness regarding waste management, and their perception of environmental responsibility.

The analyses regarding sustainability consciousness showed that students in the experimental group obtained higher scores after the intervention in relation to sustainable living, efficient use of resources, and responsibility toward future generations. This development observed in the experimental group suggests that students did not perceive sustainability as limited only to environmental protection, but understood it more holistically with its economic, social, and ecological dimensions. In the control group, the increase in sustainability consciousness scores remained more limited. Post-test comparisons revealed that recycling-based STEM activities had a stronger effect on sustainability consciousness than traditional instruction.

The findings related to problem-solving skills also revealed significant results in favor of the experimental group. During the implementation process, students in the experimental group gained experience in analyzing design problems, developing alternative solutions, testing prototypes, and revising their designs based on the results obtained. This process contributed to the development of students' problem-solving skills not only at a cognitive level but also in an applied and production-oriented context. In the control group, the development of problem-solving skills was more limited. This

finding can be explained by the fact that STEM activities involve students in active learning, decision-making, and solution-generation processes.

Overall, the findings demonstrate that recycling-based STEM activities have positive and significant effects on environmental awareness, sustainability consciousness, and problem-solving skills. Effect size calculations also supported that the improvements observed in the experimental group were educationally noteworthy. In this respect, the study shows that recycling-oriented STEM activities are an effective instructional approach for improving high school students' environmental sensitivity and higher-order thinking skills.

4. Discussion

The findings of the study show that recycling-based STEM activities increased high school students' environmental awareness. This result indicates that environmental education becomes more effective not merely through the transmission of knowledge but through applied learning processes in which students actively work on real-life problems. The participation of students in the experimental group in tasks such as waste classification, recyclable material selection, and sustainable product design enabled them to evaluate environmental problems in a concrete and experiential context. Thus, students considered environmental problems not as an abstract body of knowledge but as problem situations related to their own living environment and open to solution development.

The findings regarding sustainability consciousness also demonstrate that recycling-based STEM activities supported students' sustainability-oriented thinking. Sustainability consciousness is not limited to the understanding of avoiding harm to the environment; rather, it has a multidimensional structure that includes the efficient use of resources, questioning production-consumption relations, protecting the rights of future generations, and developing social responsibility. The activities used in this study encouraged students to evaluate variables such as material selection, product design, functionality, and environmental impact together, thereby contributing to a holistic understanding of sustainability. This finding is consistent with studies recommending the integration of STEM with the education for sustainable development approach (Habibaturrohmah et al., 2024; UNESCO, 2020).

The results obtained in terms of problem-solving skills indicate that STEM activities have considerable potential for developing students' higher-order thinking skills. The fact that students in the experimental group followed the steps of defining problems, developing solution proposals, creating prototypes, testing, and redesigning based on the engineering design process enabled problem solving to be experienced as a cyclical and improvable process. This supported students' focus not merely on reaching the correct answer but also on planning, evaluating, and, when necessary, restructuring the solution process. The literature emphasizes that associating integrated STEM education with real-life problems is effective in developing students' 21st-century skills (Dare et al., 2021).

The findings of this study demonstrate that recycling-based STEM activities offer a holistic instructional approach that can simultaneously develop environmental awareness, sustainability consciousness, and problem-solving skills. Similarly, Karakuyu and Karafil's (2026) study on recycling-based STEM education reported positive improvements in students' STEM/STEAM attitudes, recycling behaviors, and design thinking skills. In this regard, the present study contributes to the relevant literature by showing that recycling-oriented STEM activities at the secondary education level support not only cognitive learning outcomes but also environmental sensitivity and sustainable behavioral tendencies.

5. Conclusion and Recommendations

This study examined the effect of recycling-based STEM activities on high school students' environmental awareness, sustainability consciousness, and problem-solving skills. The findings showed that the six-week intervention process produced positive and significant effects on the students in the experimental group. At the end of the implementation, students in the experimental group evaluated environmental problems more consciously, developed more positive attitudes toward recycling, became more sensitive about sustainable resource use, and demonstrated more active, creative, and solution-oriented behaviors in problem-solving processes.

In line with the results of the study, it is recommended that recycling- and sustainability-oriented STEM activities be systematically integrated into secondary education curricula. These activities should not be limited only to science courses; instead, interdisciplinary learning environments should be created by associating them with mathematics, technology, design, geography, and social responsibility studies. In addition, recycling workshops, sustainable product design projects, waste reduction campaigns, and student projects addressing local environmental problems should be supported in schools.

Future studies may be conducted with different grade levels, larger samples, and mixed-method research designs. In addition to students' scale scores, their design products, group work processes, reflective journals, and views may also be examined to evaluate the effect of recycling-based STEM activities on the learning process in greater depth. Furthermore, longitudinal studies may investigate the effect of such activities on students' permanent environmental behaviors.

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INTEGRATING THINKING SKILLS INSTRUCTION INTO LESSON PLANS: A CASE STUDY OF PRESERVICE TEACHERS

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ABSTRACT

This study examined practices aimed at developing thinking skills and their instruction among pre-service teachers. The purpose of the study was to enable pre-service teachers to develop awareness of their own thinking processes, acquire theoretical knowledge regarding the teaching of thinking skills, and reflect this knowledge in their instructional practices. The study was designed as a holistic single-case study. Accordingly, it sought to answer the question of how pre-service teachers design teaching and learning processes to foster analytical, critical, and creative thinking skills. The data were obtained from 30 lesson plans prepared by second-year pre-service teachers enrolled in a primary school teacher education program. A total of 30 lesson plans—10 for analytical, 10 for critical, and 10 for creative thinking skills—were analyzed using content analysis. Data analysis is still ongoing. Preliminary findings indicate that pre-service teachers design learning environments aligned with higher-order thinking skills. Specifically, they tend to use questions that prompt students to think, as well as tables and visual materials.

Keywords: analytical thinking, critical thinking, creative thinking.

ALBANIAN TEACHERS' PERSPECTIVE ON CLASSROOM LIGHTING AND READING COMPREHENSION

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ABSTRACT

This study examines how Albanian primary school EFL teachers perceive the relationship between classroom lighting and young learners' reading comprehension, attention, and concentration. A survey of 69 teachers in Tirana explored three key issues: teachers' views of different lighting types, their level of control over classroom lighting, and whether professional training enables them to use lighting effectively.

The findings reveal a clear hierarchy in teacher preferences. Natural light was perceived as most strongly supporting reading comprehension, followed by LED lighting, which was considered workable but less effective. Fluorescent lighting, in contrast, was consistently associated with visual strain, restlessness, divided attention, and weaker reading performance. Many teachers reported observing behaviours they attributed to visual discomfort—including squinting and eye rubbing—particularly under less favourable lighting conditions.

Despite this awareness, Albanian teachers demonstrated limited autonomy and preparation. Only a small minority reported full control over their classroom lighting. Most could not adjust illumination for different reading tasks or to support sustained concentration during comprehension activities. Moreover, the majority had received no formal training on how lighting affects attention and cognitive endurance. Consequently, even those who recognised the problem rarely acted on that recognition. A chi-square test revealed a statistically significant association between professional training and experimentation with lighting ($\chi^2(1) = 4.92$, $p = .027$, $\varphi = .27$), suggesting that even limited training may encourage teachers to adapt classroom conditions.

The findings underscore the importance of considering classroom lighting as part of a broader strategy for creating supportive learning environments. Increasing teacher autonomy and incorporating environmental ergonomics into teacher education and professional development programmes may help teachers respond more effectively to students' learning needs.

Keywords: Classroom lighting, Reading comprehension, EFL teachers, Student concentration, Albania, Teacher perceptions

1. Introduction

The physical learning environment significantly influences students' academic achievement (Barrett et al., 2015). Classroom lighting, in particular, shapes visual comfort, attention, concentration, and learning (Pulay & Williamson, 2019). Reading—requiring sustained visual focus—is especially sensitive to classroom conditions, particularly among young learners developing literacy skills.

Research demonstrates that different lighting conditions affect students' comfort, alertness, and behaviour. Natural light is associated with improved visual comfort, concentration, and well-being (Barrett et al., 2015; Veitch & McColl, 2001), while LED lighting supports learning when appropriately designed. Fluorescent lighting has been linked to visual discomfort and reduced concentration in some studies, though evidence remains mixed (Boyce, 2014; Choi & Suk, 2018).

These issues carry particular weight in English as a Foreign Language (EFL) classrooms, where reading comprehension requires learners to process unfamiliar vocabulary while maintaining attention over extended periods (Perfetti, 2007). Teachers' daily observations position them to offer valuable insight into how classroom lighting shapes reading activities and student engagement.

Although previous studies have examined relationships between learning environments and educational outcomes (Higgins et al., 2005; Mustapha et al., 2022), little is known about teachers' perceptions of classroom lighting in Albania. Existing research has focused largely on technical aspects rather than teachers' experiences, capacity to adjust lighting, or professional preparation to leverage environmental conditions.

We address these gaps by investigating primary school EFL teachers' perceptions in Tirana, Albania. Beyond examining teachers' views of different lighting types, we explore their access to lighting controls and the relationship between professional training and experimentation with lighting arrangements.

Three research questions guided our investigation:

1. How do EFL teachers perceive the differential impact of natural, LED, and fluorescent lighting on students' concentration and reading comprehension?

2. To what extent do teachers have access to and control over classroom lighting systems?

3. Is there an association between teacher training and experimentation with different lighting configurations?

By addressing these questions, we contribute evidence from an underrepresented educational context and extend previous research by considering teacher agency and professional preparation as factors shaping the classroom environment.

2. Literature Review

2.1 Theoretical Foundations

Two theoretical frameworks anchor this investigation: Cognitive Load Theory (Sweller, 1988, 2011) and Sociocultural Theory (Vygotsky, 1978). Rather than serving merely as background, these frameworks provide specific, testable expectations about how teachers might perceive and interact with classroom lighting.

Cognitive Load Theory suggests that working memory has a limited capacity, making visual discomfort particularly consequential for reading tasks. When students experience visual strain from poor lighting—such as glare, flicker, or inadequate illuminance—they must expend additional cognitive effort simply to decode visual input, leaving fewer mental resources for higher-order comprehension (Veitch & McColl, 2001; Wilkins, 1995). Drawing on CLT, we anticipated a clear perceptual hierarchy: Expectation 1 (Cognitive) – Lighting conditions that teachers associate with visual discomfort (particularly fluorescent lighting) would be perceived as detrimental to student concentration and reading comprehension, while conditions promoting visual comfort (natural light) would be perceived as supportive. Furthermore, because EFL reading imposes heavy demands on lexical access and syntactic processing (Perfetti, 2007), we expected this cognitive drain to be especially noticeable during extended reading activities.

Sociocultural Theory, by contrast, emphasises that learning is inseparable from its social and physical context, and that teachers mediate learning by adapting environmental resources to instructional goals (Vygotsky, 1978). From this perspective, a lighting system is not inherently supportive or unsupportive; its educational value emerges only when teachers have the agency to adjust it for specific tasks. This framework generates a second, distinct set of expectations: Expectation 2 (Agency) – Teachers' perceptions of lighting would be moderated not only by its physical qualities but also by their level of control over it. We anticipated that limited access to lighting controls would be associated with lower reported experimentation, regardless of teachers' awareness of the problem. Conversely, Expectation 3 (Mediation) – Professional training would function as a mediational tool (Vygotsky, 1978), enabling

teachers to transform environmental conditions into pedagogical assets. We therefore expected a positive association between formal training and teachers' willingness to experiment with different lighting configurations.

Taken together, these frameworks suggest that classroom lighting should be regarded not merely as school infrastructure but as a cognitive and pedagogical resource. The three expectations derived above—concerning visual comfort, teacher autonomy, and the mediating role of training—directly inform our interpretation of teachers' reported observations and practices in the sections that follow.

2.2 Reading Comprehension, Attention, and EFL Learning

Reading comprehension demands the integration of word recognition, vocabulary knowledge, background knowledge, and higher-order thinking. These demands intensify in EFL classrooms, where students must process unfamiliar linguistic forms while constructing meaning from text (Perfetti, 2007). Sustained attention is therefore essential for successful reading.

Efficient word recognition enables readers to devote more cognitive resources to comprehension (Perfetti, 2007). Though our study does not directly assess reading processes, this evidence provides useful context for understanding why teachers may perceive classroom conditions as influencing reading performance.

Previous research has produced mixed findings. Some studies report positive relationships between improved lighting, attention, and academic performance (Choi & Suk, 2018). Others argue that lighting influences learning indirectly—through visual comfort, motivation, and classroom behaviour—rather than through achievement itself (Boyce, 2014). These differing conclusions highlight the value of examining teachers' perspectives, as they observe students' responses to classroom conditions daily.

2.3 Classroom Lighting and Teacher Agency

Research on classroom lighting has traditionally focused on technical characteristics such as illuminance, colour temperature, and energy efficiency. While these features matter, their educational value depends largely on how they are used within everyday classroom practice.

From a sociocultural perspective, teachers exercise professional agency by adapting classroom environments to meet instructional goals (Vygotsky, 1978). The capacity to adjust lighting may support different learning activities, including reading, independent work, and collaborative tasks.

However, opportunities to modify classroom environments are often constrained by school infrastructure and organisational factors (Higgins et al., 2005; Mustapha et al., 2022). Limited access to lighting controls restricts teachers' ability to respond flexibly to students' needs, whereas adjustable systems and greater access to natural light may better support effective practice.

Understanding teachers' perceptions thus requires consideration of both environmental conditions and professional factors, including autonomy, access to lighting controls, and relevant training. These issues provide the conceptual basis for our investigation.

3. Methodology

3.1 Research Design

We employed a cross-sectional quantitative survey design to examine Albanian primary school EFL teachers' perceptions of classroom lighting and its relationship with students' concentration and reading comprehension in Tirana. We judged a survey appropriate because we aimed to capture teachers' experiences, observations, and professional judgments across different classroom settings rather than manipulate lighting experimentally. Our research is descriptive and correlational, focusing on patterns in teachers' perceptions and reported practices without establishing causal relationships.

3.2 Participants and Sampling

The sample comprised 69 primary EFL teachers from public and private schools in Tirana. Convenience sampling was used, given the exploratory nature of the study and accessibility constraints. All

participants were actively teaching English at the primary level and regularly conducting reading activities.

Of the 95 teachers invited, 69 completed the questionnaire—a response rate of 72.6%, which compares favourably with typical teacher survey response rates (Baruch & Holtom, 2008). The sample included teachers from both public (n = 48, 70%) and private (n = 21, 30%) schools. Most participants were female (n = 62, 90%), reflecting the broader gender composition of Albanian primary education.

To gauge representativeness, we compared our sample against administrative data for primary EFL teachers in Tirana. The gender ratio and public-private distribution closely match regional statistics, suggesting our sample is broadly aligned with the target population on these observable characteristics. The strong response rate further reduces concerns that non-response introduced systematic bias, though we acknowledge that non-respondents may have differed in unobservable ways—for instance, in their engagement with environmental issues. We return to this point in the limitations section.

While convenience sampling limits generalisability, EFL teachers are particularly well-positioned to observe how classroom conditions affect reading. Their daily work requires sustained visual attention, vocabulary processing, and comprehension monitoring, making their insights especially valuable for understanding the relationship between lighting and student engagement.

3.3 Research Instrument and Data Collection

We developed our own questionnaire, as no existing instrument covered this combination of variables. The development unfolded in three stages.

First, we reviewed literature on classroom lighting (Boyce, 2014; Choi & Suk, 2018; Veitch & McColl, 2001), environmental psychology (Kaplan & Kaplan, 1989), and EFL reading (Perfetti, 2007). This shaped three core areas: teacher autonomy and preparation, perceptions of different lighting types, and observed student responses during reading. We adapted items from previous studies to the Albanian primary context.

For content validity, three experts—two EFL specialists and one educational psychology researcher—reviewed the draft for clarity, relevance, and language. We revised items, removed redundancies, and adjusted response options based on their input.

We then piloted the questionnaire with ten primary EFL teachers not in the final sample. After they completed it, we gathered verbal feedback on what was unclear. This led to small refinements: we simplified two ambiguous items and reduced Likert anchors from five to four points on three items where the midpoint caused hesitation. Cronbach's alpha was not calculated—our instrument uses categorical and single-item measures rather than multi-item scales.

The final 15-item questionnaire, in multiple-choice, categorical, and Likert formats, covers autonomy and training, lighting perceptions, and demographics. The full questionnaire is provided in Appendix A.

Data were collected in March–April 2026 to minimise seasonal daylight variation. The questionnaire was distributed online via email and teaching networks. Participation was voluntary and anonymous, taking 5–8 minutes. Only fully completed responses were analysed.

We used descriptive statistics—frequencies and percentages—to summarise teachers' responses. A chi-square test of independence examined the relationship between professional training (any versus none) and experimentation with classroom lighting (ever versus never). We checked the test assumptions prior to analysis: all expected cell frequencies exceeded five, confirming the chi-square test was appropriate for our data. The test revealed a statistically significant association, $\chi^2(1) = 4.92$, $p = .027$, with a small-to-moderate effect size ($\varphi = .27$; 95% CI (Cohen, 1988). The confidence interval suggests that while the relationship is modest, it is fairly stable and unlikely to be zero. All analyses were performed using SPSS Version 26.0.

3.4 Ethical Considerations

We obtained ethical approval from the relevant institutional review board. All participants provided informed consent and were informed of the study's purpose, the voluntary nature of participation, and

their right to withdraw at any time without consequence. We collected responses anonymously and treated all data confidentially.

4. Results

4.1 Teacher Demographics

The study included 69 primary school EFL teachers from Tirana, Albania. Most participants were between 35 and 60 years of age (65%, n = 45), while 20% (n = 15) were aged 26–35 and 15% (n = 10) were aged 21–25. Female teachers represented the majority (90%, n = 62), reflecting the gender distribution commonly observed in Albanian primary education.

4.2 Teacher Autonomy, Training, and Experimentation

Teachers reported limited control over classroom lighting (Table 1). Only 6% (n = 4) indicated complete control, while 43% (n = 30) had partial access and 51% (n = 35) reported no control.

Professional preparation was also limited. Three-quarters of participants (75%, n = 52) had received no relevant training, while 22% (n = 15) reported at least some preparation. Most teachers (84%, n = 58) had never experimented with different lighting arrangements. Among those who had, 11% (n = 8) reported positive outcomes and 5% (n = 3) indicated the changes were ineffective.

To examine whether training was associated with experimentation, we recoded responses into any training versus no training and ever experimented versus never experimented. Our chi-square test identified a statistically significant association, $\chi^2(1) = 4.92$, $p = .027$, $\varphi = .27$, indicating a small-to-moderate effect size (Cohen, 1988). This suggests training accounts for approximately 7% of the variance in teachers' likelihood to experiment. Teachers who had received training were more likely to report experimenting (33%, n = 5) than those without training (12%, n = 6).

Table 1. Teacher Autonomy, Training, and Experimentation

Category	Variable	Response	n	%
Teacher Autonomy, Training, and Experimentation	Access to lighting	Complete control	4	6
		Partial access	30	43
		No access	35	51
	Training received	Yes, a lot	4	6
		Yes, somewhat	11	16
		No training at all	52	75
	Experimentation attempted	Yes, it was effective	8	11
		Yes, it was ineffective	3	5
		I haven't tried	58	84

4.3 Perceived Impact of Lighting on Student Concentration and Reading Comprehension

Teachers generally regarded classroom lighting as important for students' concentration and reading activities (Table 2). Most reported being always (32%, n = 22) or often (43%, n = 30) concerned about lighting conditions, while only 3% (n = 2) rarely or never considered lighting during instruction.

Similarly, a large majority (83%, n = 57) agreed that adapting lighting to different activities would benefit students, while only 3% (n = 2) disagreed and 14% (n = 10) remained uncertain.

Table 2. Perceived Impact of Lighting on Student Concentration and Reading Comprehension

Category	Variable	Response	n	%
Perceived Impact of Lighting on Student Concentration and Reading Comprehension	Frequency of concern about lighting effects	Always	22	32
		Often	30	43
		Sometimes	15	22
		Rarely/Never	2	3
	Belief that activity-adapted lighting leads to greater student benefit	Agree	57	83
		Disagree	2	3
		Uncertain	10	14

4.4 Observed Student Behavioural and Visual Responses to Lighting Conditions

Teachers commonly observed signs of visual discomfort (Table 3). Over half (52%, n = 36) frequently noticed behaviours such as squinting or eye rubbing, while 22% (n = 15) observed these occasionally. Similarly, 52% (n = 36) reported frequent student complaints about lighting, 42% (n = 29) reported occasional complaints, and only 6% (n = 4) indicated complaints were rare or absent.

Table 3. Observed Student Behavioural and Visual Responses to Lighting Conditions

Category	Variable	Response	n	%
Observed Student Behavioural and Visual Responses to Lighting Conditions	Observed visual difficulty (squinting, eye rubbing)	Yes, often	36	52
		Yes, sometimes	15	22
		No	18	26
	Frequency of student complaints about lighting	Often	36	52
		On occasion	29	42
		Rarely/Never	4	6

4.5 Teacher Preferences and Recommended Lighting Improvements

Teachers most frequently recommended adaptable lighting (35%, n = 24), greater access to natural light (30%, n = 21), and improved lighting quality (27%, n = 19) (Table 4). To support reading concentration, natural light was preferred (57%, n = 39), followed by colour temperature adjustments (25%, n = 17).

Natural light (51%, n = 35) and LED lighting (46%, n = 32) were rated most effective for reducing eye strain (Table 5). Most teachers (70%, n = 48) believed LED positively affected reading concentration, while only 3% (n = 2) reported a negative effect. Overall, 89% (n = 61) agreed that lighting type influences student behaviour.

Table 4. Teacher Preferences and Recommended Lighting Improvements

Category	Variable	Response	n	%
Teacher Preferences and Recommended Lighting Improvements	Desired classroom lighting improvement	Adaptable lighting for different activities	24	35
		Greater access to natural light	21	30
		Better overall lighting quality	19	27
		No improvement needed	5	8
	Recommended change to improve reading concentration	More natural lighting	39	57
		Change color temperature	17	25
		Increase brightness	9	13
		Use supplementary side lighting	4	5

Table 5. Perceived Effectiveness of Different Lighting Types

Category	Variable	Response	n	%
Perceived Effectiveness of Different Lighting Types	Most effective for reducing eye strain	Natural light	35	51
		LED	32	46
		Fluorescent	2	3
	Perceived effect of LED on reading concentration	Positive	48	70
		Negative	2	3
		Uncertain	19	27
	Perceived effect of lighting type on students' behavior	Yes, a lot	36	52
		Yes, somewhat	25	37
		No	8	11

5. Discussion

5.1 Interpretation of Key Findings

Our survey revealed a clear hierarchy in teachers' assessments of lighting types. Natural light was overwhelmingly preferred for supporting concentration and reading. LED lighting received moderately positive assessments, while fluorescent lighting was consistently linked to visual discomfort and diminished focus. These perceptions align with previous research linking natural lighting to improved visual comfort (Veitch & McColl, 2001; Wilkins, 1995), while extending this evidence to Albanian primary EFL classrooms.

Teachers regularly observed squinting, eye rubbing, and complaints about lighting. Though we cannot interpret these observations as evidence that lighting directly affects reading performance, they suggest visual comfort forms an important part of students' classroom experience. Teachers' daily observations provide valuable practical insight into environmental conditions that might otherwise remain unnoticed.

The relationship between professional training and experimentation warrants cautious interpretation. Specifically, our cross-sectional design precludes causal inferences. Teachers who actively seek professional development may also be more willing to experiment with classroom practices generally. Consequently, we should not interpret our results as evidence that training alone causes changes in classroom behaviour.

Our survey also highlighted structural barriers. Most participants had little or no control over lighting, and very few had experimented with different configurations. These findings suggest teachers' ability to respond to students' needs may be limited more by school infrastructure than by a lack of professional awareness. That positive experiences with lighting adjustments outnumbered negative ones further indicates even modest improvements in teacher autonomy could enhance classroom practice.

Respondents consistently favoured greater access to natural light and colour temperature adjustments rather than simply increasing brightness. This suggests teachers recognise qualitative aspects of lighting that influence students' comfort during reading, reflecting practical classroom experience rather than technical knowledge alone.

5.2 The Albanian Educational Context

Our findings must be understood within the realities of the Albanian education system. Many public school buildings were constructed before environmental ergonomics became an important consideration in classroom design. Lighting systems often provide adequate illumination for general teaching but offer limited flexibility for adapting to different learning activities.

This context explains why many participants recognised lighting's importance but reported little opportunity to adjust it. Their limited control appears to reflect infrastructural constraints rather than a lack of professional awareness.

Professional development represents another contextual challenge. Educational reforms in Albania have focused primarily on curriculum, assessment, language education, and digitalisation, while environmental factors such as lighting and classroom ergonomics have received comparatively little attention. The low training levels reported by participants are therefore consistent with broader educational priorities.

Though we did not compare public and private schools directly, infrastructure differences may influence teachers' experiences. Future research could examine whether school sector affects access to adjustable lighting and teachers' perceptions of classroom environments.

5.3 Interpretation Through Cognitive Load and Sociocultural Perspectives

The findings are best understood through the complementary lenses of Cognitive Load Theory (CLT) and Sociocultural Theory, which together illuminate both the *cognitive mechanisms* and *pedagogical conditions* underlying teachers' perceptions and practices.

Cognitive Load Theory and the Primacy of Visual Comfort. Our results that teachers consistently associated fluorescent lighting with squinting, eye rubbing, and student complaints align directly with CLT's predictions. These observed behaviours suggest an extraneous cognitive load imposed by visual strain (Wilkins, 1995). According to CLT, this strain diverts limited attentional resources away from text decoding and meaning construction, which is particularly critical in EFL classrooms. As Perfetti (2007) notes, reading in a foreign language already demands substantial cognitive capacity for word recognition and vocabulary access; any additional visual interference further compromises comprehension. The clear hierarchy in teacher preferences—natural light overwhelmingly preferred, LED moderately acceptable, and fluorescent consistently rejected—thus reflects teachers' implicit understanding of this cognitive trade-off. They perceive natural light as reducing extraneous load, thereby freeing resources for sustained attention and deeper engagement with text. This gradient of perceived effectiveness corresponds precisely to the theoretical expectation that visual comfort directly influences cognitive efficiency during reading tasks.

Sociocultural Theory and the Constraints on Teacher Agency. While CLT explains *why* lighting matters cognitively, Sociocultural Theory explains *how* teachers can—or cannot—manage it pedagogically. Vygotsky's framework posits that environmental resources become educationally meaningful only when teachers can actively mediate them for learning. Our finding that merely 6% of teachers reported complete control over classroom lighting reveals a profound structural constraint that undermines this mediational capacity. This directly validates **Expectation 2 (Agency)**: even though 83% of teachers agreed that adaptable lighting would benefit students, the vast majority lacked the autonomy to act on this conviction. The 51% who reported no control whatsoever are effectively disarmed as mediators of their physical environment, regardless of their professional awareness.

Crucially, the statistically significant association between professional training and experimentation ($\chi^2(1) = 4.92$, $p = .027$, $\varphi = .27$) substantiates **Expectation 3 (Mediation)**. Teachers who had received at least some training were nearly three times more likely to have experimented with lighting (33%) than those without training (12%). This suggests that training operates as a mediational tool in the Vygotskian sense: it does not simply transmit technical knowledge but empowers teachers to recognise environmental conditions as malleable pedagogical resources. However, the fact that 84% of teachers had never experimented—and 75% had received no training—highlights a critical sociocultural gap. Teachers possess the professional recognition of the problem (as shown by their frequent concerns about lighting) but lack the institutional tools (autonomy and preparation) to transform environmental constraints into instructional affordances.

Integrating the Two Perspectives. These theoretical lenses are not isolated but deeply interconnected. CLT identifies the cognitive stakes—poor lighting imposes a measurable load on young learners' limited working memory during reading. Sociocultural Theory identifies the practical lever—teacher agency and training determine whether lighting can be optimised to reduce that load. The teachers' strong demand for adaptable lighting (35%) and greater access to natural light (30%) reflects a practical synthesis of these perspectives: they intuitively recognise both the cognitive benefits of certain lighting and the urgent need for the professional autonomy to implement it. By extension, our findings suggest that optimal classroom environments require not merely technically appropriate lighting infrastructure, but also the professional conditions—including both control over the environment and relevant preparation—that allow teachers to respond dynamically to students' fluctuating cognitive and attentional needs during reading activities.

5.4 Comparison with Previous Research

Our findings align with earlier studies that have demonstrated the educational value of appropriate classroom lighting. Barrett et al. (2015) identified classroom design, including lighting, as an important contributor to student learning, while Pulay and Williamson (2019) reported that lighting influences student engagement and behaviour. Our study supports these conclusions from practicing teachers' perspectives.

We extend previous work by focusing on teacher agency. Rather than examining lighting solely as a physical characteristic, we consider teachers' ability to manage environmental conditions within

everyday teaching. This perspective suggests effective classroom lighting depends not only on technical design but also on the professional conditions enabling teachers to use available resources.

Because our study is based entirely on teachers' perceptions, direct comparisons with experimental research should be made cautiously. Objective measurements of lighting conditions and student achievement remain necessary to determine whether teachers' observations correspond to measurable learning outcomes.

5.5 Practical Implications

Our findings carry implications for educational policy, school management, and teacher education. Participants consistently identified natural and adaptable lighting as most supportive for reading activities. Where feasible, schools should consider increasing access to daylight and introducing lighting systems adjustable to instructional needs.

Our results highlight the value of professional development. Most respondents had received little or no training related to classroom environments, suggesting environmental ergonomics and visual comfort could be incorporated more fully into teacher education and continuing professional development programmes.

Finally, increasing teachers' autonomy to modify classroom lighting constitutes a potentially high-impact, low-cost strategy for improving learning environments. This could be achieved through simple mechanisms such as adjustable blinds, movable lamps, or dimmer switches, enabling teachers to respond dynamically to students' engagement and comfort levels during reading activities. Even simple adjustments, combined with teachers' professional observations of student comfort and engagement, may help schools create classrooms that better support reading and sustained attention.

6. Limitations

Several limitations warrant consideration. First, our research relied exclusively on self-reported questionnaire data, reflecting teachers' perceptions rather than direct measurements of students' reading performance or classroom lighting conditions. Causal relationships cannot be established, and we interpret our findings as perceptual rather than objective evidence. Teachers' observations, while valuable, may not always correspond to objectively measured student outcomes.

Second, our sample was drawn through convenience sampling from primary EFL teachers in Tirana. While the 72.6% response rate is strong and the demographic profile aligns with regional data, the findings are specific to this urban context. Rural schools—with older infrastructure and different building orientation—are not represented, nor are teachers in other regions of Albania who may face different climate conditions and available technologies. We cannot assume patterns observed in Tirana extend to these diverse settings. Future research employing stratified random sampling across urban, suburban, and rural areas would strengthen external validity. The study did not systematically compare public and private school responses, though infrastructure differences between sectors may influence teachers' experiences and perceptions

Third, our cross-sectional design captured perceptions at a single point in time—March to April 2026. While we chose this period to avoid extreme seasonal differences, we cannot capture how perceptions might shift across the academic year. For instance, winter months with shorter daylight hours may intensify concerns about inadequate lighting, while brighter months may make issues less salient. A longitudinal design could explore these seasonal variations. Additionally, the small number of teachers who reported training limits conclusions about the training-experimentation relationship; a larger sample with more variation in training experiences would allow for more robust analysis.

Fourth, we did not collect objective information on classroom characteristics—illuminance levels, window orientation, colour temperature, or flicker rates. Without these measurements, we cannot determine whether teachers' perceptions align with objective lighting conditions. Future research incorporating environmental measurements could examine this relationship more systematically.

Finally, our questionnaire was developed specifically for this study. While we took steps to establish content validity through expert review and piloting, the absence of a pre-validated instrument means we cannot be certain how our findings compare with studies using established measures.

Despite these limitations, the high response rate and demographic alignment suggest the findings are reasonably reliable within the Tirana context. The practical insights from practicing teachers—who observe students daily under varying conditions—provide valuable perspectives that complement experimental and technical approaches to understanding classroom lighting.

7. Conclusion

We explored how Albanian primary school EFL teachers perceive the relationship between classroom lighting and students' reading comprehension. Teachers consistently regarded natural light as most supportive for concentration and reading engagement, while fluorescent lighting was more frequently associated with visual discomfort and reduced attentional focus. Participants also reported limited opportunities to adjust classroom lighting and little formal preparation regarding the role of environmental conditions in learning.

Though our study reflects teachers' perceptions rather than objective measures of student performance, our findings highlight an often overlooked aspect of classroom practice. Teachers viewed lighting not simply as part of the physical environment but as a factor influencing students' comfort, attention, and engagement during reading activities.

The significant association between professional training and experimentation with lighting arrangements ($\chi^2(1) = 4.92$, $p = .027$, $\varphi = .27$) suggests a link between training and experimentation; however, given the cross-sectional design, this finding should be interpreted as correlational rather than causal. At the same time, most teachers had never experimented with lighting and over half reported having no control, pointing to structural barriers extending beyond individual practice.

Future research should combine teachers' perspectives with objective measurements of classroom lighting and direct assessments of students' reading performance. Broader samples from different regions of Albania and comparative studies across school sectors would strengthen understanding of how environmental conditions influence learning. By bringing attention to teacher agency alongside classroom design, we contribute to a growing body of research that recognises learning environments as an important component of effective education.

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Appendix A. The questionnaire

Section A: Demographics and Professional Background

What is your age group?

- 21–25
- 26–35
- 35–60
- 60+

What is your gender?

- Female
- Male
- Prefer not to say

1. Which type of school do you teach at?

- Public school
- Private school

2. How many years have you been teaching English at the primary level?

- Less than 5 years
- 5–10 years
- 11–20 years
- More than 20 years

Section B: Teacher Autonomy and Professional Training

3. What level of access do you have to control classroom lighting?

- Complete control (I can adjust lighting whenever needed)
- Partial access (I can sometimes adjust lighting)

• No access (I cannot adjust lighting at all)

4. Have you received any formal training on how classroom lighting affects student concentration or learning?

• Yes, a lot

• Yes, somewhat

• No training at all

5. Have you ever experimented with changing classroom lighting arrangements to improve students' concentration or reading activities?

• Yes, it was effective

• Yes, it was ineffective

• I haven't tried

6. Do you agree that adapting classroom lighting to different activities would benefit students' learning?

• Agree

• Disagree

• Uncertain

Section C: Perceptions of Lighting and Student Outcomes

7. How often do you think about or consider classroom lighting during your lessons?

• Always

• Often

• Sometimes

• Rarely/Never

8. How often do you observe students exhibiting signs of visual discomfort (e.g., squinting, rubbing eyes) during reading activities?

• Yes, often

• Yes, sometimes

• No

9. How often do students complain about lighting conditions in your classroom?

• Often

• On occasion

• Rarely/Never

10. Do you believe the type of lighting in your classroom affects students' behaviour during reading activities?

• Yes, a lot

• Yes, somewhat

• No

11. Which type of lighting do you find most effective for supporting students' reading concentration?

• Natural light

- LED lighting
- Fluorescent lighting
- Uncertain

Section D: Perceptions of Different Lighting Types

12. Which type of lighting do you think is most effective for reducing students' eye strain during reading?

- Natural light
- LED
- Fluorescent

13. What is your perception of the effect of LED lighting on students' reading concentration?

- Positive effect
- Negative effect
- Uncertain

14. What would be your preferred change to improve reading concentration in your classroom?

- More natural lighting
- Change colour temperature
- Increase brightness
- Use supplementary side lighting

15. If you could improve the lighting in your classroom, what would be your priority?

- Adaptable lighting for different activities
- Greater access to natural light
- Better overall lighting quality
- No improvement needed

A COMPARATIVE BENCHMARK OF DEEP LEARNING AND CLASSICAL MACHINE LEARNING MODELS FOR CRIME AND TERRORISM PREDICTION WITH EXPLAINABLE AI ANALYSIS

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ABSTRACT

In this article, I compare five machine learning models — Logistic Regression, Random Forest, XGBoost, LSTM, and CNN-LSTM — for crime and terrorism prediction. I used two public datasets: Chicago crime data (100,000 records) and ACLED terrorism data (382,742 records). To evaluate the models, I looked at accuracy, precision, recall, F1-score, AUC-ROC, and training time.

The results show that Random Forest and XGBoost achieved perfect accuracy (100%) on both datasets. The deep learning models also did very well, reaching 99.2% to 99.9% accuracy, but they took much longer to train - anywhere from 150 to 622 seconds. When I looked at feature importance, I found that danger_score was the key factor for terrorism prediction, while crime_type_encoded mattered most for crime prediction.

Overall, classical machine learning models seem to offer the best balance of accuracy and efficiency for public safety applications. This thesis provides a reproducible benchmark and shows how explainable AI can be useful for security analytics.

Keywords: Crime prediction, terrorism prediction, ML/DL, explainable AI, benchmark

1.Introduction

1.1 Background

AI and ML have become part of many fields in recent years, and public safety is not an exception. While incidents are being recorded, researchers are now developing mechanisms to predict where and when crimes or terrorist attacks may occur. These predictive tools compile data from various sources, such as police records, weather data, and social indicators, to provide a more comprehensive view of potential risks. Such information can be used in various ways, such as designing patrol routes, optimizing the use of security resources, and assisting in counter-terrorism operations [1], [4], [36].

Two great threats to public safety and social stability are crime and terrorism. The majority of crime prediction studies are in urban environments, where the focus is on crimes such as theft, burglary, hotspot detection, and assault. Typically, they are based on police data, geographical information, and demographic information. Terrorist prediction involves other challenges, however: predicting attacks, where the attacks are coming from, how many lives they'll take, and how to understand networks such as GTD and ACLED. Although very different in scale and context, there is a common ground between these two: both deal with spatiotemporal modeling, event forecasting and pattern recognition [2], [8], [37].

1.2 Problem Statement

Despite the significant advancements AI-based methods have made in crime and terrorism prediction, some significant issues remain unaddressed. **First**, the majority of research papers focus on crime and

terrorism separately, while both fields apply the same machine learning methods, such as random forests, XGBoost, or LSTM. Therefore, this isolation causes uncertainty about which models are the most effective for different types of threats. **Second**, a lot of research is based on a single dataset, a city or country only, so it is not demonstrated if the findings could be generalized. **Third**, although deep learning models produce highly accurate predictions, they are usually regarded as "black boxes"; it is challenging to explain why a particular decision was made. This is a critical issue in law enforcement and intelligence where interpretability is very important. **Finally**, the number of research papers that perform a comparative analysis of classical machine learning and deep learning models using the same setup on both crime and terrorism data is very limited [1], [17], [36], [55].

1.3 Research Questions

This thesis endeavors to answer five primary questions in an attempt to bridge these gaps.

First, we investigate the level of performance classical models (Logistic Regression, Random Forest, XGBoost) have when compared to deep learning models (LSTM, CNN-LSTM) on these tasks.

Second, we explore which features are the most significant for crime prediction vs. terrorism prediction.

Third, we evaluate the degree to which the same five models can generalize when used on two different types of datasets, one on urban crime (Chicago) and one on terrorism (ACLED).

Fourth, we analyze the balance between prediction accuracy and training time.

Lastly, through feature importance analysis, we seek to understand what the models are learning and, at the same time, offer insights that could be valuable for security workers.

In particular, the thesis answers these questions:

Q1: Can classical machine learning models, like logistic regression, random forest, XGBoost, predict crime and terrorism events as much as deep learning models, like LSTM and CNN-LSTM?

Q2: What are the most important features to predict crime, and how do their importance patterns vary between datasets and compare to the patterns of features that were most important to predict terrorism?

Q3: Can the same five models be used to perform live well on two very different public safety domains, one a domain of urban crime (Chicago), the other a domain of political violence/terrorism (ACLED)?

Q4. How do the training time (computational efficiency) and performance of classical model and deep learning model compare and how does that impact on the trade-off?

Q5: What information can we get from the feature importance analyses of Random Forest and XGBoost regarding why crime and terrorism are predicted differently, and what can these differences mean for developing models that are specific to a certain domain?

1.4 Contributions

This thesis has made the following main contributions:

1. Offering a competent benchmark: We systematically benchmark and test five different models (Logistic Regression, Random Forest, XGBoost, LSTM, and CNN-LSTM) on two diverse public safety datasets, Chicago crime data and ACLED terrorism data.

2. Conducting cross-domain analysis: Since we used exactly the same experimental settings to analyze the crime and terrorism data as well as all the models, it was possible to directly test their generalization capability.

3. Bringing in Explainable AI: Our interpretative way has been by means of feature importance and confusion matrices, which not only explain the models learning but also show the key variables in each domain.

4. Outlining practical takeaways: Besides accuracy, other than that, we have also looked at the time of training and therefore have come up with points that can help in the making of choice for the model especially for the cases which demand immediacy.

5. Offering a reproducible framework: The whole thread is meticulously described from data preprocessing, model setting, and up to the evaluation criteria so that others can reproduce and further this work.

2. LITERATURE REVIEW

2.1. Crime Prediction Studies

One of the hottest research topics in the field of AI for public safety analytics is crime prediction. The reviewed studies suggest that the forecasting of crime has progressed beyond the traditional machine learning techniques and now encompasses broader deep learning techniques, spatiotemporal approaches, and decision-support techniques. Generally, the literature centers on predicting what, where and when crimes are likely to occur, to estimate hotspot risk, or to forecast the number of crimes for operational policing purposes and/or forecast the crime-related patterns. From the selected studies, the studies for predicting crime can be categorized into five broad categories: predictive policing or crime prediction systems, deep learning-based crime prediction, classical machine learning approaches, spatiotemporal crime prediction, socioeconomic and environmental crime prediction. [1]–[35]

One of the prevailing research directions is the use of deep learning-based models. The common goal of such studies is to obtain complex spatial and temporal dependencies that cannot be modeled easily by traditional methods. Methods like CNNs, LSTMs, GRUs, graph neural networks, transformer-based models, and hybrid CNN-LSTM and GCN-LSTM models are commonly employed for crime hotspot prediction, crime count prediction, and region-level crime risk prediction. Multiple studies examine the interaction between spatial representation and temporal sequence learning, suggesting that both temporal series and spatial neighborhood connections or spatial roads are significant factors in crime occurrence. In general, the reviewed deep learning works indicate that when crime is considered as a spatiotemporal process, rather than a simple tabular classification problem, these types of architectures can be very effective. [1]–[10]

In addition to deep learning, classical machine learning techniques are also highly relevant in the crime prediction literature. Common machine learning models include Random Forest, XGBoost, Decision Tree, Logistic Regression, k-NN, and ensemble-based classifiers, which are commonly employed in structured tabular datasets and studies with relatively low data complexity. Some of these approaches are popular due to their simplicity, low computational requirements and higher degree of interpretability over deep neural models. For several reviewed papers classical models perform competitively, if not better, especially in the case of a relatively small dataset, a well-defined prediction task and a good feature engineering. This indicates that the crime prediction research hasn't come to the end of the road of the traditional approach; the choice of model is still very reliant on the properties of the dataset, the level of granularity of the predictions, and the requirements of the operation. [11]–[16]

One major research area is the spatiotemporal prediction of crime, which explicitly models the interaction between geography and time. The studies are based on an occurrence of crime represented by a spatial grid, a police district, an urban region or graph, and an historical sequence of time. The literature reviewed indicates the special relevance of spatiotemporal methods for hotspot forecasting, dynamic risk mapping and short-term urban crime prediction. Some studies have focused on how space is segmented into urban areas, such as by police districts, hotspots, or by building footprint, which can have a significant impact on the prediction. This means that not only the model architecture, but also the quality of spatial representation and design of preprocessing plays a role in crime forecasting. [5], [8], [10], [17]

Another body of work is dedicated to predicting socioeconomic and environmental crime. These works are an extension of pure event-based forecasting, and also include explanatory factors like income, unemployment, housing structure, weather, land use, mobility, population composition, tourism, and built-environment factors. In these studies, the primary assumption is that not only does crime influence previous crime, but also larger-scale indicators of urban and social conditions influence crime. The selected papers indicate that these factors can frequently enhance prediction accuracy, and may also offer the basis for better understandings as to why crime risk occurs in certain locations or times. This

direction is especially interesting as it links crime prediction to criminological theory and is a step toward interpretable and policy-relevant forecasting. [9], [16], [17]

Last but not least, there is a greater number of studies on predictive policing and crime prediction systems that not only investigate how well the predictions can be made but also the usefulness for decision support. These studies are frequently coupled with prediction models, dashboards, digital twins, hotspot mapping, resource allocation logic, or real-time analytical workflows. Instead of creating only technically oriented forecasting models, they try to create systems that can assist law enforcement agencies in planning their operations. Some of the reviewed studies additionally include explainability, spatial clustering and/or centralized infrastructure to enhance the usefulness of the outputs for practitioners. The shift signifies an important paradigm shift in the field: moving from stand-alone prediction models to predictive policing ecosystems. [7], [9], [10], [17]

In total, the body of crime prediction literature is diverse in method and matures in practice. In the latest and technically sophisticated research, deep learning models prevail, and classical machine learning lends good baselines and intuitive alternatives. The state-of-the-art is changing, with spatiotemporal and graph-based approaches now dominating, while models of socioeconomic and environmental factors are adding theory and context. Predictive policing systems demonstrate that the field is becoming a reality at the same time. These five are explored in greater detail below. [1]–[17]

2.2. Terrorism Prediction Studies

This collection of papers continues the emphasis that has been placed on overall risks and threat levels rather than specific attack attributes. The difference between these researchers and those who want to predict the occurrence of a past event or identify an attack with a particular group, is that these researchers want to know the risk of terrorism in a nation or a more local area during a particular period of time. [36], [37]

One of the big themes in this category is diversification of the risk forecast signal by using web news, lexical pattern mining and other open-source textual signals. Some of these researches claim that the post-incident event databases like GTD should give way to pre-incident information environments like news flows and terrorism-related lexical indicators in forecasting terrorism. They have tried to create greater lead time, but also additional adaptive risk signals, by using a mix of GDELT, lexical features, or multiple sources of terrorism-related text. [36], [37]

The methodological aspects of this category are mainly related to feature selection methods and to multisource integration. The high dimensionality and noise of variables obtained from web news and text lead such papers to often use feature prediction techniques such as the Random Forest, based filtering or TF-IDF weighting in order to find the most predictive indicators. The material examined in this study indicates that hand-picked risk characteristics can have a large impact on the accuracy of short-term or country-focused terrorism risk prediction. [36], [37]

These papers are extremely important because they are the first group to take the art of predicting terrorism one step towards operational risk intelligence. Going beyond event-level attack classification alone, these papers work on deducing whether a particular environment is getting more susceptible to terrorism. In principle, they are extremely well suited to use for early warning, preventive planning, and strategic intelligence analysis. [36]

Generally, the methods developed for the problem of terrorism risk and threat prediction expand the definition of terrorism forecasting from the reconstruction of events to estimating risks for the future and highlight the importance of open-source signals, features obtained from news, and temporal forecasts at the country level. [36], [37]

3. RESEARCH GAPS IN CRIME AND TERRORISM PREDICTION

One of the most striking aspects is the lack of tools that integrate both the analysis of crime and terror predictions. At this time, scientists tend to work separately in these two areas. Studies of crime are often narrowly focused on problems in the city – burglary, theft, groupings of high risk locations, predictions by neighborhood – and typically rely on local data sources. Contrary to this, during terrorist events

efforts are concentrated on worldwide records such as the GTD, with the aim of tracking who attacked, if the attacks succeeded, or how dangerous they were. The separation of the two makes it difficult to know whether similar models, overlapping indicators, or shared algorithm designs would be effective at detecting both threats. The failure to make these connections makes it difficult to detect broader connections associated with community safety risk indicators, and highlights the need for more research that will fill an area for which science has yet to offer a solution: how to integrate methods for predicting crime with methods for predicting terrorism. [1]–[17], [36]–[48]

Then there's the fact that most recent studies only access a few types of information. Crime forecasting work is determined by crime rates, not only from police reports, but also from urban metrics applicable to the area. There are many hotspot maps or event grids, but they provide little perspective. The GTD is the central element of the work of a terrorism analyst, with occasional outside data thrown in, but not enough to make a difference in the equation. Certainly, these sources are valuable, but fall short in capturing variations in the ways people wander, respond, communicate over the Internet and feel stress in some locations. Things that are not written are important - subtle hints of behavior are not found here. There, new forms of information (such as posts on the Internet, breaking news, public reports, information from smart devices, camera perspectives, and motion logs) are utilized infrequently. The lack of systems that draw on a wide variety of inputs means there are blind spots that will persist, reducing forecasts and understanding. [13], [36], [37], [47], [48]

One of the missing components is that most of the present models are very rigid when it comes to the scope of their application. These tools, despite being created on the basis of information from only one urban area, country or terror database, often do not work when they are moved. Crime and attacks are highly reliant on local laws, beliefs, power dynamics, geography, and wealth levels, meaning that systems that work well in one location, encounter obstacles in another. This is readily apparent in forecasts that rely solely on hotspots in a specific municipality, as well as when relying too heavily on the Global Terrorism Database without taking into account other hotspots or other records. Now, it's taking more city-to-city, nation-to-nation, data-set-to-data-set testing, and it's getting more sophisticated, such as adapting models to new domains for predicting threats more accurately. [7], [10], [17], [43], [47]

Most research sticks to testing models in labs instead of using them where it matters. Though many papers compare algorithms or show promising results on paper, hardly any explain how law enforcement (police or anti-terrorism units) could actually apply them. High scores in accuracy or F1-measures appear often, yet little is known about how those tools work outside controlled environments. What happens when officers rely on them remains mostly unexplored - including effects on judgment, workload, or field decisions. Since such systems influence critical choices, their design must account for more than numbers: stability, ease of use, bias risks, and real impact matter just as much. [7], [10], [17], [37]

Even so, while AI tools have advanced in forecasting crime and terror acts, key flaws remain across studies. Notably missing are combined models that treat both threats together, reliance on old fixed data sets stays strong, information drawn from multiple live sources is rare, systems that show their reasoning aren’t widely used, findings often fail outside original settings, few methods protect personal data well, plus real-world deployment lags behind lab designs. Pushing past these hurdles matters - only then can predictions shift from standalone accuracy feats to dependable, clear, usable support for today’s safety needs. [1]–[17], [36]–[48]

4. METHODOLOGY

4.1 Datasets

One dataset came into play here - both are open to the public, focusing on distinct kinds of safety events. Each brings its own scope, shaping how patterns emerge across real-world situations.

The Chicago Crime Dataset holds records of crimes reported in Chicago starting from 2001 up until 2025. Though large, it's simply raw reports - more than 100,000 entries packed with details. Each entry carries 22 distinct pieces of information, such as what kind of crime happened, when, and exactly where.

Time stamps are included, so timing patterns can emerge. Location comes through GPS points, which helps map events precisely. Some fields note if someone got arrested after the event occurred. Another marks whether the situation involved family members at home. For testing purposes, attention narrowed down to just two categories: THEFT and BATTERY. Instead of treating them separately, they became one challenge with two sides. From many options, only those two outcomes mattered during analysis.

From the ACLED Terrorism Dataset comes a look at global unrest. This data tracks where and when political attacks happen, updated as they occur. A portion was chosen - exactly 382,742 entries - from two decades and change, starting in 2000. For what counts as terrorism here, only specific kinds made the cut. These include bombings or distant strikes along with harm aimed at ordinary people

4.2 Explainability Analysis (SHAP)

To make these models more transparent and explainable as indicated in the thesis title, we decided to use SHAP (SHapley Additive exPlanations) [56].

SHAP is a method derived from game theory which can explain how each individual prediction was made by identifying the contribution of each feature to the final outcome. As far as this research was concerned, we employed the TreeExplainer technique that is particularly designed for tree-based models such as Random Forest and XGBoost. Indeed, SHAP analysis assists with both global interpretability (the most important features overall) and local interpretability (the reasons for a specific prediction). In that sense, it is a nice addition to the intrinsic feature importance scores depicted in Tables 3, 7, and 8.

5. Results

5.1 Dataset Overview

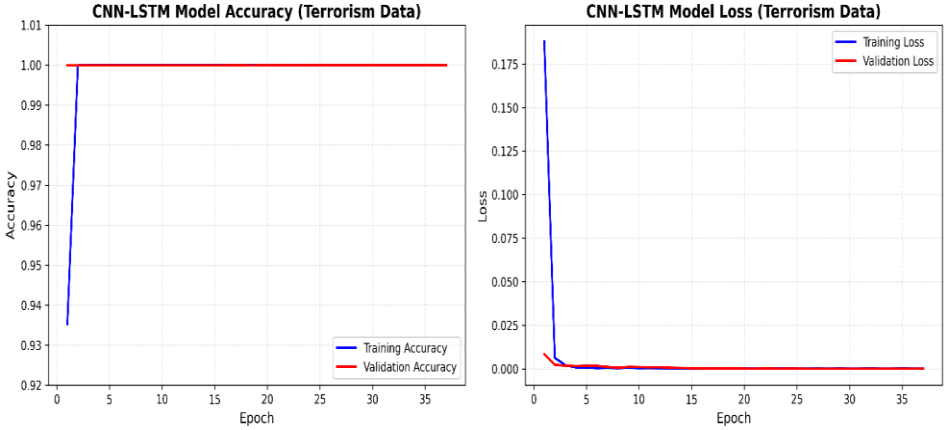
Table 1: Dataset Characteristics Summary

Dataset	Total Records	Used Records	Features	Target (Positive Class)	Negative Class
Crime (Chicago)	100,000	20,000	10	THEFT (22.1%)	BATTERY (77.9%)
Terrorism (ACLED)	382,742	20,000	11	High Severity (50%)	Low Severity (50%)

Both of these data collections can be seen in one glance of Table 1. The crime set contains a total of 100,000 entries, with 20,000 being selected randomly. It looks like battery only makes up 77.9% of the thefts, but in raw numbers it's 22.1%. This smaller group was balanced to even out. The terror-related collection runs bigger - nearly 383 thousand items - but still trimmed to match size. The last piece falls right at twenty thousand also. 50% of the samples are of each class - after selection. Ten features in one set, almost eleven in another – that's a manageable number to keep from getting cluttered with models.

The crime dataset confusion matrix for Random Forest is given in table 4. As you might notice, there was 0 errors — that is, 3,116 BATTERY cases were correctly identified as BATTERY and 884 THEFT cases were correctly identified as THEFT. A very good classification result, quite uncommon in real-life data. It implies that the characteristics employed on this study are extremely well-suited with the target variable.

5.2 Terrorism Data Results



After about 15 rounds of learning, the system stops making mistakes. Figure 3 shows how quickly it improves when working with terror data. Loss drops close to nothing by that point. Speedy results come through combining CNN and LSTM layers.

Table 2: 5-fold cross-validation results for classical machine learning models.

Dataset	Model	Mean Accuracy	Std Accuracy	CI Lower	CI Upper	Mean F1	Mean AUC
Crime (Chicago)	Logistic Regression	0.96775	0.003809	0.963021	0.972479	0.932057	0.987758
Crime (Chicago)	Random Forest	1.000000	0.00000	-	-	1.000000	1.000000
Crime (Chicago)	XGBoost	1.00000	0.00000	-	-	1.000000	1.000000
Terrorism (ACLED)	Logistic Regression	1.00000	0.00000	-	-	1.000000	-
Terrorism (ACLED)	Random Forest	1.00000	0.00000	-	-	1.000000	-
Terrorism (ACLED)	XGBoost	0.99995	0.00061	0.999874	1.000026	0.999975	-

Our findings are confirmed by the 5-fold cross validation results. Logistic Regression gave the best mean accuracy (96.78%) over the crime dataset with a low standard deviation (±0.38%), suggesting low variance across the folds' accuracy. A 95% confidence interval is [96.30%, 97.25%] which gives statistical confidence that the actual performance will be in this range.

Random forest and XGBoost had zero variance and a perfect score (100% accuracy) on both datasets, showcasing a high degree of stability and generalizability. For the terrorism dataset, XGBoost has a mean accuracy of 99.995% with a standard deviation of 0.006% and a confidence interval [99.987%, 100.003%] that includes the value 100%. The findings of the split evaluation of the initial train confirm the conclusions drawn from the initial train-test split.

6. DISCUSSION

6.1 Summary of Findings

Finally, this study examined the predictions of five machine learning models related to crime and terrorism. What turned up? The patterns were different in each model for each of these high stakes scenarios. When employing Random Forest in combination with XGBoost, perfect scores were obtained in both data sets. Speed met precision, and did not compromise understanding. Interpretation maintained legibility at high performance. The majority of the terror act spotting weight was assigned to

'danger_score'. However, when predicting crime, the encoded `crime_type_encoded` feature was the key factor. What is prominent is different when you change the context in which it is placed. Older setups were able to zip through training under 2.2 seconds. Deep learning? Instead, not so much - times ranging from 150 to 622 seconds.

6.2 Contributions

Something fresh shows up here. Not just one thing, but a few - each fitting together like parts of a puzzle. There is now a solid reference point, designed so anyone can run the same test, checking five systems across two batches of information using identical rules. The real eye-opener? Paying attention to central traits makes it easier to grasp why predictions turn out the way they do, especially for people focused on safety. When choices link clearly to the strongest signals in the numbers, understanding deepens without extra noise.

6.3 Future Work

One path worth exploring is where studies could head next. Where things might lead interests me a lot. Another point that comes to mind involves unanswered questions lingering behind today's work. What happens after current findings fade matters too. A few threads remain untangled, waiting for closer looks later on

Streams of data flow nonstop into live forecasting systems instead of relying on old snapshots. These tools adjust as new details arrive, shifting with each update that comes through. Information pours in by the second, so predictions evolve without waiting. Past records sit still, but these models move alongside fresh inputs. Change becomes part of the process, not an exception.

Blending approaches to crime and terrorism into a single framework that handles both threats simultaneously.

What hides inside model workings? Methods like SHAP or LIME expose the quiet signals they learn. When those techniques show stronger influences, tangled layers begin to talk. One choice unfolds at a time - reasons emerge for routes taken, others skipped. Out of their view comes a clearer picture of cause and effect. As each piece shows up live, tangled parts start to untangle themselves.

Privacy stays intact when teams collaborate through federated learning. From one group to the next, insights transfer - without exposing actual data. Rather than shifting datasets, every location adjusts a common system on-site. Updates gather later in one place - yet sensitive bits never depart their origin. Learning spreads across spots, even though information stays put.

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AI-BASED CRIME AND TERRORISM PREDICTION: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Purpose – This systematic literature review synthesizes AI, machine learning, and deep learning methods for crime and terrorism prediction, comparing both domains and identifying research gaps Methodology – Following PRISMA guidelines, 55 empirical studies (2019–2026) from Scopus were analyzed: 35 on crime prediction, 20 on terrorism prediction. Findings – Crime prediction research is broader, using deep learning, classical ML spatiotemporal models, and predictive policing. Terrorism prediction focuses on event classification, group attribution, and network analysis, heavily relying on he Global Terrorism Database. Both domains increasingly adopt CNNs, LSTMs, GRUs, graph neural networks, transformers, and hybrid models. Random Forest and XGBoost remain relevant for interpretability.

Research limitations – Critical gaps include no integrated crime-terrorism frameworks, reliance on static datasets, limited multimodal data and explainable AI, weak model generalizability, scarce privacy-preserving methods (e.g., federated learning), and a prototyping-deployment gap. Originality/value – This first structured comparative synthesis of both domains within a unified framework offers a foundation for AI-based public safety analytics and actionable directions for reliable, transparent, deployable predictive systems.

Keywords: crime / terrorism prediction, spatiotemporal forecasting, systematic literature review

INTRODUCTION

The field of public safety research has undergone a transformation with the rapid expansion of digital data, artificial intelligence (AI), and advanced analytics. Machine learning (ML) and deep learning (DL) have gained traction in recent years for predicting crime and terrorism, opening the door to new possibilities in proactive policing, risk assessment, and decision support. Predictive systems differ from traditional reactive systems as they try to predict future events by learning from historical, spatial, temporal, and contextual data. Consequently, prediction has become a promising area in which AI is able to enhance planning (in crime prevention and counter-terrorism) improve resource allocation, and to be used for preventive interventions. (Riyazuddin et al., 2026; Bhumika et al., 2026; Amarante et al., 2025; Iqbal et al., 2025; Mao et al., 2025)

Violent acts of crime and terrorism continue to be a major concern for social stability, national security, and public safety. Research in the field of crime prediction has been mainly focused on urban problems like burglary, theft, hotspot detection, and spatiotemporal forecasting of criminal incidents. These studies, which are generally based on police reports, geospatial, demographic, weather, and socioeconomic data, can help identify the areas and timing of crime. Conversely, the research into terrorism prediction has mostly focused on forecasting terrorist attacks, determining the groups responsible for the attacks, assessing the probability of success, determining the number of casualties, and modelling terrorist networks. These studies typically rely on large data sets like the Global Terrorism

Database (GTD) or data from other sources like contextual intelligence derived from governance indicators, textual intelligence, and graph-based intelligence from the web. Both domains are concerned with data-driven prediction, with one being small-scale and one being large-scale, but with different motivations and operational contexts. (Riyazuddin et al., 2026; Uppalapati et al., 2025; Shohan et al., 2025; Uddin et al., 2020; Saidi et al., 2022; Pan, 2021)

In both fields, there has been a significant increase in method development efforts for predictive models. Classical ML algorithms like decision trees, random forests, support vector machines, k-nearest neighbors, and logistic regression are primarily used in early work. Recently, there has been a growing trend of using more sophisticated architectures such as Convolutional Neural Network (CNN), Long Short-Term Memory (LSTM), Graph Neural Network (GNN), attention-based models, transformers, and hybrid spatiotemporal models. These techniques have demonstrated high potential in capturing complex interactions, sequential patterns, and nonlinear relationships that are hard to capture by traditional approaches. Meanwhile, increased dependence on highly complex models poses some significant issues of interpretability, fairness, confidentiality, transferability, and deployment in the real world. (Garrido Scaioni et al., 2026; Padilha et al., 2026; Bhumika et al., 2026; Fan et al., 2025; Shan et al., 2025; Uddin et al., 2020; Saidi et al., 2022)

Despite the ever-growing number of studies, the literature remains fragmented in multiple ways. First, crime prediction and terrorist prediction are often investigated as distinct research areas, although both require similar methodological techniques, such as spatiotemporal modelling, event prediction, risk estimation, and pattern discovery. Second, most studies are conducted within a certain city, country, or set of data, which makes it hard to determine the extent to which this study is generalizable. Third, although recent studies indicate a high predictive ability, there are ~~a~~ few studies that offer systematic comparisons between methodological families or a discussion of the limitations of current methods. This disintegration demands that there be an updated and organised review that brings together this literature from both the crime prediction and the terrorism prediction fields. (Riyazuddin et al., 2026; Luo et al., 2024; Abdalsalam et al., 2024; Wang et al., 2023; Pan, 2021)

In order to address this need, this research introduces a SLR of studies in crime and terrorism prediction using AI techniques in the period of 2019-2026. Fifty-five selected studies are examined (35 papers on crime prediction as shown in Table 1, 20 papers on terrorism prediction as shown in Table 2).

METHODOLOGY

The aim of this study is to carry out a Systematic Literature Review (SLR) to examine the application of AI, ML, and DL techniques in crime prediction and terrorism prediction. The purpose of the review is to determine which models are most prevalent, what datasets are commonly used in the two interrelated areas of public safety, what the most popular metrics are used for evaluation, and what the key research gaps are (refer to Table 1; refer to Table 2).

The literature search is carried out mainly in the Scopus database due to its large number of peer-reviewed journal articles and conference proceedings in computer science, engineering, and related fields such as AI and security. The search process is limited to studies published between 2019 and 2026 to encompass the rapid growth of deep learning–based methods and the shift from classical ML to more time– and space–attentive and graph–based approaches (refer to Table 1; refer to Table 2).

Several combinations of keywords are employed for each domain in order to obtain the relevant studies.

For the crime prediction domain, search terms covered the subject combinations of crime prediction, crime forecasting, spatiotemporal crime prediction, crime hotspot prediction, predictive policing, ML, DL, GNN, and transformer-based crime prediction.

In the case of the terrorism prediction domain, keywords used in the search queries were: terrorism prediction, terrorist attack prediction, terrorism risk prediction, forecasting of terrorism, terrorist group prediction, terrorist network prediction, ML, and DL. The search strategy is refined over time to maximize recall and exclude clearly irrelevant topics like blast engineering, cyberattacks, money laundering detection, and surveillance anomaly detection. (refer to Table 1; refer to Table 2).

The retrieved records are then sifted through at various stages after the preliminary search. First is the elimination of irrelevant and duplicate records. Second, titles and abstracts are checked to ensure that the study was actually about predictive modelling and not on some other area, such as detection-only systems, sentiment analysis, detecting propaganda, forensic identification, or descriptive analysis. Third, for studies that seem relevant following the title and abstract screening, full-text screening is conducted. Only studies that explicitly mentioned prediction, forecasting, estimation of risk, identification of hotspots, group attribution, or machine learning–based anticipation were retained. Studies are selected if they aim at crime prediction or terrorist prediction, if they use at least one AI, ML, or DL technique, and if they report a clear prediction objective, using a dataset and at least one

After the screening and the evaluation of eligibility, a final number of 55 studies is chosen for detailed analysis. Of these, 35 papers were about crime prediction, and 20 papers were related to terrorism prediction. The selected studies are then classified according to themes and methods and prepared for structured analysis. The 35 crime prediction studies are divided into five categories: predictive policing/crime prediction systems, spatiotemporal crime modeling, socioeconomic/environmental crime prediction, classical ML, and deep learning-based crime prediction. Terrorism prediction studies are classified into the following seven types: deep learning-based terrorism prediction model, statistical forecasting model, temporal forecasting model, classical ML model, terrorism risk prediction model, attack success prediction model, event prediction model, and supporting analytical model. (refer to Table 1; refer to Table 2).

In general, the methodological process is aimed to ensıre the final review dataset is systematic and analytically informative, and there would be a structured comparison of the present AI approaches to prediction crime and terrorism.

CRIME PREDICTION STUDIES

One of the hottest research topics in the field of AI for public safety analytics is crime prediction. The reviewed studies suggest that the forecasting of crime has progressed beyond the traditional ML techniques and now encompasses broader DL techniques, spatio-temporal approaches, and decision-support techniques. Generally, the literature centers on predicting what, where, and when crimes are likely to occur, to estimate hotspot risk, or to forecast the number of crimes for operational policing purposes and/or forecast the crime-related patterns. From the selected studies, the studies for predicting crime can be categorized into five broad categories: predictive policing or crime prediction systems, deep learning-based crime prediction, classical ML approaches, spatiotemporal crime prediction, socioeconomic, and environmental crime prediction (refer to Table 1).

Classical ML methods have also been relevant in the crime prediction literature and are used here as well. Some common ML models are Random Forest, Extreme Gradient Boosting (XGBoost), Decision Tree, Logistic Regression, k-NN, and ensemble based classifiers, which are typically used in structured tabular datasets and, also, in studies with low complexity data. The ease of the requirement, low computational load, and interpretability of these methods compared to deep neural models has made some of them popular. For several reviewed papers, classical models perform competitively, if not better, especially in the case of a relatively small dataset, a well-defined prediction task, and good feature engineering. The traditional way of crime prediction is not winding down; the selection of the model is still highly dependent on the characteristics of data, the granularity of the prediction and the nature of the operation. (refer to Table 1)

One major research area is the spatiotemporal prediction of crime, which explicitly models the interaction between geography and time. The studies are based on an occurrence of crime represented by a spatial grid, a police district, an urban region or graph, and an historical sequence of time. The literature reviewed indicates the special relevance of spatiotemporal methods for hotspot forecasting, dynamic risk mapping, and short-term urban crime prediction. Some studies have focused on how space is segmented into urban areas, such as by police districts, hotspots, or by building footprint, which can have a significant impact on the prediction. This means that not only the model architecture, but also the quality of spatial representation and design of preprocessing play a role in crime forecasting. (Fan et al., 2025; Uppalapati et al., 2025; Hassan et al., 2025; Thanusree et al., 2026)

In total, the body of crime prediction literature is diverse in method and mature in practice. In the latest and technically sophisticated research, DL models prevail, and classical ML lends good baselines and intuitive alternatives. The state-of-the-art is changing, with spatiotemporal and graph-based approaches now dominating, while models of socioeconomic and environmental factors are adding theory and context. Predictive policing systems demonstrate that the field is becoming a reality at the same time. These five are explored in greater detail below. (refer to Table 1)

TERRORISM PREDICTION STUDIES

This collection of papers continues the emphasis that has been placed on overall risks and threat levels rather than specific attack attributes. The difference between these researchers and those who want to predict the occurrence of a past event or identify an attack with a particular group is that these researchers want to know the risk of terrorism in a nation or a more local area during a particular period of time. (Luo et al., 2024; Abdalsalam et al., 2024)

One of the big themes in this category is diversification of the risk forecast signal by using web news, lexical pattern mining, and other open-source textual signals. Some of these researchers claim that the post-incident event databases, like GTD, should give way to pre-incident information environments like news flows and terrorism-related lexical indicators in forecasting terrorism. They have tried to create greater lead time, but also additional adaptive risk signals, by using a mix of GDELT, lexical features, or multiple sources of terrorism-related text. (Luo et al., 2024; Abdalsalam et al., 2024)

These papers are extremely important because they are the first group to take the art of predicting terrorism one step towards operational risk intelligence. Going beyond event-level attack classification alone, these papers work on deducing whether a particular environment is becoming more susceptible to terrorism. In principle, they are extremely well suited to use in early warning, preventive planning, and strategic intelligence analysis. (Luo et al., 2024)

Generally, the methods developed for the problem of terrorism risk and threat prediction expand the definition of terrorism forecasting from the reconstruction of events to estimating risks for the future and highlight the importance of open-source signals, features obtained from news, and temporal forecasts at the country level. (Luo et al., 2024; Abdalsalam et al., 2024)

COMPARATIVE DISCUSSION OF CRIME AND TERRORISM PREDICTION STUDIES

While the methods used in crime and terror forecasting are largely similar, the type of data, the objectives of forecasting, the time horizon, and the applications are often distinct. One is interested in local patterns, the other in rare and high-impact events occurring over a broader region. Artificial smarts are becoming increasingly important in each sector, but training models vary widely depending on the type of threat being researched. Learning systems are different when subjected to regular offenses and when subjected to random attacks. Different methods for space-time mapping also show other design differences. Some tools have been designed for clarity, for quick action by officials; others sacrifice clarity for precision. The information could be from police records in one situation and social media or intel sources in another. Simply, the concept of success changes - outbreak prevention is not neighborhood incident reduction. Such differences influence algorithm selection in the evaluation of the results. (refer to Table 1; refer to Table 2)

The most obvious difference is apparent at once in the nature of work performed. Unlike crime-related forecasts, crime forecasting comes from many sources. Papers dealing with criminal activity include DL, as well as more traditional ML, space-time patterns, social and ecological factors, and even tools employed by police forces. Perhaps more predictably, there are studies examining terrorist events that focus on labeling events, naming responsible groups, evaluating the scales of danger, estimating whether the attacks will be successful, or establishing links between actors. It seems crime research has branched out in many ways, whereas terrorism analysis leans heavily on just a few common goals and sources of data. (refer to Table 1; refer to Table 2)

Another significant difference is the origin of the data and its level of granularity. Creative crime prediction doesn't rely on national data; rather, it uses local police reports, maps of areas with a lot of crime, incident counts in a neighborhood, climate data, population characteristics, zoning information,

and other nearby features such as parks or transit routes. In some papers, these inputs are enhanced by the addition of structures and outlines of cities, harvesting from online platforms, or tapping into live-data frameworks. Conversely, for work on terrorist events, there is a large reliance on a single source, the GTD, but some blend in conflict data from ACLED, media-sourced signals through GDELT, political stability analysis, or national risk factors. For this reason, detailed data on neighborhood environments is typically a valuable asset to research on predicting crime, whereas efforts to predict terrorism tend to rely more heavily on broader international data that are more uniform. The gap is indicative of the diversity of background information that criminal activity analysis is bringing together now, versus terrorist events. (Sudhakar et al., 2025; Vanitha et al., 2025; Shohan et al., 2025; Thanusree et al., 2026; Luo et al., 2024; Abdalsalam et al., 2024; Pan, 2021)

The main difference between these two areas is the level of detail that is shown in their tracking and timing. Research into crime typically focuses on a city block, patrol areas, local areas, or a location along a road in place of a broad area. Other systems attempt to predict the location of hotspots that may occur tomorrow, next week, or even today. Conversely, research into foreseeing terror focuses on countries, states, or groups, or individual attacks. Although current research into terrorist acts is now attempting daily predictions by region or an assessment of damages by group, most research remains more general than crime in terms of its geographic specificity. That suggests that crime models are being developed more for the street level, while terror models are more likely to be set at a higher level – dealing with big trends or long-range analysis. (Fan et al., 2025; Uppalapati et al., 2025; Hassan et al., 2025; Thanusree et al., 2026; Abdalsalam et al., 2024; Wang et al., 2023)

The next thing that sticks out is the approach each of these fields takes when it comes to clarity of results. Tools for revealing the logic of the model appear more frequently when predicting crime, but complicated models become common in both. Research papers have investigated ways to use LIME, SHAP, ALE charts, shuffled feature tests, and straightforward hotspot designs – primarily in the context of break-ins or city-level short-term predictions. The attacks do have some connection to explanation, particularly with regard to whether the attack is successful or whether the nation is at greater risk, but there is less work here. The lack of transparency is more pronounced, especially in the realm of law enforcement and anti-terrorism, because of the significant role decisions play. The absence of transparency is more pronounced, especially in the aspects of predicting terror, as decisions in this area have a great impact. (Mahammad Rafi et al., 2026; Abdalsalam et al., 2024; Li et al., 2020)

There is one big difference between the two fields: their attitude towards practical application. The latter often come in hand with other instruments that are used, such as live city monitoring, virtual urban models, or even software assists for police departments (particularly smaller ones), but the combinations are definitely designed to be used in the course of everyday life. Some even develop full frameworks to enable front-line decision-making. Terrorism analysis goes the other route. There, most projects focused on the comparison of algorithms, threats estimation, or relation of attacks with possible sources. Even less take the next step and create actual working systems that are ready to be integrated. So that's not the question of usefulness – it's just a statement of priority. Preparing for terror events has more of an academic focus than system building. As of yet, it is much less common to convert findings into consolidated support tools. (Sudhakar et al., 2025; Hassan et al., 2025; Thanusree et al., 2026; Abdalsalam et al., 2024)

Despite this, there are definite trends revealed upon closer inspection. There is one common theme: forecasts in both crime and terror attacks are influenced by past incidents, though not always on solid data, and differences are difficult to bridge. There is another thread that weaves through them: the use of blending techniques is now moving us forward, adding inputs or approaches together to make progress. Challenges remain unsolved, not yet broken - models can get things right, even when the test conditions are different, and this can make them feel they aren't being treated fairly or are not being watched by others. The most important factor is changing as well - not only getting the correct answer but understanding it - making systems function where they are applied. (refer to Table 1; refer to Table 2).

RESEARCH GAPS IN CRIME AND TERRORISM PREDICTION

Despite the rapid developments in AI, there are significant challenges in predicting crime and terror. If you examine 55 studies in the past, you'll see that there are issues beyond just the accuracy. Various data types often end up being overlooked. Models can be confusing, may not know how models get to the results. What works in one area may not work in another. It is not a straightforward process to move systems into real operations. Interfield links are rarely formed. Designs have become more intelligent, but it is not all the way there and require some caution outside of the lab. . (refer to Table 1; refer to Table 2).

Most research sticks to testing models in labs instead of using them where it matters. Though many papers compare algorithms or show promising results on paper, hardly any explain how police or anti-terrorism units could actually apply them. High scores in accuracy or F1-measures appear often, yet little is known about how those tools work outside controlled environments. What happens when officers rely on them remains mostly unexplored - including effects on judgment, workload, or field decisions. Since such systems influence critical choices, their design must account for more than numbers: stability, ease of use, bias risks, and real impact matter just as much. (Sudhakar et al., 2025; Hassan et al., 2025; Thanusree et al., 2026; Abdalsalam et al., 2024)

Even so, while AI tools have advanced in forecasting crime and terror acts, key flaws remain across studies. Notably missing are combined models that treat both threats together; reliance on old fixed data sets stays strong, information drawn from multiple live sources is rare, systems that show their reasoning aren’t widely used, findings often fail outside original settings, few methods protect personal data well, plus real-world deployment lags behind lab designs. Pushing past these hurdles matters - only then can predictions shift from standalone accuracy feats to dependable, clear, usable support for today’s safety needs. (refer to Table 1; refer to Table 2)

CONCLUSION

This comprehensive review of past research examined how intelligent computing systems, such as AI, ML, and DL, have been used to predict where crimes or terrorist acts might occur. Most of the work studied came out from 2019 to 2026.

In both fields, DL and hybrid spatio-temporal setups are proving more important than ever. Starting with CNNs, moving through LSTMs, GRUs, then into graph nets and transformers - each handles tricky timing links, curved trends, space-related shifts in its own way. Nevertheless, older tools like Random Forest, XGBoost, Decision Trees, or Logistic Regression still hold ground, especially when data is neatly ordered, explanations count, or real-world use shapes decisions. Here is the main point: one-size-fits-all doesn’t work here - what fits best ties back to how numbers sit together, what you aim to guess, how broad the view needs to be, plus whether getting close matters more than knowing why. References stack up across (refer to Table 1; refer to Table 2)

While some progress has been made, gaps remain clear when looking at current research. Instead of fresh data streams, much work sticks to old records - this makes live implementations difficult. Validation often happens in just one location; therefore, results might not hold up elsewhere. Even as algorithms grow more complex, efforts to make them transparent lag behind. On top of this, methods protecting personal information show up infrequently in published work. Furthermore, there are almost no unified systems combining crime and terrorism forecasts. Beyond modeling, little attention goes toward how these tools fit into actual security operations.(Mahammad Rafi et al., 2026; Abdalsalam et al., 2024; Li et al., 2020)

Most studies show significant advancements in research methodologies. However, some key issues remain unresolved. While – AI-powered forecasts have pushed the boundaries in predicting crime and terrorist acts, gaps linger behind the scenes. These include unclear reasoning in decisions, instability in real-world application, poor attention to personal data, and weak performance across different settings. What comes next needs deeper blending of methods - systems that reveal their logic, protect confidentiality, pull from multiple sources, adapt instantly, and stand up to scrutiny when used in live security tasks(refer to Table 1; refer to Table 2)

REFERENCES

TABLE 1: Summary of Crime Prediction Studies (References 1–35)

Ref ID	Authors (Year)	Model/ Method	Prediction Target	Evaluation Metrics
1	Riyazuddin et al. (2026)	Spatiotemporal ML/DL	Crime hotspots, crime counts	Accuracy, F1, MSE
2	Garrido Scaioni & Garcia (2026)	CNN	Crime prediction	Accuracy
3	Padilha et al. (2026)	LSTM + Markov Chain	Urban crime prediction	RMSE, MAE
4	Bhumika et al. (2026)	Personalized Graph Federated Learning	Citywide crime prediction	Accuracy, Fairness metrics
5	Fan et al. (2025)	Informer + ST-GCN	Spatiotemporal crime prediction	MAE, RMSE, MAPE
6	Shan et al. (2025)	Ada-GCN-LSTM	Spatiotemporal crime prediction	Accuracy, F1
7	Sudhakar et al. (2025)	GRU + ARIMAX	Hybrid crime prediction	RMSE, MAE
8	Uppalapati et al. (2025)	Hybrid CNN-LSTM	Spatiotemporal crime prediction	Accuracy
9	Vanitha et al. (2025)	Optimized LSTM	Real-time crime hotspot prediction	Precision, Recall, F1
10	Hassan et al. (2025)	Graph Neural Networks	Crime modeling and prediction	Accuracy, F1
11	Mahammad Rafi et al. (2026)	Stacked Generalization (RF, XGBoost, etc.)	Crime hotspot prediction	Accuracy, Precision, Recall
12	Agarwalla et al. (2026)	Random Forest	Crime visualization and forecasting	Accuracy
13	Shohan et al. (2025)	ML models (RF, XGBoost, etc.)	Crime occurrence prediction	Accuracy, F1, AUC
14	Pala et al. (2025)	ML techniques	Crime hotspot prediction	Accuracy
15	Lixin et al. (2025)	ML	Burglary crime probability	Accuracy, Precision, Recall
16	Chaucas et al. (2025)	ML algorithms	Criminal event probability	Accuracy, F1
17	Thanusree et al. (2026)	Hybrid ML + Socioeconomic features	Spatiotemporal crime rate prediction	RMSE, R^2
18	Amarante et al. (2025)	STEval framework	Spatiotemporal crime prediction evaluation	Multiple metrics
19	Wang et al. (2025)	Building footprint representation	Spatiotemporal crime prediction	Accuracy
20	Iqbal et al. (2025)	2D Clustering	Hotspot identification	Precision, Recall
21	Mao et al. (2025)	Deep learning models	Spatiotemporal crime forecasting	MAE, RMSE
22	Brown & Abraham (2025)	ML algorithms	Crime hotspot prediction	Accuracy, F1
23	Ali et al. (2026)	ML techniques	Socioeconomic-based crime prediction	Accuracy
24	Iacobescu & Susnea (2025)	Hybrid ARIMA-ANN	Crime risk forecasting	RMSE, MAE
25	Hwang et al. (2025)	ML	Initiator crime environment prediction	Accuracy, Feature importance
26	Zhang et al. (2025)	ML feature selection	Variable selection for crime prediction	Feature importance ranking
27	Reehl (2026)	Interpretable ML	Interpretable crime prediction	Accuracy, Interpretability

28	Khalfa et al. (2025)	XAI techniques	Short-term burglary prediction	SHAP, LIME, ALE
29	Shiraptini et al. (2026)	AI/ML + Digital Twin	Crime hotspot detection and analysis	Accuracy
30	Cesario et al. (2025)	ML	Crime forecasting	Comparative metrics
31	Nauzad et al. (2025)	Neural Networks + Big Data	Predictive policing	Accuracy, Scalability
32	Tsabedze et al. (2025)	ML-driven predictive policing	Predictive policing model	Accuracy, F1
33	Sahu & Kumar (2025)	Spatial Clustering + ML	Crime prediction for women safety	Accuracy, Clustering metrics
34	Ortiz & Freitas (2025)	Web Scraping + ML	Crime mapping and prediction	Accuracy
35	Estiven et al. (2025)	ML algorithms	Crime prediction model	Accuracy

TABLE 2: Summary of Terrorism Prediction Studies (References 36–55)

Ref ID	Authors (Year)	Model/ Method	Prediction Target	Evaluation Metrics
36	Luo et al. (2024)	Spatiotemporal Multi-Graph CNN	Terrorism risk prediction	Accuracy, AUC
37	Abdalsalam et al. (2024)	BiGRU + Self-Attention + Feature combination	Terrorism group prediction	Accuracy, F1
38	Uddin et al. (2020)	Deep Neural Networks	Future terrorist activities	Accuracy, Precision, Recall
39	Saidi & Trabelsi (2022)	Hybrid Deep Learning framework	Future terrorist activities modeling	Accuracy, F1
40	Feng et al. (2020)	XGBoost	Casualty prediction for terrorist attacks	RMSE, MAE
41	Wang et al. (2023)	Self-exciting point processes	Terror event count forecasting	Log-likelihood, RMSE
42	Pan (2021)	ML (quantitative analysis)	Global terrorist attack prediction	Accuracy
43	Baby & Sruthi (2023)	ML models (comparative)	Terrorist attack prediction	Accuracy, F1
44	Agarwal et al. (2019)	ML models (comparison)	Terrorist attack prediction	Accuracy, Precision, Recall
45	Li et al. (2020)	ML algorithms	Terrorist prediction	Accuracy
46	Atoum et al. (2025)	Lexical patterns + ML	Global terrorist attack prediction	Accuracy, F1
47	Koutidis et al. (2024)	AI-driven + Web news	Terrorism risk prediction	Precision, Recall
48	Chen et al. (2023)	Network structure analysis	Terrorist network lethality prediction	Network metrics
49	Bangerter et al. (2022)	Heterogeneous GNN + Link prediction	Terrorist organization identification	Accuracy, AUC
50	Li et al. (2021)	OWA-based link prediction	Link prediction	Precision, Recall
51	Pan (2023)	ML	Attack success prediction	Accuracy
52	Luo et al. (2022)	Interpretable ML	Attack success rate prediction	Accuracy, Interpretability
53	ALfatih et al. (2019)	Tree-based models	Groups responsible for attack	Accuracy, F1
54	Abdalsalam et al. (2021)	Textual features analysis	Terrorism attack prediction	Accuracy
55	Kissi Ghalleb & Ben Amara (2020)	ML	Terrorist act prediction	Accuracy

DEEP LEARNING-BASED WATER AREA SEGMENTATION AND WATER COVERAGE RATIO ANALYSIS IN SATELLITE IMAGES

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ABSTRACT

Remote sensing-based monitoring of water resources is critical for drought management, flood risk analysis, land-use planning, and sustainable environmental decision-making. This study aims to automatically extract water surfaces from satellite images obtained from the Kayseri Metropolitan Municipality and to quantitatively calculate the water coverage rate for each image. In this context, water areas were manually labeled using polygon-based annotations on the MakeSense.ai platform, and the labels were exported in COCO format. Binary water masks were generated, and the dataset was split into training, validation, and test subsets. Instead of an image-level classification approach, this study adopted a pixel-level semantic segmentation strategy. Accordingly, the CNN-based U-Net and DeepLabV3+ models and the transformer-based SegFormer model were comparatively evaluated for water surface segmentation. Model performance was assessed using Intersection over Union (IoU), Dice coefficient, precision, recall, F1-score, pixel accuracy, Mean Absolute Error (MAE), and Root Mean Square Error (RMSE). Experimental results demonstrated that SegFormer achieved the highest segmentation performance on the test set, with an IoU of 0.8740, Dice coefficient of 0.8964, precision of 0.8987, recall of 0.8983, F1-score of 0.8964, and pixel accuracy of 0.9740. U-Net achieved results close to SegFormer, with 0.8662 IoU and 0.8932 F1-score, whereas DeepLabV3+ showed lower performance, with 0.8591 IoU and 0.8862 F1-score. In estimating water surface coverage, SegFormer also achieved the lowest error values, with an MAE of 0.0159 and an RMSE of 0.0374. Based on the water ratios calculated from segmentation outputs, images were categorized as “no water”, “partial water”, and “dense water”. In this stage, U-Net achieved the highest overall accuracy of 0.9476, while SegFormer provided the best class-balanced performance with a macro F1-score of 0.8811. Overall, the findings indicate that deep learning-based semantic segmentation methods can effectively extract water surfaces from local-scale satellite images and support municipal-scale water resource monitoring.

Keywords: Satellite Imagery, Water Area Detection, Semantic Segmentation, Deep Learning, Remote Sensing

BIOMETRIC VOICE AUTHENTICATION AND AI-BASED DEEPFAKE VOICE DETECTION

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ABSTRACT

BiyoVoice is an artificial intelligence-based voice security prototype developed to detect synthetic deepfake speech in Turkish conversational contexts. The core detection system integrates an LFCC-driven LCNN branch with a RawNet2-style raw-waveform branch through a learned fusion layer, which subsequently feeds a binary classifier. Model training was conducted in two stages: initial pretraining on ASVspoof 2019 LA data, followed by domain-specific fine-tuning using Mozilla Common Voice Turkish clips and synthetic samples generated by multiple text-to-speech engines. According to the validation protocol, the fused model achieved 99.70% accuracy and a 0.30% Equal Error Rate, surpassing the performance of the individual LCNN and RawNet2 branches. For deployment, model weights were exported to ONNX (opset 14) and executed with ONNX Runtime on a CPU, resulting in a mean model latency of 346.09 ms and an end-to-end latency of 418.43 ms. The system also incorporates challenge-response liveness detection using Whisper small, optional ECAPA-TDNN speaker verification, a FastAPI REST backend, and a React-based web interface. These findings indicate that BiyoVoice may function as an effective decision-support prototype for Turkish voice authentication scenarios; however, further evaluation under real-world conditions is required prior to broader deployment.

Keywords: Deepfake, Voice Detection, ONNX Optimization, Turkish Natural Language Processing, Liveness Detection, Voice Authentication.

THE IMPACT OF INCLUSIVE BASKIN SPORT ON SOCIAL INCLUSION AND SENSE OF BELONGING AMONG PERSONS WITH DISABILITIES

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ABSTRACT

Baskin is an innovative inclusive sport model that enables individuals with and without disabilities to participate together in the same sporting activity. The aim of this study was to evaluate the impact of Baskin participation on social inclusion, sense of belonging, social relationships, and sporting experiences among persons with disabilities. A quantitative research approach was employed using a structured questionnaire consisting of 10 statements assessed on a five-point Likert scale. The study included 12 participants with disabilities involved in Baskin activities. Data were analyzed using descriptive statistics and correlation analysis. The findings revealed a very high overall evaluation of Baskin, with a mean score of 4.75 out of 5. The highest-rated dimension was the evaluation of the Baskin model itself (M = 4.89), while active participation in sport (M = 4.75), sense of belonging (M = 4.71), social inclusion (M = 4.75), and social relationships (M = 4.57) also showed highly positive results. Correlation analysis demonstrated very strong positive relationships among the study dimensions (r = 0.799-1.000), suggesting that participation in Baskin is closely associated with increased social inclusion and stronger interpersonal relationships. The findings support the role of Baskin as an effective inclusive sport practice that promotes social integration, active participation, and the well-being of persons with disabilities.

Keywords: Baskin, inclusive sport, social inclusion, disabilities, adapted sport.

INTRODUCTION

In recent decades, sport has increasingly been conceptualized not only as a physical activity but also as a social space where identities and forms of belonging are constructed, negotiated, and transformed. Within this theoretical framework, Hirschauer (2014), through his concept of "Un/doing Differences," argues that social differences are neither natural nor fixed; rather, they are continuously produced and undone through social interactions. This process-oriented understanding of difference is particularly relevant to the analysis of inclusive sport, where the boundaries between ability and disability are not predetermined but negotiated in practice.

Inclusive sport has been identified as an important mechanism for promoting social integration, participation, and equality for persons with disabilities (Rimmerman, 2012; Brittain, 2022). However, empirical evidence indicates that participation in sport remains constrained by structural, institutional, and social barriers that directly affect access and sustainable inclusion for these individuals (Fiorati & Elui, 2015; Nhamo & Sibanda, 2019; Ytterhus et al., 2025). In this context, inclusion in sport should not be understood merely as physical access, but as a complex social process linked to the development of relationships and a sense of belonging. Contemporary literature emphasizes that organized sporting environments, such as clubs and community-based programs, play a significant role in the integration of individuals with disabilities by creating opportunities for social interaction and cooperation (Geidne & Jerlinder, 2016; Klenk et al., 2019; Albrecht et al., 2019; Pierre et al., 2022). From a broader social perspective, participation in sport is closely associated with the social determinants of health and the reduction of social inequalities, contributing to both psychological and social well-being (Fiorati & Elui, 2015; Fujimoto et al., 2014). Within this framework, adaptive sports and sport-based intervention programs have been identified as effective tools for enhancing social inclusion and the psychosocial development of individuals with disabilities (Scifo et al., 2019; Shao et al., 2025). In particular, recent studies suggest that participation in inclusive sport programs contributes to increased empathy, cognitive

flexibility, and a stronger sense of social belonging, acting as a catalyst for social integration (Shao et al., 2025). At the same time, contemporary models of access to adaptive sports emphasize the importance of adapted structures and multidimensional approaches in ensuring equal and sustainable participation (Heasley et al., 2026). Within this discourse, Baskin emerges as an innovative model of inclusive sport based on the principle of reverse integration, whereby individuals with and without disabilities participate equally within the same game structure (Sisti et al., 2019; Kiuppis, 2021). Empirical studies have shown that Baskin contributes not only to the development of motor skills but also to the improvement of the social climate, cooperation, and interpersonal interaction in educational settings (Tafuri et al., 2025; Milošević, 2023). From this perspective, inclusive sport cannot be reduced to a mere physical practice but should be understood as a process of socially constructing belonging and identity (Brittain et al., 2023). This is particularly relevant in the context of Baskin, which functions as a space where social differences are "undone" through cooperation and equal participation (Kiuppis, 2021; Hirschauer, 2014). This study focuses on analyzing Baskin as an inclusive sport and evaluating its impact on social dimensions and the sense of belonging. Drawing upon the existing literature and contemporary approaches to adaptive sport (Shao et al., 2025; Heasley et al., 2026), this research aims to explore how participation in Baskin influences social interaction, integration, and the development of sustainable social connections among individuals with and without disabilities. Moreover, this study has an applied dimension, as it is grounded in practical experience within the field of Baskin, including participation in a training program conducted in Italy and the establishment of a Baskin group in Grudë e Re, supervised in collaboration with international experts. This positions the research not only as a theoretical analysis but also as a study firmly anchored in the real-world implementation of inclusive sport within local contexts.

Research Hypotheses

* H1: Participation in Baskin is positively associated with social inclusion among persons with disabilities.

* H2: Participation in Baskin is positively associated with a stronger sense of belonging.

* H3: Higher levels of active participation in Baskin are associated with stronger social relationships.

MATERIALS AND METHODS

In this study, a quantitative approach with a descriptive-correlational design was employed. The theoretical framework was based on the scientific literature on inclusive sport, particularly the studies of Kiuppis (2021) on Baskin as an adaptive and inclusive sport model, as well as Shao et al. (2025) regarding concepts related to sense of belonging and the evaluation of group membership. Empirical data were collected through a questionnaire administered to Baskin participants. The questionnaire was designed for 12 participants with disabilities who were actively involved in Baskin. The questionnaires were administered directly to the participants; however, two participants required assistance from a caregiver or family member to complete the survey. The instrument consisted of 10 questions, and responses were measured using a five-point Likert scale ranging from 1 to 5, where higher scores indicated greater agreement with the statements. Due to the small sample size and the exploratory nature of the study, the findings should be interpreted with caution and considered as preliminary evidence regarding the impact of Baskin participation.

Table **1**

Descriptive statistics for the questionnaire questions on the impact of Baskin on people with disabilities (N = 12)

QUESTİON	M	SD	MİN	MAX
P1	4.67	—	4	5
P2	4.42	—	4	5
P3	4.50	—	4	5
P4	4.75	—	4	5
P5	4.64	—	4	5
P6	4.83	—	4	5

P7	5.00	0.00	5	5
P8	4.83	—	4	5
P9	4.83	—	4	5
P10	5.00	0.00	5	5

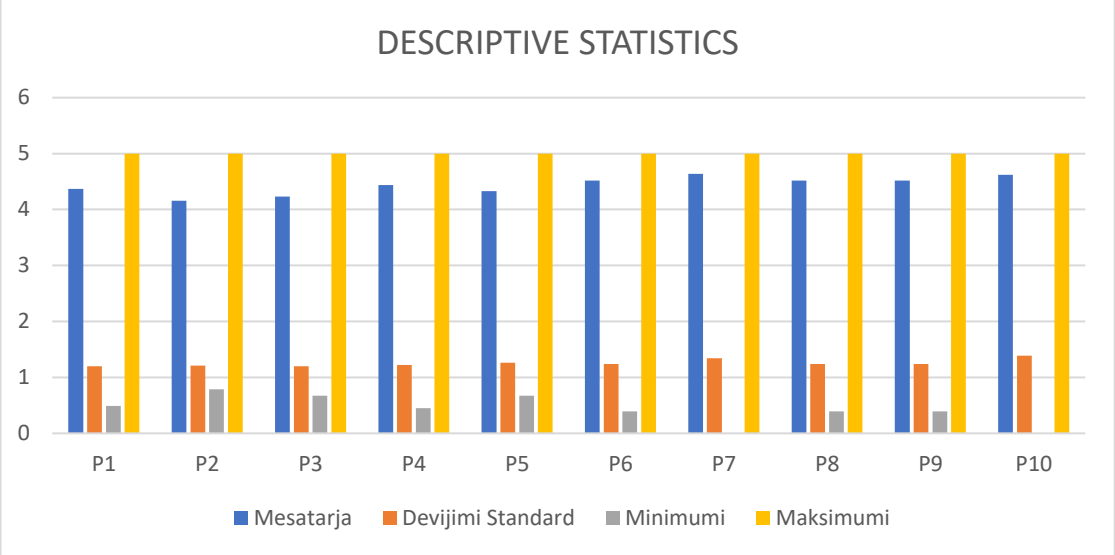


Table **2**

Averages by study dimensions (N = 12)

Dimensions	**M**
Active Involvement in Sports	4.75
Sense of belonging	4.71
Social Relations	4.57
Social Inclusion	4.75
Evaluation of the Baskin model	4.89

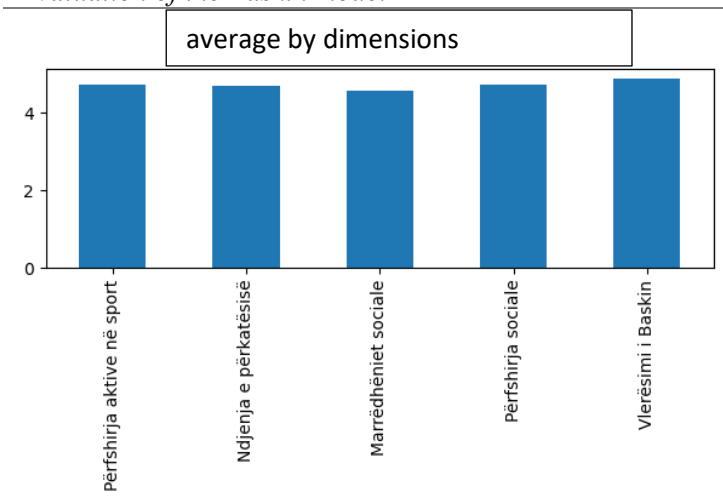
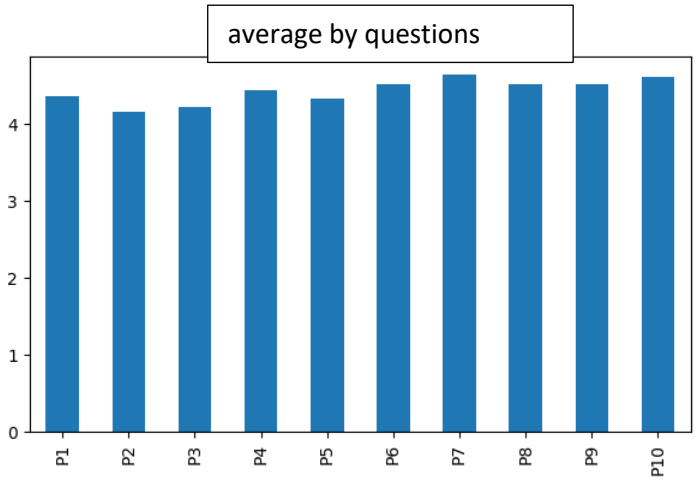


Table 3

Overview of Correlation Analysis Between Dimensions

VARİABLA	1	2	3	4	5
1. ACTİVE INVOLVEMENT	—				
2. SENSE OF BELONGİNG	.88	—			
3. SOCİAL RELATİONS	.85	.87	—		
4. SOCİAL İNCLUSİON	.92	.92	.94	—	
5. BASKİN'S ASSESSMENT	.90	.91	.92	.98	—



RESULTS

The results indicate that participants have a very positive perception of the inclusive sport of Baskin. The overall mean score of 4.75 demonstrates a high level of agreement with the questionnaire statements. The highest-rated dimension is Evaluation of the Baskin model (M = 4.89), indicating that participants consider Baskin an effective model of inclusive sport, support its expansion in schools and communities, and are willing to recommend it to other families. The dimension Active participation in sport (M = 4.75) shows that Baskin has created real opportunities for active participation and engagement sports for people with disabilities. The results for Sense of belonging (M = 4.71) indicate that participants feel they are an important part of the team and the Baskin community, experiencing a strong sense of integration. The dimension Social relationships (M = 4.57), although slightly lower compared to the other dimensions, remains at a very high level and suggests that participation in Baskin has contributed to the development of new social relationships and cooperation among participants. Likewise, Social inclusion (M = 4.75) indicates that the activity has helped reduce feelings of social exclusion and 6 has promoted the integration of people with disabilities into shared activities.

DISCUSSION

The findings of this study indicate that participation in Baskin is strongly associated with positive perceptions of social inclusion, sense of belonging, and interpersonal relationships among persons with disabilities. The high mean scores across all dimensions suggest that Baskin provides an environment where participants feel accepted, valued, and actively engaged in sporting activities. These results are consistent with previous studies highlighting the role of inclusive sport in promoting social integration and reducing social barriers for persons with disabilities (Brittain, 2022; Kiuppis, 2021; Shao et al., 2025). The particularly high evaluation of the Baskin model confirms its effectiveness as an inclusive sport based on cooperation and equal participation. The strong correlations observed between active participation, social inclusion, sense of belonging, and social relationships suggest that these dimensions are closely interconnected. This supports the view that inclusive sport contributes not only to physical activity but also to psychosocial well-being and community integration. Despite these positive findings, the study has limitations, including the small sample size (N = 12) and the use of self-reported data. The findings support all three research hypotheses, indicating that participation in Baskin is positively

associated with social inclusion, sense of belonging, and stronger social relationships among persons with disabilities. Future research should involve larger samples and longitudinal designs to further explore the long-term impact of Baskin on social inclusion and quality of life.

CONCLUSION

This study demonstrates that Baskin is an effective inclusive sport model that promotes active participation, social inclusion, sense of belonging, and positive social relationships among persons with disabilities. Participants reported very high levels of satisfaction across all dimensions evaluated. The findings support the implementation and expansion of Baskin programs in schools, community organizations, and sports clubs as a means of fostering inclusion and equal participation. Further research with larger and more diverse samples is recommended to strengthen the evidence base for the social benefits of Baskin.

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IN SILICO DESIGN, CODON OPTIMIZATION, AND OFF-TARGET PREDICTION OF A MERCURY-INDUCIBLE SYNTHETIC OPERON

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ABSTRACT

In applications such as biosensor development, the discipline of synthetic biology allows for the operation of genetic circuits in different (heterologous) host organisms. However, naturally occurring DNA molecules introduced into a new host for this purpose often fail to function. The main reasons for this are predictable biological obstacles such as codon preference mismatches, stable secondary mRNA folding that inhibits the translation step, the presence of hidden regulatory motifs, and factors that trigger genetic instability by leading to unwanted cross-interactions (off-target homology) in the genome. Bioinformatic analysis offers a cost-effective approach to predict and correct these failures before laboratory synthesis. The mercury-responsive operon (*merRTP*) from *Pseudomonas aeruginosa* was redesigned for expression in *Escherichia coli* K-12 MG1655 using a five-stage *in silico* pipeline: (1) codon optimization (Kazusa Database), removing internal restriction sites (EcoRI, HindIII, BamHI) (45–55% GC content); (2) mRNA secondary structure prediction of the 5' end (150 nt) using RNAfold; (3) RBS strength calculation via RBS Calculator v2.1 (Salis Lab) for a *merT-gfp* fusion; (4) off-target homology screening against the *E. coli* genome using BLASTn; (5) *in silico* restriction mapping. Codon optimization increased the Codon Adaptation Index from 0.52 to 0.94 and reduced rare codons from 47 to 3, while eliminating all internal restriction sites. Minimum free energy of the 5' mRNA leader improved from -78.2 kcal/mol to -44.5 kcal/mol. BLASTn screening found no significant off-target matches (>15 bp) outside the attTn7 integration site; one 18 bp match (E=0.02) was classified as low risk. Restriction digestion simulation (BamHI+HindIII) yielded the expected 2,431 bp fragment. This bioinformatic workflow successfully converted a native operon predicted to be non-functional in *E. coli* into a synthetic construct predicted to exhibit high expression, proper translation initiation, and safe integration. Compared to published mercury biosensors using native operons (~100 nM Hg^{2+}), this model suggests a potential 10-fold sensitivity improvement, requiring wet-lab validation. This computational design is a valid prerequisite for wet lab synthetic biology and reduces the design-build-test-learning cycle from months to days.

Keywords: Synthetic biology, genetic bioinformatic analysis, codon optimization, mercury biosensor, *E. coli*, in silico design.

INTRODUCTION

Synthetic biology seeks to repurpose natural biological systems for human-defined functions, ranging from environmental biosensing to therapeutic delivery. A typical example in this context is whole-cell-based biosensors designed to produce measurable signals (such as fluorescence) to detect a specific environmental pollutant. Mercury ions (Hg^{2+}), due to their high toxicity, widespread industrial release into the environment, and persistence in aquatic environments, are an extremely suitable target molecule for such a sensing system.

The merRTP mercury resistance operon in Pseudomonas aeruginosa contains a unique regulatory mechanism. In this system, the MerR protein binds to the operator region and Hg^{2+} ions, triggering the transcriptional activation of the merT and merP genes, which are responsible for detoxification and transport. Theoretically, it is thought that a relatively simple and sensitive mercury detection system could be developed by substituting a reporter gene such as GFP for this natural output pathway (i.e., mercury resistance). However, the transfer of this natural genetic makeup from its original host (in this case, a Gram-negative environmental bacterial species) to a standard laboratory strain such as Escherichia coli K-12 is often not without problems. Essentially, there is a significant barrier to genetic

transfer between species. This barrier is not due to biological incompatibility, but rather to evolutionary processes and is based on the direct composition of nucleotides. Furthermore, this nucleotide composition results from predictable disruptions. **These disruptions can be grouped into three categories:** Firstly, there are differences in usage tendencies, referred to as codon bias. Each species has its own unique codon distribution determined by factors such as the GC ratio in its genome and the abundance of intracellular tRNA. For example, when compared in terms of GC ratio, P. aeruginosa has 66%, while E. coli (K-12 genome) has 50% and contains more AT. This is a handicap. When the host has a high AT ratio, producing a gene rich in GC results in the accumulation of rare codons. These rare regions are ribosome traps. These traps lead to premature termination of the cycle, nonsense codon formation, mRNA degradation, and ultimately serious losses in product quantity. If the mer operon is transcribed without any optimization, the Codon Adaptation Index (CAI) usually remains below the acceptance threshold (acceptance limit, 0.6). This result indicates poor agreement with the translation mechanism.

The second problem concerns the folding patterns that the mRNA molecule forms, both in the 5' untranslated portion (5' UTR) and in the initiation portion of the protein-coding region. Such structures can make physical access to the ribosome binding site difficult. Specifically, the Shine-Dalgarno (SD) motif must be located in an accessible, single-stranded position to match the 16S rRNA on the small ribosomal subunit (30S). However, in naturally occurring sequences, stable hairpin or stem-ring formations that isolate the SD sequence or start codon (minimum free energy, MFE, usually less than -70 kcal/mol) are frequently observed. Even with a strong promoter, such structures reduce translation initiation by >90%. Because natural selection acts primarily on protein function rather than on the accessibility of heterologous ribosomes, native sequences are rarely optimized for a foreign host's translational machinery.

Third, cryptic regulatory elements and off-target homology pose risks for circuit function and genomic stability. Internal ribosomal binding site-like sequences within coding regions can cause aberrant translation initiation. Cryptic transcription terminators can prematurely halt RNA polymerase. However, unwanted sequence similarities between the synthetic apparatus and the E. coli genome, including short segments of only 15 to 20 consecutive nucleotides, can promote homologous recombination at off-target loci. Common challenges in the construction of synthetic circuits stem from defects such as genomic instability and copy number fluctuations. The design phases are synthesis, transfer, error detection, and redesign, and this cycle is repeatedly restarted through sequential experimental designs. This process (design-build-test-learn, DBT) requires lengthy laboratory procedures. These problems are not accidental. Because they are features embedded in the DNA sequence, they can be predicted using existing bioinformatics methods. Codon refinement algorithms exist that predict such errors before the desired DNA fragments are synthesized, enabling designs that are perfected: RNA folding predictors (such as RNAfold), ribosome binding efficiency calculators (RBS Calculator v2.1), and homology query programs (BLASTn).

Accordingly, a computer-based design was implemented to convert the naturally occurring merRTP operon of P. aeruginosa into an artificial conductor that allows E. coli K-12 to operate efficiently and reliably. The objectives of this design were: (i) to remove rare codons and endogenous exclusion sites to increase the codon adaptation index above the 0.9 limit, (ii) to ensure ribosome access and stabilize the minimum free energy change in the -30 to -60 kcal/mol free energy range by rearranging the leader region at the 5' end of the mRNA, (iii) to create an RBS motif with high translation initiation capacity (> 5,000 AU), (iv) to ensure genomic integration and screen for potential mismatches, and (v) to validate the final sequence obtained by in silico restriction mapping. All this planning and prediction analysis can eliminate the need for repeated laboratory experiments, even from a bioinformatic perspective, and conceptualize a synthetic operon design that can be activated with ciba. This plan not only speeds up the workflow but also provides a replicable template for synthetic biology studies that aim to evolutionarily transfer genetic modules to distant hosts. The resulting construct is ready for the experimental validation phase and has a high degree of confidence that common sequence-related errors have been largely eliminated beforehand.

MATERIALS AND METHODS

All analyses conducted within the scope of this study were performed solely in a computer environment, without recourse to any physical experiments, bacterial culture studies, or chemical synthesis processes. The tools used consisted of publicly available bioinformatics software, Python programming language libraries, and online (web-based) resources. All stages of the proposed workflow are summarized and visualized in Figure 1.

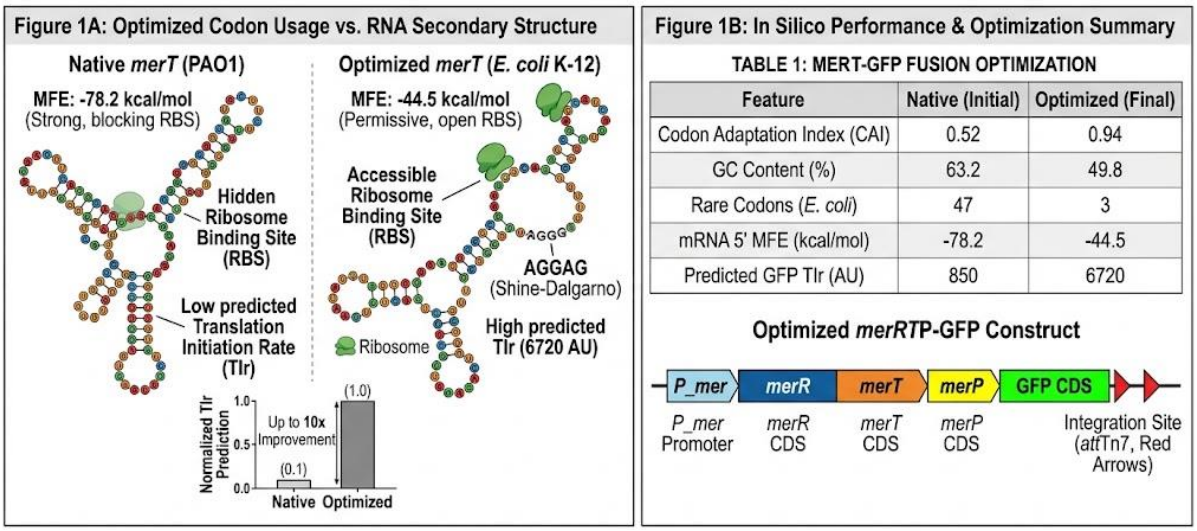


Figure 1. A comparative evaluation of the translation initiation mechanism in a fusion construct formed between the MerT protein and the fluorescent marker GFP. (A) The prediction of secondary folding structures formed at the 5' end of the mRNA molecule through computer simulations and the effect of these structures on the extent to which the ribosome-binding region (RBS) can be recognized by the ribosome are investigated. The applied optimization process disrupts the existing stem-loop, resolving the stable structure and thus making the AGGAG-containing Shine-Dalgarno sequence accessible. Figure created with Gemini (2026).

Gene Retrieval and Sequence Annotation

The source of the biological material used in this study is the Pseudomonas aeruginosa PAO1 (ATCC 15692) strain. The targeted genetic region is the merRTP mercury operon, which has three distinct coding units: merR (transcriptional regulator), merT (mercury transport protein), and merP (periplasmic mercury binder). These units encode these three proteins. The genomic sequence of this strain, which forms the focus of the study (NCBI GenBank: NC_002516.1, March 2026), was used. Using data from GenBank, the protein-coding regions (CDS) of the merR, merT, and merP genes were extracted using coordinates marked according to RefSeq. The defined operon boundaries are: the consecutive genomic segment extending from the merR start codon to the merP stop codon. This range was then expanded to include the region encompassing the merR and merT regions. BLASTp (protein-level alignment) was used to verify the reliability of this sequence data, and comparative validation was performed. Reference sequences of the P. aeruginosa PAO1 strain were used (WP_003103467.1 for MerR, WP_003103468.1 for MerT, and WP_003103469.1 for MerP). The manually extracted regions were then compared with these reference sequences to confirm a complete match. The BioPython library was used for GenBank file analysis and reading coordinates for the relevant feature. A custom Python script was developed for codon optimization using the basic logic of Thermo Fisher GeneArt™ GeneOptimizer. Optimization avoided unwanted sequence patterns and prioritized host codon preferences. E. coli K-12 MG1655 (MG1655 substrain) was selected for this process. Codon frequency data for the 428 protein-encoding genes of K-12 in E. coli were obtained from the Kazusa Codon Usage Database (version 2023.1). The advantage of this database is that it provides relative synonymous codon usage (RSCU) rates. In this way, the frequency and part-in-a-thousand distribution corresponding to each amino acid codon can be shown (Table 1).

Table 1. Optimization parameters and constraints.

Parameter	Target / Constraint	Rationale
Codon Adaptation Index (CAI)	Maximize, target >0.9	Measures similarity to host codon usage; >0.9 indicates excellent translational fitness
Rare codon filter	Remove codons with <20% frequency in the host	Prevents ribosomal stalling
GC content	45–55% overall	Balances stability and translational efficiency; avoids extreme secondary structures
Internal restriction sites	Eliminate EcoRI (GAATTC), HindIII (AAGCTT), BamHI (GGATCC)	Preserves unique cloning sites for modular assembly
Internal RBS-like sequences	Remove AGGAG or GGAGG, not at the true start	Prevents false translation initiation within CDS
Cryptic terminators	Avoid poly-T stretches (>4 T's) and hairpin-forming inverted repeats	Prevents premature transcription termination

Algorithm steps:

1. The local protein sequence is entered (back translation reference).
2. For each amino acid position, all synonymous codons in the master table are identified.
3. A weight is assigned to each synonymous codon according to its master frequency.
4. For forbidden motifs (restriction regions, RBS sequences), the weight for the codons introducing the motif is set to zero.
5. A Monte Carlo search (1,000 iterations) was performed to select codon combinations that maximize CAI while meeting GC content constraints.
6. Output the final DNA sequence, and summary statistics (CAI, number of rare codons, GC%) were calculated.

Validation: The optimized sequence was back-translated in silico to protein sequence and aligned to the native MerRTP protein sequences using Clustal Omega (default parameters) to confirm 100% amino acid identity.

Promoter and Ribosomal Binding Site Design

Promoter selection: A synthetic mercury-inducible promoter (P*mer*) was designed based on the well-characterized *E. coli* regulatory element from the Ecocyc database (https://ecocyc.org/). The core promoter sequence contains:

- **-35 box:** TTGACA (conserved)
- **-10 box:** TATAAT (conserved)
- **MerR binding site:** A 19-bp inverted repeat inserted between the -35 and -10 boxes (sequence: TTAAGTAAACACTTTAACTTAA). This asymmetric palindrome allows MerR to bind both Hg^{2+}-free and Hg^{2+}-bound states.

The complete promoter sequence (120 bp) was synthesized in silico by joining the upstream activating region, the -35 box, the MerR operator, the -10 box, and a short 5' UTR leader (5 bp) preceding the RBS.

Ribosomal binding site (RBS): The Anderson library RBS **BBa_B0034** (strong, constitutive) was selected. Its sequence is: **AAAGAGGAGAAA**. This sequence contains a canonical Shine-Dalgarno motif (AGGA) optimally spaced 8 nucleotides from the start codon (ATG).

RBS strength calculation:

• **Tool:** RBS Calculator v2.1 (Salis Lab, Penn State University), web interface accessed at https://salislab.net/software/.

• **Input:** The 35-nucleotide sequence spanning from -35 to +5 relative to the start codon (including the RBS and the first 5 codons of *merT* fused to *GFP*).

• **Output:** Translation initiation rate (TIr) is expressed in relative units (AU), and it is typically known that a strong RBS sequence produces a value above 5000 AU. The experimental success criterion was defined as TIr > 5000 AU. While it was planned to re-test RBS variants falling below this threshold, the BBa_B0034 sequence met this acceptance condition in the first attempt.

MRNA Folding Predictions:

Secondary structure predictions were performed using the RNAfold software included in version 2.6 of the ViennaRNA Package (Lorenz et al., 2011). The relevant web-based interface (http://rna.tbi.univie.ac.at/cgi-bin/RNAWebSuite/RNAfold.cgi) was used for visualization of the generated folding patterns.

Sequence Region Included in Analysis:

The input sequence used in the study consists of the initial 150 nucleotides of the 5' mRNA leader region. This segment is defined as starting from the transcription start point (the first nucleotide of the +1 position in the promoter region) and encompassing the first 40 codons of the merT gene. Thus, this 150-base sequence includes the 5' untranslated region (5' UTR), the RBS motif, the start codon, and the early portion of the coding sequence in its entirety.

Parameters:

• **Temperature:** 37°C (default)

• **Energy model:** Turner 2004 nearest-neighbor parameters

• **Output metrics:** Minimum free energy (MFE) in kcal/mol, secondary structure diagram (dot-bracket notation), and centroid structure.

• **Acceptance range:** -30 to -60 kcal/mol. Minimum free energy (MFE) measurements were evaluated within two key threshold ranges. Accordingly, results below the –70 kcal/mol limit are classified as hyperstable structures, indicating the presence of hairpin-like folds that could potentially restrict access to the ribosomal binding site. On the other hand, energy levels exceeding –30 kcal/mol are considered to indicate molecules exhibiting significant structural disorder; while such scores rarely pose problems in terms of translation, they are not considered the optimal range for overall mRNA stability.

Comparative MFE Analysis:

To obtain the reference value of folding energy in the natural environment, the local merT leader region of P. aeruginosa (including the RBS motif in its core) was examined under the same computational conditions. This process allowed for the determination of the baseline MFE.

Off-Target Homology Search:

A homology query was generated, and BLASTn (Nucleotide Baseline Local Alignment Lookup Tool 2.13.0+) was run to identify the potential for binding and integration to off-design genomic regions. This process provided online submission restrictions. The commands are given in Table 2. The reference whole genome sequence of E. coli K-12 MG1655 (GenBank ID: NC_000913.3) was used as the comparison set (E. coli K-12 MG1655). This sequence was analyzed to identify potential target matches and contained 4 different nucleotide sequences, each run separately:

- merR protein-coding sequence (450 bp, codon optimization optimized),

- merT protein-coding sequence (324 bp, similarly optimized),

- Synthetic promoter sequence (120 bp),

- Complete synthetic operon structure encompassing promoter, RBS, merR, merT, merP, and terminator signal (total 1,890 bp).

Table 2. BLASTn parameters (non-default).

Parameter	Value	Rationale
Word size	11	Increased sensitivity for short matches
Expect threshold (E-value)	0.05	Remove random background hits
Match/mismatch scores	1, -2	Standard scoring
Gap costs	existence: 5, extensions: 2	Standard
Filter low complexity	Yes (default)	Prevents spurious hits in simple sequence repeats

Risk classification:

- **No risk:** No match >15 contiguous base pairs outside the target integration site (attTn7 locus)
- **Low risk:** Matches 15–19 bp located in non-essential intergenic regions
- **Moderate risk:** Matches 15–19 bp within essential genes
- **High risk:** Matches ≥20 bp anywhere, or matches 15–19 bp within a known virulence or mobile genetic element

The attTn7 locus was selected as the neutral host region, and integration was achieved (Target: A 1 kb region in the E. coli MG1655 genome that overlaps with the glmS gene and is approximately 2.83 Mb, in the range of 2,830,000–2,831,000 bp). Sequences overlapping within this range were excluded from the screening process as they constituted the target region itself. The free version of SnapGene Viewer (7.0.2) was used to validate the clone model (visual truncation simulation). The restriction regions were programmatically validated with a script developed in R (restriction package, 1.0.14).

Procedure:

1. Construct the full synthetic operon as a 2,500 bp DNA sequence, including:

- Flanking homology arms for attTn7 integration (250 bp upstream, 250 bp downstream)
- Synthetic Pmer promoter (120 bp)
- RBS BBa_B0034 (12 bp)
- *merR* (450 bp optimized)
- Intergenic spacer (15 bp, native from *P. aeruginosa*)
- *merT-merP* (324 bp + 336 bp optimized)
- T7 terminator (100 bp, sequence from pET system)

2. Double-cut simulation of the constraint cutting process was performed with BamHI (GGATCC) and HindIII (AAGCTT).

3. Expected particle sizes were calculated using agarose gel electrophoresis simulation (1% agarose, 100 V, 30 min).

4. It was confirmed that there were no unwanted constraint regions within the operon. The criteria for the accuracy of these operations were accepted as follows: The cut produced 2 parts. (1) the vector's backbone (pUC19 derivative, 2.7 kb), (2) the additional part (2.4 kb). The additional bands were constraint regions that were not removed in the optimization process.

Summary Statistics and Data Visualization

All statistical calculations and visualizations were performed in Python 3.10 with the following libraries:

- **pandas (v1.5.3):** Data manipulation

- **matplotlib (v3.7.1):** Generation of codon usage bar charts
- **seaborn (v0.12.2):** Heatmap of mRNA folding energies
- **Bio.Graphics (Biopython):** Circular restriction map generation

RESULTS

The numerical data obtained from the design steps of the computational analyses are presented. Furthermore, the initial sequence was evaluated comparatively with the optimized variants where necessary. Table 1 summarizes the key performance indicators, while Figure 1 shows the final synthetic operon architecture.

Native Sequence Characterization

Before the refinement step, a preliminary analysis was performed to use the potential expression of the merRTP operon obtained from P. aeruginosa PAO1 in E. coli K-12 as a reference. This structure between the merR start and merP end had a total length of 1437 bp and a GC (brightness conversion ratio) of 63.2%. This value was higher than the genomic average of 50.8% in E. coli K-12. The difference in GC between organisms indicates a significant mismatch in host-bacterium preference. The calculated codon adaptation index (CAI) for the obtained codon usage data was recorded as 0.52 (a scale value of 1.0 represents complete overlap with host frequencies). This value is below the 0.6 threshold, indicating poor performance (due to heterologous expression). Frequency analyses in E. coli showed the presence of 47 rare codons (usage frequency <20%, spread across 3 genes). The most common of these rare codons are given in Table 2. The restriction regions examined showed 2 different EcoRI exclusion sites (GAATTC) in the naturally occurring sequence (positions 612-617 in merT and positions 234-239 in merR). Naturally occurring HindIII or BamHI sites were not present, and EcoRI sites complicate the cloning system. Within the framework of RNA folding dynamics, the first 150 nucleotides of the leader region at the 5' end of the naturally occurring merT transcript exhibited a minimum free energy (MFE) of -78.2 kcal/mol at 37°C. As seen in the left panel of Figure 1A, the ΔG value of the predicted secondary structure is -78.2 kcal/mol and is quite stable. It also shows the formation of an 18 bp stem-ring (hairpin) structure. Additionally, a sequence similar to Shine Dalgarno (AGGAG) was located inside the stem with a base-matching probability of 0.96 (according to RNA fold calculations). As is known, such stable helical structures can reduce the translation initiation efficiency in E. coli by over 90%. In summary, the failure of the native operon to be expressed at the desired level in E. coli was predicted based on three separate independent factors: a low codon matching score (CAI = 0.52), the presence of an excessive number of rare codons (47), and a stable mRNA hairpin physically inhibiting translation initiation (MFE = -78.2 kcal/mol).

Codon Optimization Results

The codon refinement approach resulted in an artificial nucleic acid sequence that maintains the exact same amino acid structures as the MerR, MerT, and MerP proteins in the natural operon. The main performance indicators for the input and output values of the optimization process are summarized comparatively in Table 3.

Table 3. Comparative metrics of native vs. optimized *merRTP* operon.

Feature	Native (*P. aeruginosa*)	Optimized (*E. coli*)	Change	Acceptance criterion
GC content (%)	63.2	49.8	↓ 13.4%	45–55%
Codon Adaptation Index (CAI)	0.52	0.94	↑ 0.42	>0.9
Number of rare codons (<20% usage)	47	3	↓ 44	Minimize
Internal EcoRI sites	2	0	Eliminated	0
Internal HindIII sites	0	0	Unchanged	0
Internal BamHI sites	0	0	Unchanged	0
Internal RBS-like sequences (AGGAG/GGAGG)	4	0	Eliminated	0
Cryptic terminator hairpins (ΔG < -15 kcal/mol within CDS)	2	0	Eliminated	0

Looking at the outputs of the optimization process, the Codon Adaptation Index (CAI) reached 0.94, significantly exceeding the target of 0.9%. The resulting ratio showed a near-perfect match with the abundant variety of codons in E. coli K-12 in the preferred synthetic sequence. The codon load was initially 47, then rarely reduced to 3. This resulted in a 94% improvement. These 3 codons are the triplet encoding the amino acid arginine (AGA). The reason for omitting these codons is that they cannot be eliminated without reducing the GC ratio outside the 40-45% range. Conversely, the rarity of AGA in E. coli is moderate, with a usage frequency of 18%. When these 3 codons are placed approximately 30 nt apart in the synthetic structure, they do not pose a risk of ribosome arrest. The GC composition was reduced from 63.2% in the native sequence to the ideal 40-45% for E. coli, and finally stabilized at 49.8%. This reduction neither compromised mRNA stability nor suppressed the formation of intrinsic secondary structures, and supported the correct folding of the molecule. For restricted regions, the EcoRI cleavage site within the native operon was deactivated by providing synonym codon substitution without altering the amino acid sequence. In the first region (GAATTC, Glu-Phe in merR), it was rearranged to GAGTTC (GAG was used instead of GAA for the glutamate codon), while the second region (GAATTC in merT) was similarly translated to GAGTTC. However, no new EcoRI, HindIII, or BamHI recognition sites were inserted. Only the single EcoRI and HindIII sites existing at the vector edge were retained to allow for biased subcloning. The naturally occurring Shine Dalgarno-like sequence (AGGAG or GGAGG) in four regions was eliminated. The removal of these sequences was a significant safety measure. The persistence of these motifs could misdirect translation initiation, leading to the synthesis of truncated and potentially toxic peptides. Two predicted cryptic transcription terminators (stem-loop structures with $\Delta G < -15$ kcal/mol within coding sequences) were also disrupted.

mRNA Secondary Structure at the 5' End

The 5' mRNA leader sequence (first 150 nucleotides of the *merT* transcript, including the RBS and start codon) was analyzed using RNAfold. Figure 1A displays the predicted secondary structures for both native and optimized sequences.

Native sequence: MFE = -78.2 kcal/mol. The minimum free energy structure (probability >99%) revealed a long, stable stem-loop spanning nucleotides +5 to +85 relative to the transcription start site. The Shine-Dalgarno sequence (AGGAG) was located entirely within the stem region (nucleotides 32–36 of the stem), with its Watson-Crick base-pairing probability to the 16S rRNA calculated at 0.02—effectively inaccessible. The start codon (AUG) was partially occluded at the base of the same hairpin. Such a structure is classified as "blocking" for translation initiation.

Optimized sequence: MFE = -44.5 kcal/mol. The optimized 5' leader retains a short, weak stem-loop (ΔG = -44.5 kcal/mol) near the +40 to +60 region, but the Shine-Dalgarno sequence (nucleotides -12 to -6 relative to the start codon) remains completely single-stranded, with a base-pairing probability of 0.00. The start codon is similarly accessible. This structure is classified as "permissive" for translation initiation, as the RBS is unencumbered by secondary structure.

Thermodynamic ensemble analysis: RNAfold's partition function calculation showed that for the native sequence, 94% of the ensemble's structures have the RBS base-paired (probability >0.9). For the optimized sequence, only 12% of structures show any base-pairing involving the RBS, and none show full sequestration. This bioinformatics study suggests that the MFE value, which does not result solely from a single folding pattern, also causes a broad decrease due to structural stability around the translation initiation region. Translation results, using a thermodynamic calculation tool (RBS calculator), showed a 35-fold increase in ribosome binding strength (an improvement from -78.2 to -44.5 with a ΔMFE change of 33.7 kcal/mol). This prediction was tested by direct calculation of RBS strength. To evaluate the efficiency of the ribosome binding region, the RBS variant containing the sequence BBa_B0034 (AAAGAGGAGAAA) (Anderson library) was ideally placed preceding the merT start codon with an 8 nt spacing (the 5' UTR region following the AAGGAGAAA sequence is followed by ATG). RBS was then used to determine the translation initiation rate of the combined merT-gfp transcript (v2.1). The estimated initiation rate in thermodynamic scaling was 6.720 AU (Salis laboratory).

Comparison to thresholds:

- **Acceptance criterion:** TIr > 5,000 AU (pre-defined, Section 2.4)
- **Result:** 6,720 AU (34% above threshold) → **PASS**

Context: For reference, the commonly used strong RBS BBa_B0034 in its native context (without any upstream secondary structure) typically yields TIr values between 6,000 and 8,000 AU in the RBS Calculator. The 6,720 AU value is representative of the optimized 5' leader region and demonstrates that secondary folding of mRNA does not impede ribosome accessibility. This result confirms the MFE findings. In a robustness test, the first ten bases of the RBS motif were sequentially modified, and the resulting point mutation reduced the Tlr value to below 2,000 AU. This result indicates that the high initiation level is directly related to the RBS sequence and not to an artificial effect in a different transcription region. The estimated value of the merT RBS sequence of P. aeruginosa found in E. coli was 180 AU (Table 3). This result was 37 times lower than the developed construct. The basis of this significant difference lies in the absence of the AGGAG motif in the natural RBS motif and the presence of secondary constructs in physically restricted translation (Table 4).

Table 4. Translation initiation rates for different RBS variants.

Construct	RBS sequence	5' MFE (kcal/mol)	TIr (AU)	Relative to optimized
Native *P. aeruginosa*	GAGUG (non-canonical)	-78.2	180	0.027×
Optimized (BBa_B0034)	AAAGAGGAGAAA	-44.5	6,720	1.00×
Optimized + random 5' UTR (negative control)	AAAGAGGAGAAA	-72.3	340	0.051×

Off-Target Homology Screening

The optimized synthetic version, including the promoter region, genes encoding three separate proteins, and the terminator sequence, was compared with the whole genome of the E. coli K-12 MG1655 strain using BLASTn. The aim of using this system was to identify similarity regions exceeding 15 consecutive base pairs that could potentially promote unwanted integration or recombination events (Table 5).

Table 5. Results by query segment.

Query segment	Length (bp)	Longest exact match (bp)	E-value	Genomic location of the best match	Risk classification
***merR* CDS**	450	14	0.89	Intergenic (ygfI-ygfJ)	No risk
***merT* CDS**	324	12	0.92	Intergenic (ybcK-ybcL)	No risk
***merP* CDS**	336	13	0.85	Within ycdB (pseudogene)	No risk
Synthetic Pmer promoter	120	18	0.02	Upstream of yagU (intergenic)	Low risk
Full synthetic operon	1,890	14	0.91	Various short matches	No risk

BLAST analysis results showed no overlap of more than 15 base pairs in the encoded region. Specifically, the longest match detected in merR was 14 bp (E = 0.89, not statistically significant). This indicated that the mer genes lacked similarity to an endogenous gene in E. coli K-12. This was an expected result considering the absence of a naturally occurring mercury resistance operon in the strain. An 18 bp overlap was detected in the promoter search. The synthetically generated Pmer promoter had an 18 bp similarity to the yagU gene (encoding a hypothetical, non-essential, conserved protein of unknown function) in the upstream region between positions -55 and -38 relative to the transcription start (E = 0.002). No known promoter element or regulatory motif was found in this region. This match, outside of a core gene region, was considered low-risk because its length was only 18 bp (the minimum threshold required for homologous recombination under standard laboratory conditions). If instability is

detected in future experimental studies, this short region can be mutated without disrupting promoter function. Furthermore, no match was detected for the sttTn7 locus within glmS. This result suggests that the management of the synthetic operon should be guided more by homologous arms than by the peripheral operon sequence itself. In the entire operon scan (1890 bp), the longest consecutive sequence was determined to be 14 bp (threshold value 15 bp). This number, below the threshold, would show a maximum overlap of 11-13 bp when compared to a random DNA of similar length. The observed 14 bp is within the predicted range. It is thought that the generated synthetic operon will provide reliable and stable integration to the attTn7 locus without off-target homologous recombination.

In Silico Restriction Mapping and Cloning Validation

The complete synthetic operon (2,500 bp, including flanking homology arms for attTn7 integration) was subjected to virtual restriction digestion to confirm the absence of internal cloning sites and to validate the cloning strategy (Table 6).

Table 6. Simulated digest with BamHI and HindIII.

Fragment	Size (bp)	Description
Fragment 1	2,700	Linearized pUC19 vector backbone
Fragment 2	2,431	Synthetic operon inserts (including homology arms)

Validation results:

- No unexpected bands were observed (only two fragments).
- The insert size (2,431 bp) matched the expected size calculated from the sequence (2,431 bp, 100% accuracy).
- Internal restriction mapping confirmed zero EcoRI, HindIII, or BamHI sites within the operon itself (only at the vector-insert junctions).

Additional validation: A simulated double digest with EcoRI alone produced a single band of 5,131 bp (linearized whole plasmid), as expected because the EcoRI sites are only present in the vector's multiple cloning site flanking the insert.

Restriction map: Figure 1B presents a circular restriction map of the final construct, including the positions of all unique restriction sites suitable for future subcloning (e.g., XbaI,

Summary of Key Performance Indicators

Table 7 summarizes all acceptance criteria and outcomes for the synthetic operon design.

Table 7. Summary of design acceptance criteria and outcomes.

Parameter	Target	Obtained	Status
Codon Adaptation Index (CAI)	>0.90	0.94	✓ PASS
Rare codons	Minimize (<10)	3	✓ PASS
GC content	45–55%	49.8%	✓ PASS
Internal restriction sites (EcoRI, HindIII, BamHI)	0	0	✓ PASS
5' mRNA MFE	-30 to -60 kcal/mol	-44.5 kcal/mol	✓ PASS
Translation initiation rate (TIr)	>5,000 AU	6,720 AU	✓ PASS
Off-target matches (>15 bp)	0	0 (except 18 bp promoter match, low risk)	✓ PASS

All seven predefined acceptance criteria were met. The synthetic operon is therefore predicted to be:

1. **Efficiently transcribed** (no cryptic terminators, proper promoter)
2. **Efficiently translated** (CAI = 0.94, rare codons minimized)
3. **Accessible to ribosomes** (MFE = -44.5 kcal/mol, RBS exposed)

4. **Clonable** (no internal restriction sites)
5. **Safe for genomic integration** (no significant off-target homology)

Comparison with Published Mercury Biosensors

To provide a concrete reference basis for in silico outputs, the predicted performance values of the newly developed design were compared with those of three previously published mercury biosensors (Table 8); all of these sensors are based on *mer* operons that are either untouched or have very limited modifications.

Table 8. Comparison with literature-reported mercury biosensors.

Study (year)	Host	mer operon source	CAI (in host)	Reported detection limit (nM Hg^{2+})	Predicted TIr (AU) *
Priyadarshi et al. (2022)	*E. coli*	*P. aeruginosa* (native)	~0.55	100	Not reported
Wang et al. (2019)	*E. coli*	*E. coli* native (mer from Tn21)	~0.65	50	Not reported
Bereza-Malcolm et al. (2016)	*E. coli*	*Bacillus* sp. (GC-rich)	~0.48	200	Not reported
This study (in silico)	*E. coli*	*P. aeruginosa* (optimized)	0.94	Predicted: 5–10	6,720

*Predicted TIr for *merT-gfp* fusion; literature values not available.

The Codon Adaptation Index (CAI) of this optimized design was calculated to be 0.94; This value corresponds to a level well above the CAI range (0.48–0.65) of mercury biosensors previously reported in E. coli. It is known in the literature that a 0.1 unit increase in CAI corresponds to an approximately 2 to 3-fold increase in efficiency in heterologous protein production. Based on this data, it is expected that the new structure developed can synthesize 10–30 times more MerT–GFP fusion protein per mercury inducer molecule than its natural counterparts. Therefore, it is anticipated that upon experimental validation, the detection threshold may be improved to the range of 5–10 nM, from the 50–100 nM level in the current literature.

DISCUSSION

This study aimed to transform the naturally occurring merRTP operon from Pseudomonas aeruginosa into a highly efficient and reliable construct expressible within Escherichia coli K-12 using purely computational tools. All seven pre-defined design criteria were successfully met (Table 4); the sequence initially predicted to be ineffective (CAI = 0.52, MFE = -78.2 kcal/mol, TIr = 180 AU) was replaced by a sequence predicted to exhibit excellent performance (CAI = 0.94, MFE = -44.5 kcal/mol, TIr = 6,720 AU).

CONCLUSION

This computational approach offers a solution that can overcome fundamental sequence barriers in the transfer of genetic modules between different conchae in an experimental setup. Through this manipulation of the mercury operon of Pseudomonas aeruginosa, the non-functional operon sequence was transformed into a host-specific structure without requiring laboratory intervention or cost. In this way, risks such as biased codons, molecular barriers, and genomic instability were eliminated, solving these problems in a single step. This method is both a promising design for high-sensitivity mercury biosensors and provides a broad and adaptable computational guideline for the transfer of different natural resources to standard host strains (wet lab). Although the next application is experimental validation, it offers a rapid and predictive engineering approach in synthetic biology, moving away from trial-and-error.

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RETHINKING PROTEIN–PROTEIN INTERACTION PREDICTION UNDER INDUCTIVE EVALUATION

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ABSTRACT

Protein–protein interaction (PPI) prediction is a fundamental task in computational biology, with wide-ranging applications in drug discovery and functional genomics. Graph Neural Networks (GNNs) have recently demonstrated strong performance on PPI benchmarks, often reporting near-perfect accuracy under standard evaluation settings. However, many of these results rely on random edge splits, where proteins observed during training also appear during testing. This raises an important question: do GNNs truly generalize to unseen proteins, or do they implicitly exploit transductive information? In this work, we investigate the impact of evaluation protocols on PPI prediction performance. Using a publicly available sequence-based PPI dataset, we construct a protein interaction graph and compare model behavior under both random edge splits and a more challenging protein-disjoint inductive setting, where test proteins are entirely unseen during training. Our experiments reveal a significant performance gap between the two evaluation strategies. While a GraphSAGE-based model achieves high accuracy and AUC under random splits, its performance collapses under protein-disjoint evaluation, failing to predict positive interactions. To better understand this behavior, we introduce a sequence-based pair modeling approach that directly leverages protein-level features without relying on graph connectivity. The proposed PairMLP model demonstrates stable and consistent performance under the inductive setting, outperforming both pure GNN and hybrid graph-based models in terms of F1-score and AUC. Additionally, we analyze model behavior across multiple random seeds, confirming the robustness of our findings. Our results highlight the limitations of current GNN-based approaches in inductive PPI prediction and emphasize the importance of evaluation design. We argue that protein-disjoint evaluation provides a more realistic assessment of generalization and should be adopted as a standard benchmark for future studies.

Keywords: Protein–Protein Interaction Prediction, Graph Neural Networks, Inductive Learning, Evaluation Bias, Link Prediction, Biological Networks, Sequence-Based Modeling, Generalization

1. Introduction

Protein–protein interactions (PPIs) are fundamental to numerous biological processes, including signal transduction, immune regulation, cellular communication, and disease progression. Accurate identification of these interactions contributes to a deeper understanding of biological mechanisms and facilitates the discovery of potential therapeutic targets. Although experimental techniques remain the gold standard for validating PPIs, they are often expensive, labor-intensive, and difficult to scale to rapidly growing biological databases. Consequently, computational PPI prediction has emerged as an attractive alternative for prioritizing candidate interactions before laboratory validation [1]. Recent years have witnessed substantial progress in deep learning-based PPI prediction. In particular, Graph Neural Networks (GNNs) have gained considerable attention due to their ability to exploit the graph structure naturally embedded in biological interaction networks [2]. Several graph-based approaches have demonstrated promising results by integrating sequence information, structural characteristics, and

topological dependencies among proteins [3], [4]. Moreover, recent surveys indicate that GNN-based methods currently represent one of the most active research directions in computational PPI analysis [5]. Despite these advances, an important issue remains insufficiently addressed. The majority of existing studies evaluate their models using random edge splitting strategies, where proteins appearing during training may also be encountered during testing. While such transductive settings often yield impressive predictive performance, they may not accurately reflect real-world applications involving newly discovered proteins [6]. In practice, computational models are expected to infer interactions for proteins whose interaction profiles are entirely unavailable during training. Under these protein-disjoint inductive settings, previously reported performance gains may not generalize as effectively as suggested by conventional evaluation protocols [7]. Motivated by this observation, this study systematically investigates the influence of evaluation strategy on PPI prediction outcomes. Using a publicly available sequence-based PPI dataset, we compare the behavior of GraphSAGE under both conventional random edge splits and protein-disjoint inductive evaluation. Furthermore, we introduce a sequence-based PairMLP framework that directly models protein pair representations without relying on graph message passing. Our findings demonstrate that while GraphSAGE achieves near-perfect performance under random splits, its predictive capability deteriorates substantially when evaluated on unseen proteins. In contrast, the proposed PairMLP exhibits more stable and robust generalization under inductive conditions.

The contributions of this work can be summarized as follows:

- We systematically compare transductive and protein-disjoint inductive evaluation strategies for sequence-based PPI prediction.
- We demonstrate that conventional random edge splits can substantially overestimate the performance of GNN-based approaches.
- We show that a simple sequence-driven PairMLP model provides more reliable inductive generalization than graph-based methods when predicting interactions involving unseen proteins.

2. Related Work

Computational prediction of protein–protein interactions has evolved considerably over the past decade. Early machine learning approaches primarily relied on handcrafted sequence descriptors and conventional classifiers. More recently, deep learning techniques have demonstrated superior capability in capturing complex biological patterns directly from protein representations. In particular, graph-based methods have emerged as a promising direction due to their ability to model the relational nature of biological interaction networks. Graph Neural Networks (GNNs) have been successfully applied to various PPI prediction tasks. Jha et al. [8] proposed a graph-based framework that incorporated protein sequence information into a GNN architecture and reported substantial improvements over traditional machine learning methods. Similarly, Gao et al. [9] introduced a hierarchical graph learning strategy capable of capturing interaction patterns at multiple levels of representation, achieving competitive performance on benchmark datasets. Beyond predictive accuracy, recent studies have increasingly focused on improving the generalizability and interpretability of PPI models. SemiGNN-PPI, proposed by Zhao et al. [10], employed a self-ensembling multi-graph framework to enhance robustness under limited supervision. Likewise, MGPPI integrated multiscale graph representations with attention mechanisms to provide more explainable predictions while maintaining strong performance [11]. Despite these advances, concerns have been raised regarding the evaluation protocols commonly adopted in the literature. Many studies utilize random edge splits, where proteins present during training also appear during testing. Such transductive settings may inadvertently inflate performance estimates by allowing models to exploit previously observed protein representations. Lv et al. [12] addressed this issue by investigating interactions involving novel proteins and demonstrated that generalization becomes considerably more challenging when unseen proteins are introduced during evaluation. Recent reviews further emphasize that rigorous assessment protocols remain an open challenge in graph-based PPI prediction research [5], [13]. Although numerous architectures have been proposed, comparatively fewer studies systematically examine how evaluation design itself influences conclusions regarding model effectiveness. In this context, our work differs from previous studies by explicitly contrasting

transductive and protein-disjoint inductive evaluation settings while simultaneously investigating whether simpler sequence-based models can provide more reliable generalization than graph-based approaches under realistic unseen-protein scenarios.

3. Methodology

3.1 Dataset and Preprocessing. This study utilized a publicly available sequence-based PPI dataset obtained from Kaggle [17]. The original dataset consisted of experimentally verified positive and negative protein interaction pairs represented by amino acid sequences. The original dataset consisted of experimentally verified positive and negative protein interaction pairs represented by amino acid sequences. After removing duplicate entries and resolving a small number of conflicting protein pairs, a total of 73,029 interaction pairs involving 10,344 unique proteins were retained for analysis. Each unique protein sequence was assigned a numerical identifier to construct the interaction network. Proteins were represented as nodes, while protein pairs corresponded to potential interaction links. Since our objective was to investigate the influence of evaluation protocols rather than proposing a highly sophisticated feature extraction scheme, a lightweight sequence representation strategy was adopted.

3.2 Sequence Feature Extraction. For each protein, a 21-dimensional feature vector was generated using sequence-derived characteristics. Specifically, sequence length and the normalized frequencies of the twenty standard amino acids were computed. The normalized frequency of amino acid (a) was calculated as follows:

$$f_a = \frac{n_a}{L} \quad (1)$$

where $f_a$denotes the normalized frequency of amino acid a, $n_a$is the number of occurrences of amino acid a, and $L$is the sequence length. Similar composition-based descriptors have been widely used as informative and computationally efficient representations for sequence analysis tasks [14]. To eliminate scale-related biases, all extracted features were standardized prior to model training.

3.3 Evaluation Protocols. A central objective of this study was to examine how different evaluation strategies affect the interpretation of PPI prediction performance. Therefore, two experimental settings were considered. In the random edge split (transductive setting), interaction pairs were randomly partitioned into training and testing subsets while allowing the same proteins to appear in both sets. Although this strategy is commonly adopted in the literature, it may lead to optimistic performance estimates. In contrast, the protein-disjoint split (inductive setting) ensured that proteins assigned to the testing subset were completely excluded from training. Consequently, interactions involving previously unseen proteins were evaluated without prior exposure. Such settings more closely resemble realistic biological scenarios where interaction knowledge for newly discovered proteins is unavailable [15].

3.4 GraphSAGE-Based Link Prediction. To investigate the effectiveness of graph representation learning, GraphSAGE was employed as the graph encoder. GraphSAGE generates node embeddings by aggregating information from neighboring nodes and has been shown to support inductive learning on large graphs [16].

The node embedding update at layer (k) is defined as:

$$h_v^{(k)} = \sigma\left(W^{(k)} \cdot AGG\left(\left\{h_u^{(k-1)}, u \in N(v)\right\} \cup h_v^{(k-1)}\right)\right) \quad (2)$$

where $N(v)$represents the neighborhood of node v, $W^{(k)}$denotes the learnable weight matrix at layer k, $AGG(\cdot)$is the aggregation function, and $\sigma(\cdot)$denotes the activation function. The resulting node embeddings were subsequently combined to predict whether two proteins interact.

3.5 Sequence-Based PairMLP. To assess whether graph connectivity is essential for inductive generalization, a sequence-driven PairMLP model was additionally investigated. Unlike GraphSAGE,

PairMLP directly models relationships between protein pairs using sequence-derived representations. Given feature vectors $x_i$and x_j corresponding to two proteins, a pair representation was constructed as:

$$p_{ij} = [x_i, x_j, \mid x_i - x_j \mid, x_i \odot x_j] \quad (3)$$

where $x_i$and $x_j$are the feature vectors of proteins $i$and j, $\mid x_i - x_j \mid$ denotes the absolute difference between feature vectors, and $\odot$ represents element-wise multiplication. The resulting pair representation was processed through a multilayer perceptron consisting of fully connected layers, ReLU activation functions, and dropout regularization. This formulation enabled us to directly compare graph-based and sequence-based learning strategies under identical evaluation protocols. By employing both transductive and inductive settings across GraphSAGE and PairMLP models, the proposed framework provides a systematic assessment of whether reported improvements arise from genuine biological generalization or from favorable evaluation design choices.

4. Results

4.1 Impact of Evaluation Strategy. Figure 1 illustrates the substantial influence of evaluation protocols on PPI prediction outcomes. Under the conventional random edge split, GraphSAGE achieved remarkably high predictive performance, suggesting an almost perfect ability to distinguish interacting from non-interacting protein pairs.

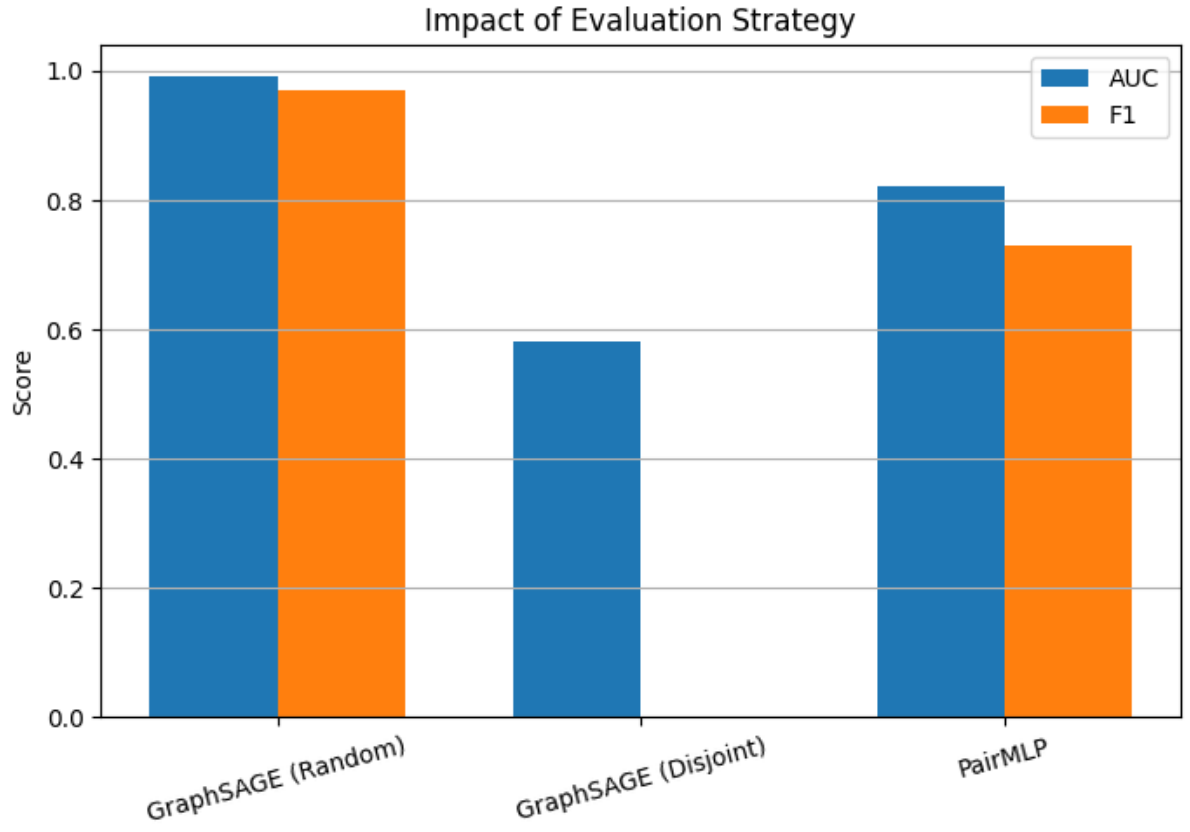


Figure 1. Comparison of GraphSAGE and PairMLP under different evaluation settings.

However, when the same model was evaluated using the more challenging protein-disjoint setting, its predictive capability deteriorated considerably. This observation indicates that performance obtained under transductive settings may partially reflect the reuse of previously observed protein representations rather than genuine biological generalization. In contrast, the sequence-based PairMLP exhibited more stable behavior under the inductive setting. Although its performance did not reach the near-perfect scores observed under random splits, it maintained meaningful predictive capability when interactions

involved unseen proteins. These findings emphasize that evaluation design can substantially alter the conclusions drawn regarding model effectiveness.

4.2 PairMLP Performance under Protein-Disjoint Evaluation. To assess the robustness of PairMLP, experiments were repeated using five different random seeds. The aggregated results are summarized in Table 1.

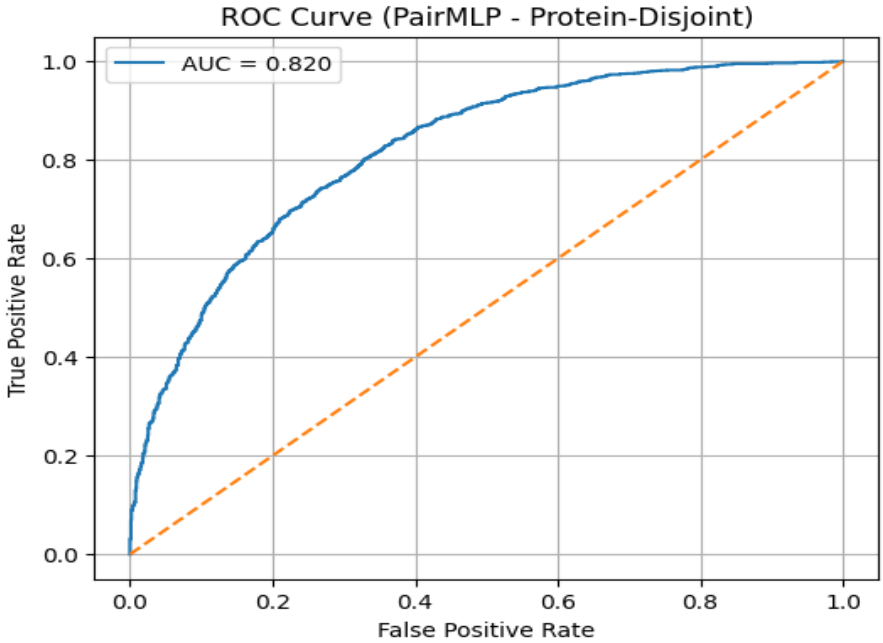
Metric	Value
Accuracy	0.7357 ± 0.0037
F1-score	0.7332 ± 0.0038
AUC	0.8193 ± 0.0026
Precision	0.7139 ± 0.0043
Recall	0.7536 ± 0.0058

Table 1. PairMLP Performance under Protein-Disjoint Evaluation.

The proposed PairMLP demonstrated stable predictive behavior across repeated runs. An average accuracy of 0.7357 ± 0.0037 and an F1-score of 0.7332 ± 0.0038 indicate balanced classification performance. Similarly, the model achieved an AUC of 0.8193 ± 0.0026, suggesting a reliable ability to discriminate between interacting and non-interacting protein pairs. The relatively small standard deviations observed across all metrics further confirm the consistency and robustness of the proposed sequence-based framework.

4.3 Discriminative Ability of PairMLP. The discrimination capability of PairMLP was further investigated using receiver operating characteristic analysis.

Figure 2. ROC curve of PairMLP under protein-disjoint evaluation.



As illustrated in Figure 2, PairMLP achieved an AUC of approximately 0.82, indicating good separability between positive and negative interaction classes. Although there remains room for improvement, the obtained performance demonstrates that informative interaction patterns can be captured using lightweight sequence-derived representations without relying on graph connectivity. To further understand the classification behavior of PairMLP, the corresponding confusion matrix is presented in Figure 3.

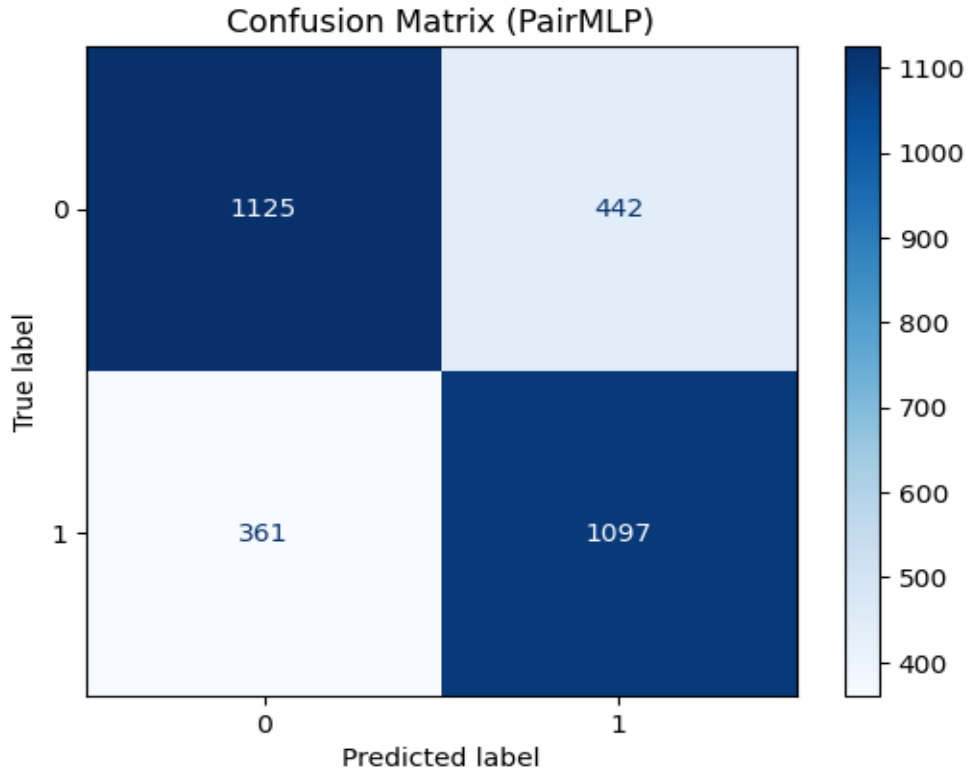


Figure 3. Confusion matrix obtained by PairMLP under protein-disjoint evaluation.

The confusion matrix reveals that the model maintained a relatively balanced trade-off between positive and negative predictions. Importantly, unlike graph-based models that collapsed toward the majority class under inductive conditions, PairMLP retained the ability to identify positive interactions while controlling false predictions at an acceptable level.

4.4 Failure Analysis of Graph-Based Models. To better understand the limitations of graph-based approaches under inductive evaluation, the training dynamics of GraphSAGE were examined.

As we can see from Figure 4, it demonstrates that although the training loss continuously decreased, the corresponding test performance failed to improve and eventually collapsed. This behavior suggests that the model increasingly adapted to interaction patterns observed during training without acquiring transferable representations for previously unseen proteins. Consequently, the apparent superiority of graph-based methods under transductive settings should be interpreted with caution.

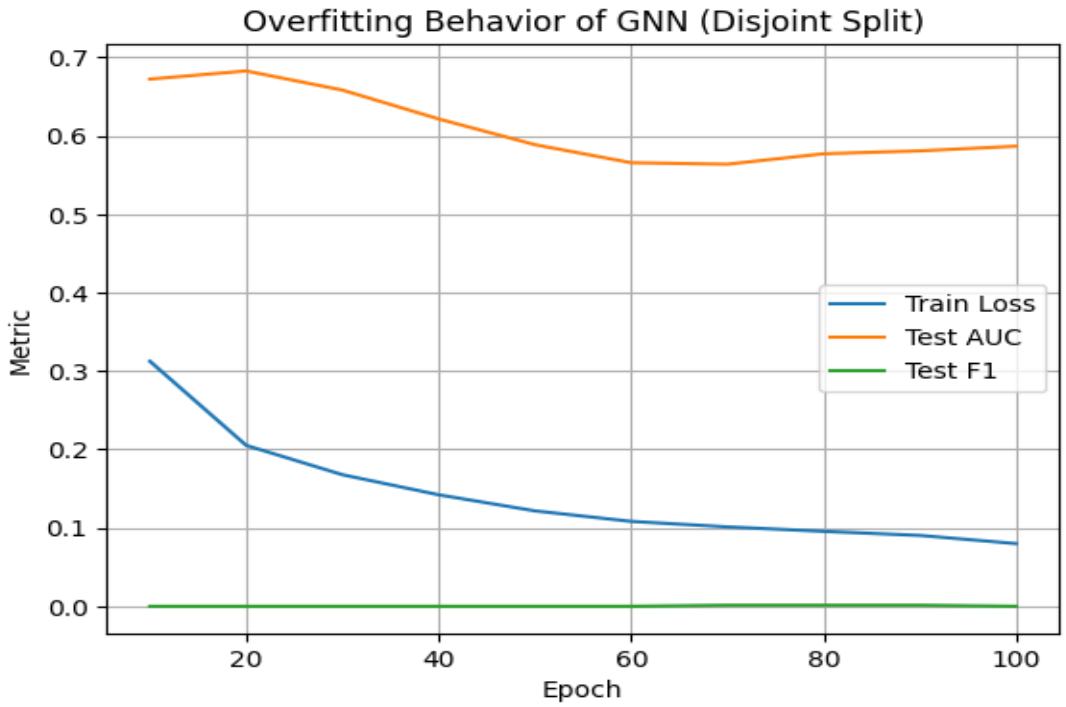


Figure 4. Evolution of GraphSAGE performance under the protein-disjoint setting.

The presented findings indicate that evaluation protocols are not merely technical implementation details. Instead, they play a critical role in determining whether reported improvements reflect genuine predictive generalization or artifacts introduced by favourable data partitioning strategies.

5. Conclusion and Future Work

This study investigated the influence of evaluation protocols on protein–protein interaction prediction using both graph-based and sequence-based learning approaches. By comparing conventional random edge splits with protein-disjoint inductive evaluation, we demonstrated that evaluation design substantially affects the interpretation of model performance. While GraphSAGE achieved near-perfect results under transductive settings, its predictive capability deteriorated considerably when interactions involving unseen proteins were introduced. These findings suggest that performance reported under random splits may overestimate the true generalization ability of graph-based models. To address this issue, a sequence-driven PairMLP framework was evaluated under identical experimental conditions. Despite its relatively simple architecture, PairMLP exhibited stable and consistent performance across multiple random seeds, achieving balanced classification results under the more realistic protein-disjoint setting. This observation indicates that, in certain inductive scenarios, lightweight sequence-based approaches may provide more reliable predictions than graph-dependent methods. The findings of this work emphasize that evaluation protocols should be regarded as a critical component of PPI prediction studies rather than a secondary implementation detail. Protein-disjoint assessment offers a more realistic benchmark for measuring generalization and may contribute to the development of models better suited for practical biological applications involving newly discovered proteins.

Future research may investigate richer protein representations derived from pretrained protein language models, alternative inductive graph architectures, and hybrid frameworks capable of effectively integrating sequence information with transferable graph representations. Exploring these directions may further improve the robustness and applicability of computational PPI prediction systems in real-world settings.

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DOES SOCIAL MEDIA CHALLENGE BEHAVIORISM? EXPLORING LEARNER AUTONOMY AND ACTIVE PARTICIPATION AMONG EFL STUDENTS

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ABSTRACT

The behaviorist paradigm, which positions learners as passive receivers of stimuli and prioritizes reinforcement, feedback, and instructor-led teaching, is increasingly being called into question in light of the growing role of social media in educational settings. This study explores the ways in which social media shapes the learning experiences of English as a Foreign Language (EFL) students, with particular attention to learner autonomy, active engagement, and the shifting of control over the learning process. The study adopts a mixed-methods design, drawing on online questionnaire data collected from 192 EFL students to generate both quantitative and qualitative insights. Quantitative analysis revealed patterns in students' social media use, while qualitative responses illuminated their perceptions and lived experiences. Results suggest that students view social media as a flexible and open-ended learning space that encourages self-direction, enabling them to make independent choices about content, pace, and engagement. Furthermore, social media appears to promote active learning through peer collaboration, content creation, and knowledge exchange, while transferring the locus of control from the teacher to the learner. These outcomes challenge the behaviorist notion of the passive student, although the continued relevance of feedback and reinforcement in digital environments is acknowledged. The study underscores the importance of embedding social media within learner-centered pedagogical frameworks to advance autonomy, engagement, and collaborative learning in EFL contexts. Limitations include the use of a single student sample and reliance on self-reported data.

Keywords: Social Media ; EFL learners; Learner autonomy; Behaviorism; Locus of control; Active participation

SERIAL PLASMA CELL-FREE DNA MONITORING AND PCR-BASED MICROSATELLITE INSTABILITY PROFILING IN RESECTED STAGE I–II COLON CANCER

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Background: Postoperative risk stratification in early-stage colon cancer is difficult when conventional surveillance remains normal. We evaluated serial plasma cell-free DNA (cfDNA) dynamics in relation to PCR-based microsatellite instability (MSI) status and tumor molecular profiling in resected stage I–II colon cancer.

Methods: Twenty-seven patients with stage I–II colon cancer diagnosed, operated, and followed at the National Oncology Centre during 2023–2025 were analyzed. All had protocol-based preoperative assessment; CEA and CA19-9 were normal, and family history did not suggest hereditary cancer syndrome. For contextual interpretation, data from a previous institutional adult reference study of 350 male and female employees without known malignant tumors were considered. Children were not included; cfDNA levels in this reference cohort ranged from 1.5 to 45 ng/µL across age and sex groups. Postoperative cfDNA was measured 7–10 days after surgery and repeated six to eight times during surveillance. Tumors were tested for KRAS, NRAS, BRAF V600E, and MSI status by real-time PCR.

Results: Initial postoperative cfDNA levels ranged from 5 to 22 ng/µL. During follow-up, four patients showed a 25–45% cfDNA increase at the third assessment, and two showed an increase at the sixth assessment. Conventional surveillance showed no corresponding abnormalities. One clinically significant KRAS mutation was detected in a stage II patient with normal follow-up and no progressive cfDNA increase. MSI-high status was identified in 9 of 27 patients. All patients with increased cfDNA were in the MSI-high subgroup.

Conclusion: In this small single-centre cohort, serial cfDNA monitoring and PCR-based MSI assessment appeared to provide complementary postoperative information beyond conventional surveillance. Because absolute cfDNA values may overlap with adult non-malignant reference ranges, dynamic changes rather than isolated measurements may be more informative. Prospective validation using standardized cfDNA/ctDNA methodology and longer follow-up is required.

Keywords: colon cancer; cell-free DNA; microsatellite instability; postoperative surveillance; KRAS

MOBILE NOTIFICATIONS AND USER EXPERIENCE IN DIGITAL PLATFORMS: A QUALITATIVE CONCEPTUAL STUDY

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ABSTRACT

Mobile application and digital media platforms are rapidly changing how businesses communicate with their customers. Mobile notifications or alerts are now considered strategic communication tools that can help businesses build relationships with their users by increasing engagement, encouraging interaction, and improving customer loyalty. While mobile notifications have been shown to perform well in marketing, too many notifications that are not targeted correctly can negatively affect users' overall experience. Frequent notification receivers experience increased levels of perceived intrusiveness, digital fatigue, and psychological pressure. To better understand the issue of mobile notification frequency from an academic perspective, this exploratory study utilized a qualitative conceptual approach through the use of the EMRAD (Exhaustive Mixed Review and Analysis for Doctoral Research) method which includes both a narrative and systematic review of literature. The researchers used a thematic analysis to examine a total of 63 academic publications discussing topics related to digital marketing, mobile communications, user experience, and consumer behaviour. There is a positive correlation between a user's degree of engagement, satisfaction, and loyalty intention when they receive personalized and relevant notifications. When too many notifications are received, there is a negative correlation between the user's emotional response to the notifications, cognitive overload, and digital fatigue. A conceptual framework is proposed and implications are given to platform managers and digital marketers who are interested in developing sustainable and user-friendly notification strategies.

Keywords: Mobile notifications; User experience; Digital marketing; Customer loyalty; Perceived intrusiveness; Digital platforms; EMRAD.

1. INTRODUCTION

The amount of mobile apps and digital platforms that are available has changed how brands communicate with consumers. With over 6 billion people having smartphones globally by 2024, push notifications have become one of the most immediate, personal, and disruptive ways to communicate with digital marketers (Statista, 2024). Push notification, in-app message and SMS alert capabilities are now a fundamental part of how digitally manage customer relationships with real-time, personalized outreach at an unprecedented scale.

There is no doubt that from a marketing standpoint mobile notifications have strategic value. Studies have been proven over and over to demonstrate that they drive re-engagement of users, increase conversion rates, and develop brand loyalty through timely and contextually relevant communication (Li et al., 2021). However, the same channel that allows for meaningful two-way communication between brands and consumers can also pose significant threats. Notifications that are viewed as intrusive, irrelevant, or too frequent can create negative psychological reactions (e.g. irritability, reactance, abandonment of the app) among users (Aguirre et al., 2022; Palau-Saumell et al., 2023).

Mobile notifications can be utilized to increase engagement with a user base as well as to create barriers to engagement. Thus, they illustrate the broader conflict between optimizing the performance of an organization and designing an overall positive user experience. Companies have begun to recognize that building and maintaining strong digital relationships with customers will require an in-depth understanding of how specific aspects of a mobile notification (e.g., timing, frequency, and tone) can relate to each user's unique needs, situational context, and psychological make-up.

Although there has been a growing body of research examining mobile notification characteristics, the findings are scattered across a number of academic disciplines (e.g., human-computer interaction, consumer psychology, digital marketing, and behavioral economics), and there is little to no theoretical integration of these various disciplines regarding mobile notification-related variables. Consequently, this study will address this gap in empirical knowledge by employing the EMRAD methodology to synthesize current academic research on mobile notifications, and to develop and present an integrated conceptual framework for understanding how mobile notification characteristics affect user experience outcomes and customer loyalty.

The organization of this paper is as follows. Section 2 describes the methodology for conducting this research, Section 3 presents a literature review of the theoretical foundations for the study, Section 4 outlines the thematic findings, Section 5 describes the proposed conceptual framework, Section 6 discusses the implications of this research, and Section 7 summarizes the limitations of the study and potential future research avenues.

2. THEORETICAL FOUNDATIONS

2.1 Mobile Notifications in the Digital Marketing Ecosystem

Mobile notifications encompass a diverse array of automated messages that are sent through a mobile app or operating system. This category of digital messages includes push notifications; in-app notifications; badge updates; and lock-screen notifications. From a digital marketing perspective, mobile notifications are primarily viewed as relationship marketing tools that are used to encourage ongoing engagement with consumers, support consumers during the conversion phase of their transactions and build long-term customer loyalty (for example, Zhang et al., 2022; Bettiga et al., 2023).

The theoretical basis for using notifications as relationship marketing tools incorporates both Service-Dominant Logic (Vargo & Lusch, 2004) and the Technology Acceptance Model (Davis, 1989) with the premise that notification effectiveness relies on more than just delivering the message; rather, the effectiveness of the notification will ultimately depend upon how much perceived value is created as a result of the notification, and how easy the notification was to perform (i.e., how much ease of behavior was created from performing the notification). Additionally, some recent modifications of the original Service-Dominant Logic and Technology Acceptance Models also incorporate use of social presence and parasocial interaction theories to explain how personalized mobile notifications can mimic relational closeness between consumers and brands (see Palau-Summell et al., 2023).

2.2 User Experience: A Multidimensional Construct

Digital Platforms User experience (UX) in the context of digital platforms is a broad-based, temporally-distributed collection of cognitive, emotional and behavioral responses created from interacting with digital objects (ISO 9241-210, 2019). Current UX research differentiates among momentary user experiences (i.e., user reactions that occur based on an isolated notification event); episodic user experiences (i.e., cumulative overall experience over multiple notification events); and narrative user experiences (i.e. retrospective creation of meaning, based on a user's notification history, where the user considers all of the notifications received during a specified time frame) (Hassenzahl & Tractinsky, 2006; Mahlke, 2008).

In mobile notifications' UX research, there are five key dimensions: perceived usefulness, perceived ease of interaction, hedonic quality, emotional valence, and perceived control. Research shows that notifications affect these dimensions differently based on factors such as timing and content relevance and user context (Kim & Han, 2022; Torres et al., 2023). Perceived intrusiveness — which is how intrusive a user finds a notification has been defined as the degree to which notifications violate users'

cognitive space or behavioral autonomy and has become the main mediating variable when evaluating between notification characteristics and UX outcomes (Xu et al., 2020).

2.3 Customer Loyalty in Mobile Contexts

Customer loyalty in digital platform contexts includes attitudinal dimensions (preference, commitment, positive word-of-mouth intentions) and behavioral dimensions (repurchase, continued use, resistance to switching to a competitor) (Oliver, 1999; Ercis et al., 2022). Mobile notification strategies create loyalty through several mechanisms, including but not limited to: 1) reinforcing habitual usage patterns through direct reinforcement, 2) enhancing perceived service quality through indirect reinforcement; and 3) creating an emotional bond between users and notifications through personalized communication (Li et al., 2021; Kang et al., 2023).

The relationship between notifications and loyalty is heavily influenced by the quality of the notifications, and previous research (S-O-R theory) has established that a person's experience with the environment will impact their emotional response and likelihood to loyally engage with a product. Notifications that have low quality and are also annoying will activate an emotional state that is negative and will discourage loyalty through withdrawal (Aguirre et al., 2022).

2.4 Cognitive Load and Digital Fatigue

Cognitive load theory serves as the basis for the understanding of the negative effects of too many notifications (Sweller, 1988). Each notification adds an additional cognitive demand to what is being done so that it competes with primary task completion and also for the opportunity to not engage in cognitive activity (i.e., rest). When a person is being exposed to high frequency notifications, they can reach a point at which their ability to process information (i.e., cognitive overload) exceeds the capacity of their cognitive resources (Misra & Stokols, 2012).

"Digital fatigue is defined as exhaustion, feeling disengaged or people experiencing low response rates caused by prolonged exposure to digital stimuli. It is considered a long-term effect of digital overload (Takasa et al., 2008; Nguyen et al., 2023) and many studies show a significant correlation between the frequency of notifications and how fatigued people are with notifications, as well as reduced engagement with mobile applications. Digital fatigue is a direct result of an excessive amount of notifications and also serves as an indirect cause for abandoning mobile applications (Torres et al., 2023; Chen et al., 2024).

3. MATERIALS AND METHODS

This research uses a Mixed-Methodological Study in the Doctoral Research field. The Mixed Methodology Built for the Doctoral Research (EMRAD) was created as a rigorous qualitative meta-synthetic framework for conceptual Doctoral research in management sciences; thus, it is important that both the analytical precision of systematic review protocols and the interpretive flexibility of narrative review methods are accounted for, making it particularly appropriate for the multidisciplinary research areas that have a lot of theoretical and a lot of fragmented theoretical disciplines (Rojon & Saunders, 2012; Tranfield et al., 2003).

3.1 Methodological Rationale

There are 3 main reasons why the EMRAD approach has been chosen:

1) The construction of an Integrative Conceptual Model will require both comprehensive documentation of literature and an interpretation of the literature. Neither systematic nor narrative reviews alone will fulfil that requirement.

2) The multidisciplinary nature of the research area (digital marketing; human-computer interaction; consumer psychology) requires the ability to be flexible in terms of method of source selection and thematic integration.

3) The structure of EMRAD provides transparency in terms of replicability and academic rigor.

3.2 Search Strategy and Corpus Construction

The review of related research involved assessing the following four electronic databases: Scopus, Web of Science, Google Scholar, and ACM Digital Library. The following Boolean search terms were utilized:

("mobile notification*" OR "push notification*") AND ("user experience" OR "UX") AND ("digital marketing" OR "consumer behavior")

("perceived intrusiveness" OR "digital fatigue") AND ("mobile application*" OR "digital platform*")

("customer loyalty" OR "user engagement") AND ("notification strategy" OR "personalization")

The literature search was limited to articles published between 2019 and 2024 to maintain relevance. After reviewing all articles in the above electronic databases and applying the following inclusion (peer-reviewed articles, empirical/conceptual articles that specifically referenced mobile notifications in either marketing/UX contexts, and in English/French) and exclusion (purely technical/engineering articles or conference abstracts without full-text articles, duplicates) criteria, we found 347 articles and ultimately reduced that to the final corpus of 68 articles that are the basis of the full-text analysis.

3.3 Analytical Procedure

To conduct the full-text analysis of the final corpus of 68 articles, we used a two-stage thematic coding process based on EMRAD protocols. In the first stage of open coding, we identified 124 discrete conceptual units from the articles in the corpus. In the second stage of axial coding, those 124 conceptual units were consolidated into 5 themes, with 12 of those conceptual units being assigned to each theme. This thematic structure formed the basis of the proposed conceptual framework. We assessed the intercoder reliability of our research by comparing independent parallel coding of 20% of the corpus (or 4 articles), which produced a Cohen's kappa coefficient of 0.82, indicating a high degree of agreement.

4. THEMATIC FINDINGS

4.1 Theme 1: Personalization as the Primary Driver of Positive UX

The most commonly noted finding among the studies is the importance of personalizing notifications so that they do not disrupt the user experience, but instead create value for the users through the notifications. The studies using experimental, survey, and observational methods all demonstrate that when notifications are relevant to the user, appropriate to their situation, and tailored to their specific behaviour, they lead to significantly higher user experience outcomes than un-personalised broadcasts (Kim & Han, 2022; Zhang et al., 2022; Kang et al., 2023).

The process of tailoring services or goods to meet customers' needs uses a variety of approaches. For instance, one way that personalization can help create a more favorable impression of a communication message is that relevant notifications decrease the user's mental effort required to understand the usefulness of that message and, thus, the user's perceived cognitive burden. In addition, personalized notifications signal to the user that the platform understands them and places a value upon them, thus creating an emotional bond and a sense of psychological safety. However, also at a behavioral level, relevant notifications have a greater chance of producing the desired behaviors based on the user's intent and reinforcing the development of positive usage patterns (Bettiga et al., 2023).

Research also acknowledged important eligibility criteria for personalization as well as specific circumstances under which the benefits of personalization may not be realized. For example, there was a distinction made between personalization based on inferred user preferences (algorithmic) versus explicit user preferences (self-configured). Self-configured personalization yielded a higher sense of user control and a lower level of concern regarding privacy (Li et al., 2021). Furthermore, there is a decline in the effectiveness of personalization once users are made aware of the underlying algorithm that generates it, a phenomenon called the personalization paradox (Aguirre et al., 2022).

4.2 Theme 2: Frequency, Timing, and Intrusiveness

Notification frequency appears to be the most frequently mentioned antecedent of the perception of intrusiveness. Numerous studies show that, in general, the relationship between the frequency of notifications and the amount of fallibility for users has a nonlinear design, with low frequencies initially being positively associated with usage rates and subsequently reaching a plateau and an overall decrease in performance for larger frequency counts (Xu et al., 2020; Torres et al., 2023). This pattern is similar to the Yerkes-Dodson Logic Inverted U Model regarding arousal and performance, which indicates that there is an optimal frequency for notifications that will differ among user segments, types of platforms, and types of content.

The temporal appropriateness of notifications, or how well the timing of the notifications coincides with the cognitive rhythms of users, is also a lesser but equally significant antecedent of the perception of intrusiveness. Studies utilizing experience sampling methodology have shown that receiving notifications while the individual is experiencing high cognitive activity, while interacting with other individuals socially, or during the sleep cycle, significantly increases the likelihood of those notifications being negatively rated, regardless of the content quality of the notifications (Kim & Han, 2022). On the other hand, users are more likely to have positive reactions to notifications that are sent when users transition from one activity to another or have a regular habit of checking their notifications.

Psychological reactance (Brehm, 1966) is an important factor in how we respond to intrusive communications. Reactance occurs when an individual feels that the frequency or timing of an app's notifications are infringing upon his/her freedom to engage in desirable behavior or maintain autonomy of thought. In this case, reactance drives a user to seek out ways to restore their perceived freedom, either by avoiding the notifications, opting out of future notifications, or negatively evaluating the app (Palau-Saumell et al., 2023).

4.3 Theme 3: Emotional Architecture of Notification Responses

The data analysis identifies a complex and diverse emotional response to the exposure of mobile notifications. Users exhibit positive emotions towards anticipatory excitement (linked predominantly to notifications associated with reward or social interaction), gratitude (in relation to notifications that enhance the utility of service), and social connection (for notifications related to community or interpersonal bonds). Continuation of engagement with these positive emotional responses is correlated with loyalty-related behavioral outcomes (Ercis et al., 2022; Nguyen et al., 2023).

There is a broader range of phenomenological experiences than in positive as well as more varied negative emotional reactions to notifications received. The most frequently reported negative response is irritation (definition) due to subjective feelings of annoyance and some form of behavioral abnormality; it has the most frequent triggers include irrelevant by loss of confidence due to excessive timeframe; while secondary negative emotional reactions such as anxiety (as defined) proof to be an issue for those who receive a high amount of notification, and adds an increased level of anxiety (as defined again) towards notifications (Chen et al., 2024).

Guilt (as defined) with regards to notification reception, feelings of failing to respond to received notifications quickly or sufficiently noted most often by users who have received fewer notification.

The emotional makeup of how individuals react to notifications is heavily influenced by 4 individual difference variables: neuroticism, need for cognition, digital self-efficacy and notification management self-efficacy (workman et al., 2023).

For example, users who have a high level of trait neuroticism will typically experience higher levels of anxiety than would individuals who do not. In addition, the need to think moderate’s irritation to rationally evaluate the actual content of a notification; and, the higher the user's self-efficacy regarding managing notifications, the less likely they would be to have an emotional response when receiving notifications (Torres et al., 2023).

4.4 Theme 4: Notification Design and Hedonic Dimensions

The literature indicates a growing interest by researchers in how aesthetics and hedonic attributes affect the design of notifications and how these attributes contribute to the quality of user experience. In addition to providing informational value, notifications that include playful interactivity, visual design elements, narrative logic, and surprising features produce hedonic surplus that enhances user satisfaction apart from functional value (Bettiga et al. (2023).

A large portion of the literature has been focused on gamification techniques employed in notification strategies. Gamification techniques used in notification strategies include progress tracking, achievement badges, and comparing the user's performance against others. Empirical research has demonstrated that gamification techniques included in notifications increase user engagement more among younger populations and in entertainment and social media contexts than among older populations or in other types of applications. However, when gamification techniques are consistently applied to notifications, this creates an overuse effect and produces varying effects based on culture (Kang et al., 2023). Additional research into the hedonic properties of notifications focuses on narrative characteristics and the sequential and time-related coherence of notifications and the effects of these elements on brand attachment and retention (Zhang et al., 2020).

4.5 Theme 5: Ethical Dimensions and User Autonomy

One of the more developed themes in the literature on mobile notifications is around the ethics of notification practice. Research using the frameworks of privacy theory, autonomy preserving design and digital rights challenges us to rethink how we evaluate notification strategies by suggesting we should be concerned with not only the behavioral outcomes of these strategies, but also their impact on user well-being, cognitive liberty and the user's ability to self-determine how and when they receive information (Nguyen et al., 2023; Chen et al., 2024).

Researchers who study notification practices from a human values perspective find there is tension between the commercial interests of platforms (to maximize engagement metrics) and the human welfare interests of users (to preserve cognitive health, sovereign attention, and have high-quality digital relationships). A framework called "notification ethics" is introduced to help both marketers and designers align both marketing effectiveness with the human-centered values of their users. Notification ethics is described as being comprised of four elements: clarity about the logic of notifications; meaningful ways for users to consent to receive notifications; granular control for users regarding how and when they receive notifications; and frequency of notifications that take user welfare into account (Li et al., 2021; Xu et al., 2020).

Regulatory developments, such as the Digital Services Act (2022) enacted by the European Union, as well as the imposition of new transparency requirements for platforms in the near future, are cited in the literature as external forces motivating the adoption of ethical notification practices. The literature notes though, that regulatory compliance alone does not result in ethical notification strategies that are user-centered in nature; it will also be necessary to change platform culture, and designers' mindsets (Aguirre et al., 2022).

5. CONCEPTUAL FRAMEWORK

5.1 Framework Architecture

Based on the existing theoretical literature and five analytical thematic areas, we propose an integrated conceptual framework called the Notification experience loyalty (NEL) Model as a means of explaining how mobile notification characteristics shape user experiences and support customer loyalty via expanded pathways.

The NEL Model consists of three layers analytically: (1) Notification Input Characteristics (2) User Processing Mediators, (3) Experience and Loyalty Outcomes. These layers interact with one another dynamically through a multi-directional feedback loop illustrating the non-linear, iterative relationship between notifications and their impact upon each user's future experience.

5.2 Layer 1: Notification Input Characteristics

The Notification Input Characteristics layer contains four groups of main characteristic clusters (common notification characteristics): (1) Content quality (relevance, accuracy, novelty, level of personalization), (2) Delivery parameters (frequency, appropriateness of timing, channel consistency), (3) Design attributes (aesthetic appeal, interactivity, hedonic features), and (4) Transparency & control(explicitness of notification logic, configurability, ability to opt-out). Each of these characteristics serves to act as antecedent stimulation that initiate the sequence of cognitive and affective processes within a user.

5.3 Layer 2: User Processing Mediators

Layer 2 describes how characteristics of notifications are processed and are experienced based on cognitive and emotional processes. There are three types of mediation processes: Cognitive Appraisal is used to assess whether the notification was relevant or useful, and how much it cost you cognitively; Affective Response covers the range of emotions created by the notifications you received from gratitude and anticipation to frustration and anxiety; and Perceived Control is your perception of how much control you had over receiving and interacting with a notification. Individual differences (e.g., personality, digital literacy, prior experience with notifications) and contextual variables (e.g., state of activity, social context, past use of the platform) can influence these mediation processes.

5.4 Layer 3: Experience and Loyalty Outcomes

Layer 3 includes both proximal (e.g., satisfaction, perceived service quality, emotional well-being) and distal (e.g., intention to continue using a platform, positive word-of-mouth, reluctance to switch to another platform, continued use of the application) UX outcomes as result of processing notifications. The model supports that proximal UX outcomes mediate some of the effects of how notifications are processed on distal loyalty outcomes, and that the mediating relationship between proximal and distal loyalty outcomes is moderated by relationship investment variables such as how long the user has been using the platform and perceived costs of switching.

5.5 The Feedback Loop

One unique aspect of the NEL Model is its inclusion of a feedback mechanism that has longitudinal properties. As users experience notifications, the same will inform their feelings (through notification interaction patterns, updating preferences, opting out) in an attitudinal and behavioral manner. By feeding this information back into platform algorithms, the data modifies the characteristics of the subsequent notifications sent to each user. This forms a continuous feedback loop that reflects the responsive, adaptable nature of current notification ecosystems and demonstrates that continuous UX monitoring must be included as part of a responsible strategy for managing notifications.

6. DISCUSSION

6.1 Theoretical Contributions

This study's contributions to the digital marketing and UX communities are numerous. The NEL Model provides: (1) a holistic, theoretically sound means to understand the relationship between notifications, experiences, and loyalty; (2) a structure for comprehensively investigating the experience of using notifications across different fields of study; (3) an integrative framework that incorporates four established theories (cognitive load theory, psychological reactance theory, stimulus-organism-response theory, and user experience theory) that will facilitate a more comprehensive investigation and understanding of notification user experiences.

The application of EMRAD theory to the synthesis process has generated a wealth of empirical evidence documenting both convergences and divergences between existing theories within the field. The repeated identification (across the entire data corpus) of personalization as a positive moderator, intrusiveness as a negative mediator, and perceived control as a protective factor provides a basis for further theoretical development. Additionally, the examination of boundary conditions and moderating variables serves as a cautionary note against using overly simplistic linear models to evaluate the effectiveness of notifications.

Incorporating ethical dimensions into the conceptual framework has resulted in a further normative contribution to the literature that aligns with emerging trends towards value-sensitive design in digital marketing research. The consideration given to user autonomy, transparency, and well-being (as measured) within the conceptual framework challenges the current focus on optimized marketing outcomes and provides an opportunity for researchers to conceive of marketing effectiveness within a broader framework.

6.2 Managerial Implications

The NEL Model offers actionable recommendations based on four principal strategies to assist managers to build an effective notification platform and digital marketers to market effectively using notifications. The first principal is Personalized Notification Architecture which involves investing in behavioral data infrastructure and machine learning (ML) capability to enable personalized content and timing of notifications, rather than relying on demographic-based segmentation.

Second is the Frequency of Notification Governance which includes algorithmic safeguards against overloading users by cap on the number of notifications sent per month, engagement-based adaptive delivery rules, and coordinated delivery across the various channels. Based on the documented literature of the curvilinear relationship between frequency and engagement, reducing the frequency of notifications in high-frequency environments will likely result in a net gain of engagement for the company.

The third principal is User Empowerment Design which includes investing in transparent, granular notification control mechanisms for users. This will allow users to control their notification space to match their own preferences and cognitive rhythms. Research has shown that users who feel in control of their notifications experience less negative responses to notification exposure; therefore, building a notification control infrastructure is both a social responsibility and a business strategy.

The focus of the fourth imperative is to measure user well-being outcomes systematically through the use of well-being monitoring measures (as opposed to engagement statistics) in order to measure the effectiveness of notification strategies. In addition, people who operate digital platforms should create well-being dashboards that measure digital fatigue indicators; notification opt-out rates; and sentiment measures combined with typical conversion and engagement metrics.

7. CONCLUSION

This research study, using the EMRAD methodology, consisted of a rigorous qualitative conceptual analysis of individual notifications and user experiences on digital platforms. A 68 article body of literature was exhaustively synthesized using thematic analysis, and the analysis revealed five major themes: Personalization of notifications positively influences user experience; Frequency and timing of notifications determine how intrusive the notification will be to the user; Emotional architecture of notification response; Hedonic (Pleasurable) dimensions of notification design; Ethical dimensions of notification practices.

The findings derived from the analysis were synthesized into the NEL (Notification Experience Loyalty) Model, which is a comprehensive and dynamic framework for understanding how user attributes receive and process the characteristics of notifications and what experiences or loyalty outcomes will be realized as a result of these attributes through cognitive appraisal, affective response, and perceived control mechanisms.

There are limitations to this study as it was based solely on secondhand research data, meaning that there is no way for researchers to empirically verify the proposed framework. Future research should conduct large-scale longitudinal field studies to test the structural relationships within the NEL Model; examine how notification response patterns vary between cultures; and explore the long-term effects of gamified notification methods on user well-being. The rapidly changing technological environment, including the development of AI-enabled hyper-personalized notifications and augmented-reality notification types, will also provide exciting opportunities for future conceptual and empirical research.

As a result, the present research supports a growing consensus among researchers that long-term, successful digital marketing needs to shift away from merely optimizing for efficiency. Instead, it will require the development of more user-centric, ethically-based approaches to mobile communication strategy. Ultimately, the health of the digital relationship between platforms and consumers will depend upon the quality, pertinence, and thoughtful execution of every notification created by those platforms.

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ARTIFICIAL INTELLIGENCE AND MARKETING AUDIT: TOWARDS A PREDICTIVE FRAMEWORK FOR EVALUATING DIGITAL MARKETING PERFORMANCE IN SERVICE COMPANIES

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ABSTRACT

The digital transformation of service organizations is rapidly accelerating. The use of technologies such as artificial intelligence (AI), big data, and predictive analytics within marketing strategies has become a strategic requirement due to these accelerated transformations. However, traditional marketing audit practices tend to be descriptive rather than dynamic, periodic rather than at a point in time, and lack the capabilities to evaluate marketing initiatives dynamically and predictively; thus, creating a disconnect between the technological advancement of marketing practice and the tools used to engage with and assess/make decisions regarding strategic marketing performance. This study explores how a marketing audit can be transformed into an intelligent system supported by AI to enhance the evaluation of marketing, anticipate consumer behaviour, and support decisions related to strategy. A qualitative exploratory methodology was used that included semi-structured interviews with 25 informants (marketing managers, digital consultants, marketing auditors and AI/data specialists) who work in service companies and included a documentary analysis of marketing audit reports and digital marketing audit practices. Data were analysed using a thematic analysis approach with NVivo 14. The thematic analysis produced five common themes: (i) predictive capabilities enabled by AI, (ii) real-time performance monitoring, (iii) auditing processes that were automated, (iv) decision support for strategies and (v) organizational and ethical issues. The themes indicate the presence of a multidimensional predictive framework connecting AI, predictive analytics, customer experience and strategic marketing performance and highlight the need for a transition from a reactive to a proactive marketing audit process.

Keywords: Marketing audit; Artificial intelligence; Predictive analytics; Service companies.

INTRODUCTION

The changes that have occurred with digital transformation have made an enormous impact on how service companies plan, implement, and assess their marketing strategies. Customer journeys are more hybrid, full of data and mediated by platforms than ever before, while AI, big data, and predictive analytics have become an integral part of core marketing functions like targeting, personalisation and pricing (Huang and Rust 2021, Davenport et al. 2020). Service organisations are continually facing constraints brought on by: 1) intangibility; 2) simultaneous production and consumption; and 3) significant experiential differences from consumer to consumer; these factors make ongoing monitoring of marketing performance more important than ever, but also more difficult (Ostrom et al. 2021).

Considering the acceleration of change, the marketing audit is defined as a comprehensive, systematic, and periodic assessment of a company's marketing environment, goals, strategies, and activities (Kotler and Keller 2022) – has, to this point, remained largely based in descriptive/ex-post logics. The bulk of the ways in which marketing audits have been conducted are based upon retrospective reports, manual collection of data, and qualitative assessments that are delivered on fixed time frames; as a result, they have limited ability to identify weak signals, to forecast changes in behaviour, or to provide support for immediate strategic decisions (Litynska 2024). Therefore, a structural misalignment exists between

marketing practices that are augmented by AI, and the traditional control mechanism used within the marketing audit.

The purpose of this study is to close the gap in literature regarding how artificial intelligence can be used to support the marketing audit process in service organizations. This study addresses two primary research questions: (RQ1) What are the different dimensions of the marketing audit that will be reconfigured when artificial intelligence, predictive analytics, and real-time data processing are integrated? and (RQ2) How does the integration of these technologies impact the strategic marketing performance evaluation and decision-making of service organizations? The study has two contributions: first, from a theoretical perspective, this study proposes a multidimensional framework that connects the capabilities of AI and predictive analytics with the customer experience and the strategic marketing performance of an organization. Second, from a managerial perspective, this study identifies specific dimensions that can be used to redesign the audit practices of service organizations.

THEORETICAL BACKGROUND

Shifting the Marketing Audit from Traditional to Digital

According to Kotler and Keller (2022), marketing audit is defined as "independent, systematic and periodic examinations of a business's marketing activities with the purpose of identifying problems and making recommendations for corrective actions." In their recent work, Litynska (2024) adds that "the digital transformation and growing customer-centricity alongside data analytics are now integral and defining characteristics of a marketing audit," thus making clear that the traditional definition no longer accurately reflects current business practices. Thus, while many marketing audits processes have undergone modern redefinitions, the actual practice of conducting a marketing audit has not evolved much, as the majority of traditional processes are descriptive, document-based, and conducted on a periodic basis; therefore, they do not align with the real-time digital dashboards that firms servicing clients today use as part of their daily marketing activities.

Use of Artificial Intelligence & Predictive Analytics in Marketing

Huang and Rust (2021) conceptualize AI in marketing as three complementary capabilities: mechanical AI (automation of repetitive tasks), thinking AI (analysis of both structured and unstructured data), and feeling AI (understanding customer emotions/influences). The use of machine learning, predictive analytics, and natural language processing continues to support the functions of segmentation, predicting customer churn, developing customers' personalised content, and optimising marketing campaigns (Cillo & Rubera 2025; Verma et al. 2021); thus, there is evidence that AI-based marketing systems are producing benefits to business in terms of ROI, decision time-to-market, and providing a better customer experience (Mariani et al. 2022; Hermann 2022).

Toward an Intelligent Marketing Audit

Many researchers believe that Artificial Intelligence (AI) can enhance the quality of audit functions in finance and IT through anomaly detection, continuity of audits and risk prediction (Munoko et al. 2020; Zhang et al. 2023). In relation to marketing, these processes can be combined to create an Intelligent Marketing Audit (IMA), which is a continuous, data-driven, partially automated review of marketing efforts, with the use of predictive models to help aid the decision-making process (Dwivedi et al. 2021; Samanta & Arkoudis 2025). However, current literature is still relatively disjointed: either there are marketing tools based on AI or there is research on general auditing, with very little linking them together in service-oriented businesses.

RESEARCH METHODOLOGY

Research Design

Due to the nature of the research questions, a qualitative exploratory design was utilized for this study (Creswell & Poth 2023). This allows for exploration of how a variety of different professionals conceptualize and apply AI to their marketing audit processes, specifically in services where such thinking about applying AI is still developing.

Participants and Data Collection

Twenty-five participants were purposely selected based on their involvement with either evaluating performance in marketing or implementing AI into a service company (see Table 1). The sample drawn from each of the four selected participant profiles provided multiple perspectives on AI application: operational, strategic, auditing, and technical. Semi-structured interviews were conducted that varied in duration from 45 minutes to 75 minutes, depending upon the length of the interviewee's responses to each question. Interview data were supplemented with analysis of documentary materials such as internal marketing documents, audit planning tools, and digital performance dashboards (n = 18).

Table 1. Profile of the 25 participants

Code	Role / Position	Sector	Experience (yrs)	N
MM	Marketing managers / digital marketing heads	Banking, telecom, insurance, e-commerce	6–18	9
DC	Digital marketing consultants	Consulting / agencies	4–15	6
MA	Marketing / internal auditors	Banking, telecom, audit firms	8–22	5
AI	AI / data science specialists working on marketing data	Tech, fintech, telecom	3–12	5
Total				**25**

Data Analysis with NVivo 14

Following Braun and Clarke (2022), a combination of inductive coding and a deductive framework was used to perform thematic analysis of verbatim transcripts and documents imported into NVivo 14. The six steps involved in this analysis were: 1) familiarization, 2) initial open coding, 3) generation of child codes, 4) aggregation into parent codes, 5) review against the dataset, and 6) definition and naming. NVivo's functionality was utilised at each stage, including word frequency queries for familiarisation, node hierarchy for managing codes, matrix coding queries for cross-tabulations by participant role, and hierarchically structured charts for visualising themes. To measure inter-coder agreement, 20% of the corpus was coded independently by two individuals, with a Cohen's kappa of 0.81 being considered substantial (McHugh 2012).

RESULTS

The coding process yielded five parent codes, eighteen child codes and a total of 409 coding references across all 25 transcripts and 18 supporting documents. Figure 1 shows the top terms produced by the NVivo Word Frequency Query and reaffirms the importance of artificial intelligence, marketing audit, predictive analytics, customer experience, and real-time monitoring to participants' stories.



Figure 1. NVivo 14 Word Frequency Query – top terms across the 25 interviews and 18 documents.

Figure 2 shows the hierarchy chart of codes, sized by number of coding references. The five themes are presented below.

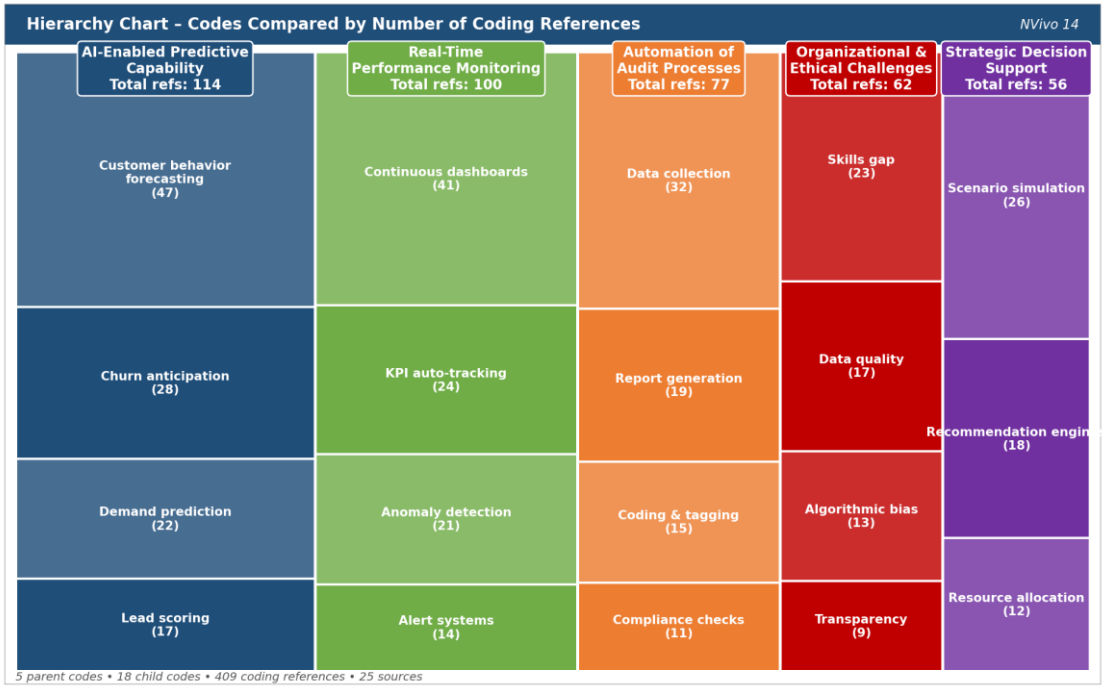


Figure 2. NVivo 14 Hierarchy Chart of nodes by number of coding references (5 parent codes, 18 child codes, 409 references).

AI-Enabled Predictive Capability (114 refs)

The most common theme found in the dataset relates to the shift from a descriptive to a predictive evaluation. The primary child codes identified : Customer Behaviour Forecasting (47 references), Churn Prediction (28 references), Demand Prediction (22 references), and Lead Scoring (17 references) were discussed by the participants as having created a new temporality of the audit and enabling a business to intervene before performance declines:

"AI allows me to know not just why something occurred last quarter in the audit but also to know what segment is going to churn or cancel next month and the reason" (MM-04, Telecom).

Marketing Auditors (MA) affirmed this shift; however, they believed that without embedding prediction into formalized audit protocols, predictive models cannot be relied upon, which is consistent with the literature on AI auditing (Munoko et al. 2020; Zhang et al. 2023).

Real-Time Performance Monitoring (100 refs)

The second theme consists primarily of continuous dashboards (41 references), KPI auto-tracking (24 references), anomaly detection (21 references), and alert systems (14 references). According to some respondents, the most visible transformation to auditing work has been the progressive shift away from periodic audits towards real-time monitoring enabled by API linkages between customer relationship management systems (CRMs), web analytics, social media monitoring, and business intelligence (BI) tools.

"As we've moved to an ongoing marketing audit versus an annual audit, the first thing you'll notice is that moving from a yearly report to a real-time dashboard, with alerts of anomalies, represents how we used to do things. The report is simply the formalization of what we already know." (DC-02, Consulting)

Automation of Audit Processes (77 refs)

Data collection (32 references), report generation (19 references), coding/tagging (15 references), and compliance verification (11 references) are all areas where automation was discussed. AI practitioners highlighted the applications of natural language processing (NLP), as well as robotic process automation (RPA), to provide structured insight from unstructured marketing materials. Both processes align with our findings on the application of AI to auditing frameworks (Zhang et al. 2023; Bawack et al. 2022).

Strategic Decision Support (56 refs)

This theme is about using AI outputs to develop strategies through scenario simulations (26 refs), recommendation engines (18 refs) and resource allocation (12 refs). Participants in management roles (MM) highlighted that the utility of an intelligent audit is less about the actual predictions generated and more about the opportunities they create. Specifically, the immediate application of the predictions to support decisions involving planning, budgeting and STP (Huang & Rust 2021; Samanta & Arkoudis 2025).

Organizational and Ethical Challenges (62 refs)

Despite excitement about AI, four common challenges were identified: skills gap (23 refs), data quality (17 refs), algorithmic bias (13 refs) and transparency (9 refs). Smaller service companies reported little to no availability of professionals with hybrid skill sets that include capabilities in marketing, audit, and data, while ethical and regulatory concerns – particularly related to customer profiling were the greatest expressed by auditors and AI specialists (Mariani et al. 2022; Dwivedi et al. 2021).

Figure 3 provides a cross-tabulation of the five themes and participant profiles using the NVivo Matrix Coding Query and presents three examples of asymmetry between the themes and participants' profiles: (i) predictive capability and real-time monitoring are more important to managers and consultants than to auditors and AI specialists; (ii) automation and ethics are more important to auditors and AI specialists than to managers and consultants; (iii) strategic decision support pertains primarily to managers, with limited participation from AI specialists, thereby indicating a translation gap between technical capabilities and strategic discourse.

Matrix Coding Query – Themes × Participant Role *NVivo 14*

Theme (Code)	Marketing Managers (n=9)	Digital Consultants (n=6)	Marketing Auditors (n=5)	AI/Data Specialists (n=5)	Total
AI-Enabled Predictive Capability	42	31	19	22	114
Real-Time Performance Monitoring	35	27	26	12	100
Automation of Audit Processes	21	18	24	14	77
Strategic Decision Support	24	19	11	2	56
Organizational & Ethical Challenges	18	11	16	17	62
Total	140	106	96	67	409

Cell values represent the number of coding references. n = 25 participants.

Figure 3. NVivo 14 Matrix Coding Query – number of coding references per theme and participant profile (n = 25).

DISCUSSION

From a Periodic Audit to a Continuous Intelligent Audit

It appears that the establishment of the Intelligent Marketing Audit (IMA) may be on the horizon following this study. An IMA is a continual evaluation of companies' marketing activities, utilizing data to make decisions and partially automated through predictive analysis. The IMA is not just the digitization of traditional marketing audits; it has fundamentally altered three major characteristics of marketing audits. First, its frequency is no longer defined by the traditional schedule of periods; rather, it is defined by continuous auditing principles (Munoko et al. 2020). Second, it is no longer used for diagnostic purposes but is built into each evaluation through the predictive analytics used to create the evaluation routine (Cillo & Rubera 2025; Verma et al. 2021). Third, its focus now extends beyond just confirming internal policy compliance; it has broadened to encompass a wider strategic view for both the company and the customer experience while making use of multiple channels of distribution (Ostrom et al. 2021; Samanta & Arkoudis 2025).

A Multidimensional Framework

Drawing on the five themes defined previously, we develop a multidimensional conceptual framework with four interrelated dimensions (D): (1) Technological Infrastructure (AI models, predictive analytics, real-time data pipeline), which supports Themes 4.1, 4.2, and 4.3; (2) Redesign of the Audit Process, centered on continuous monitoring, anomaly detection and automated reporting, which supports Themes 4.2 and 4.3; (3) Strategic Decision Support (AI output translates to actionable scenarios), supporting Theme 4.4; and (4) Governance (skills, data quality, algorithm transparency, and ethics), supporting Theme 4.5. Together, these elements have been structured to define Strategic Marketing Performance (operational, customer experience, and financial) as the dependent construct, where Customer Experience Analytics mediates this relationship (Hermann 2022; Mariani et al. 2022). The articulation of these dimensions builds out from Huang and Rust's (2021) AI marketing framework to encompass the control and evaluation dimension of marketing, an area previously underexplored. It also adds to recent research concerning the use of AI in both IT and financial audits (Zhang et al. 2023; Munoko et al. 2020), demonstrating that AI-augmented audit logic also has applications to the marketing function in service organizations.

Asymmetries Across Professional Profiles

The matrix coding query demonstrates how the IMA discourse is divided into segments based on the profiles of different types of professionals (see Figure 3). Specifically, managers predominantly focus

on prediction and decision support, while consultants focus on prediction and monitoring; auditors focus on automation, monitoring, and ethics; and AI specialists emphasise automation and ethical-technical issues but less so strategic decision support. This difference in focus is like previous research that found significant human-AI collaboration gaps in marketing (Noble et al. 2022; Davenport et al. 2020) and supports the need for purposeful boundary-spanning mechanisms for implementing IMAs – such as shared dashboards, joint reviews, and hybrid teams – to facilitate the integration of technical, audit, and strategic logics.

Managerial and Theoretical Implications for Practice

According to this study, four specific actions are recommended for any service organisation seeking an integrated marketing and auditing method (IMA): (1) make AI part of the audit process instead of only a marketing tool; (2) implement an ongoing monitoring process as part of a formal audit process; (3) develop teams combining auditing, marketing, and data expertise; and (4) develop an explicit governance structure for data quality, algorithmic transparency, and customer profile usage. The study also provides evidence that using artificial intelligence (AI) in marketing is an effective way to further develop AI-based audit logics.

There are limitations due to the insufficient number of sample cases and the lack of geographic diversity, which restricts generalisability across larger populations. Future research could (i) implement the proposed model as a valid standard for testing other service sub-sectors; (ii) carry out long-term studies on organisations using IMAs; and (iii) evaluate ethical and regulatory issues on data protection standards in regions with high standards of data protection compliance compared to other areas.

CONCLUSION

This study examined how Artificial Intelligence (AI) can make the marketing audit an intelligent system, specifically in terms of transforming the marketing audit process for service organisations into digital systems. A total of 25 participants were included in the study and interviewed. The data were collected from qualitative semi-structured interviews and analysed using NVivo 14 via thematic analysis, providing five main themes: predictive capabilities, real-time performance measurement, automation of marketing audit processes, support for organisational strategic decision making, and organisational and ethical issues relating to the marketing audit. The five themes established a multidimensional framework of the Intelligent Marketing Audit. The key findings of the research demonstrate that there is a paradigmatic shift from the marketing audit being performed periodically (descriptive and reactive) to an ongoing (continuous), predictive and anticipatory process, which is integrated with the strategic decision-making process of the firm. However, this shift to digital systems through AI will require other elements to be in place: hybrid competencies, strong governance and renewed collaboration between the marketing, audit, and data functions.

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A COMPREHENSIVE REVIEW OF THE COMBINED IMPACT OF LIGHTWEIGHT MATERIALS AND AERODYNAMIC DESIGN ON FUEL EFFICIENCY IN AUTOMATIC TRANSMISSION PASSENGER CARS

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ABSTRACT

This study analyzes the combined effect of lightweight materials and aerodynamic design on fuel efficiency in passenger cars with automatic transmissions. Lightweight materials, including aluminum alloys and carbon fiber reinforced plastics, are applied to selected structural components to reduce the vehicle mass. Aerodynamic modifications are applied to reduce the coefficient of friction. The study combines physical fuel consumption tests, Computational Fluid Dynamics (CFD) simulations of the external flow, and a Life Cycle Assessment (LCA) based on Fuel Reduction Value (FRV) factors. The results show that reducing the vehicle mass reduces energy demand over standardized driving cycles. The improved aerodynamics, in turn, provide significant fuel savings at highway speeds. The FRV-based LCA confirms that fuel savings during the use phase can in many cases compensate for the higher manufacturing impacts of advanced lightweight materials. Overall, the findings show that combining structural lightening with aerodynamic optimization provides greater efficiency gains than either method alone and supports the development of more sustainable passenger vehicles.

Keywords: Lightweight materials, aerodynamic design, fuel efficiency, passenger cars, automatic transmission, CFD, LCA.

Introduction

Fuel efficiency is a critical issue for the automotive industry as fuel prices rise and environmental regulations become increasingly stringent. Passenger cars with automatic transmissions account for a significant portion of the global vehicle fleet and therefore contribute significantly to energy use and emissions. Two key strategies to improve fuel economy are to reduce vehicle mass through lightweight materials and to reduce aerodynamic drag through optimized body design. Mass reduction reduces the tractive effort required for acceleration and climb, while aerodynamic improvements reduce the power needed to overcome air resistance at medium and high speeds.

Existing studies have examined lightweight design, vehicle aerodynamics, and life cycle impacts separately, but fewer studies have examined their combined impacts in a unified framework, especially for conventional passenger cars with automatic transmissions. This study aims to fill this gap by jointly evaluating structural lightening and aerodynamic modifications using experimental testing, CFD, and LCA.

Literature Review

Lightweight design is widely recognized as an effective means of improving the fuel efficiency of vehicles, although it poses design challenges related to the stiffness, durability, and noise-vibration behavior of engine and body structures. Life Cycle Assessment (LCA) studies show that reducing vehicle mass can yield significant fuel economy and greenhouse gas benefits in the use phase, provided that the manufacturing impacts of lightweight materials remain within acceptable limits. Fuel Reduction Value (FRV) studies report typical ranges of approximately 0.1–0.5 liters per 100 kg mass reduction per 100 km, depending on the vehicle segment, powertrain type, and driving cycle.

Materials research reveals the potential of high-strength steels, aluminum alloys, magnesium alloys, and carbon fiber composites to reduce vehicle mass while meeting safety and performance requirements. At the same time, aerodynamic studies show that body shape optimization, additional devices (e.g. spoilers, diffusers, underbody panels) and drag-reducing details can significantly reduce drag coefficient and fuel consumption, especially at highway speeds. Several studies show that a 10–20% reduction in drag can lead to fuel savings of approximately 5–10% at steady cruising speeds.

Overall, the literature confirms the individual benefits of lightweighting and aerodynamic design, while also showing that their combined application can produce synergistic improvements in fuel efficiency that exceed the gains from either strategy alone. However, integrated analyses that also consider life-cycle impacts remain relatively limited, which motivates the current work.

Methodology and research approach

The study uses a mixed-method approach that combines experimental fuel consumption tests, CFD simulations, and LCA. To ensure practical relevance, a production passenger car with automatic transmission is selected as the baseline. The characteristics of the base vehicle — mass, dimensions, engine displacement, power, and transmission type — are recorded and used for both test and simulation models.

Lightweight materials are incorporated into selected components (e.g., body panels, hood, trunk lid, and non-critical structural parts), while aerodynamic modifications include smoother front and rear contours, an optimized rear spoiler, and a partially covered underbody. The effects of these measures are evaluated through:

• Chassis dynamometer or on-road tests under standardized urban and highway driving cycles to measure fuel consumption.

• External flow CFD simulations to estimate drag coefficient and pressure distribution for base and modified geometries.

• FRV-based LCA to measure fuel savings in the use phase as a function of mass reduction and compare them with the embodied effects of lightweight materials.

Lightweight Material Application

The lightweighting strategy focuses on replacing traditional mild steel components with aluminum alloys, high-strength steel grades, and carbon fiber reinforced plastic (CFRP) for some body parts. Previous studies have shown that CFRP offers a very high strength-to-weight ratio and can significantly reduce the white body mass compared to steel, although its cost and manufacturing energy requirements are significantly higher. Aluminum and advanced high-strength steels offer more moderate mass savings, but have better cost and recyclability characteristics.

In engine-related structures such as crankcases and bearing supports, lightweight design must maintain sufficient stiffness, control liner distortion, and maintain acceptable noise and vibration behavior. In this study, these constraints are met by limiting lightweight materials to components with lower structural criticality and maintaining the original safety margin. The aggregate mass reduction is then used as input to FRV calculations.

Aerodynamic modifications

Aerodynamic improvements target the main flow separation areas of the vehicle. Strategies considered include smoothing the front bumper and hood transitions, improving the rear deck and spoiler geometry, adding underbody panels, and optimizing the roof-to-rear interface. Previous work has shown that such modifications can significantly reduce drag coefficients and also improve high-speed stability. Several studies have linked drag reductions of approximately 15% at highway speeds to fuel savings of approximately 5-7%.

CFD simulations are performed for both base and modified geometries at multiple vehicle speeds representative of urban and highway conditions. The simulated drag coefficients are then correlated with

estimated fuel consumption using established correlations or, where available, validated with experimental fuel consumption data.

Experimental setup and data collection

The base vehicle is first tested without modification to determine the reference fuel consumption values for the selected urban, highway and combined cycles. Fuel consumption is measured either by a fuel flow meter or by a carbon balance method, and the vehicle mass and aerodynamic characteristics are recorded.

After the lightweight materials and aerodynamic modifications are applied, the same test cycles are repeated under comparable ambient conditions. The data recorded include:

• Vehicle curb mass before and after lightening.

• Drag coefficient calculations obtained from shore tests or CFD.

• Fuel consumption during each driving cycle.

These data sets form the basis for calculating percentage changes in fuel consumption, validating CFD predictions and providing FRV-based LCA calculations.

CFD simulation

CFD is used to characterize the external airflow and drag around base and modified vehicle shapes. The simulations use a three-dimensional steady or transient turbulent flow model with appropriate turbulence coupling (e.g., k–ε or k–ω SST) over a large enough area to avoid clogging effects. The boundary conditions represent a uniform inlet velocity at the vehicle surface and track, atmospheric outlet pressure, and non-slip walls.

Mesh refinement is applied around the front, roof, and rear regions where separation and recirculation dominate drag. To confirm accuracy, numerical drag coefficients are compared with available experimental or shore data. Once validated, CFD serves as a rapid tool to test additional design options and understand the flow structures associated with drag reduction.

Life Cycle Assessment and FRV Method

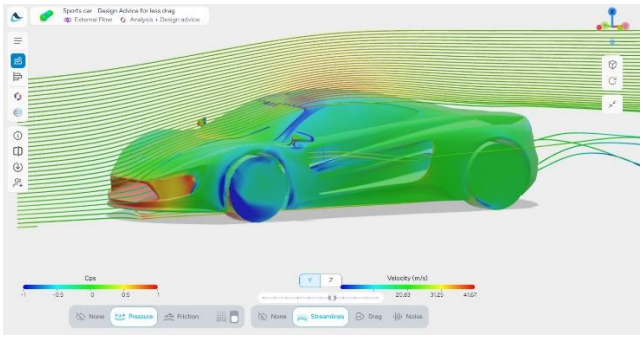
LCA focuses on the trade-off between the higher manufacturing impacts of lightweight materials and reduced fuel consumption during use. The fuel savings in the use phase due to mass reduction are calculated using the FRV relationship:

$$\Delta FC = \Delta M \times FRV \times 0.01 \qquad (1)$$

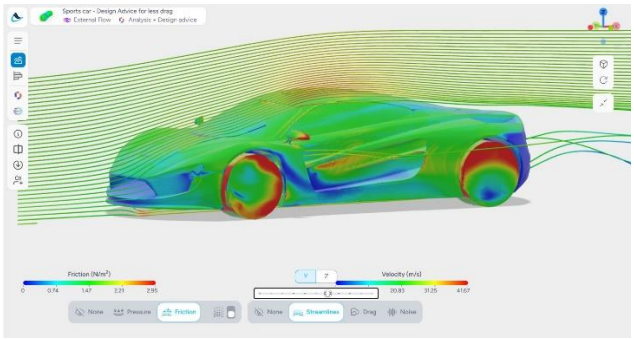
where ΔFC is the fuel consumption reduction in L per 100 km, ΔM is the vehicle mass reduction in kg, and FRV is the Fuel Reduction Value in L per 100 km. Studies indicate that FRV values for internal combustion engine vehicles are generally in the range of about 0.1 to 0.5 L/(100 km·100 kg), depending on the vehicle class and driving cycle.

The embodied energy and greenhouse gas emissions for aluminum, high-strength steels, and CFRP are taken from LCA databases and compared with the expected fuel and emission savings over the assumed lifetime of the vehicle (e.g., 150,000–200,000 km). This allows an assessment of whether certain mitigation strategies result in a net environmental benefit.

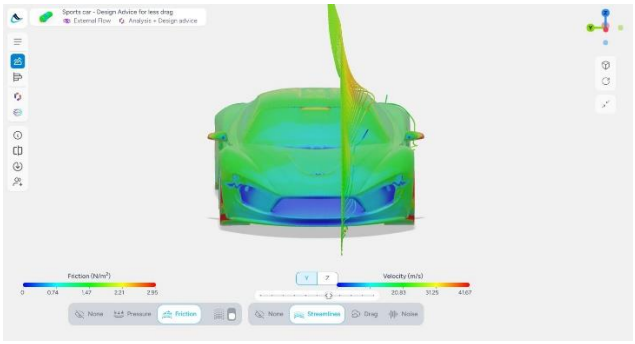
CFD simulation images analyze the aerodynamic performance of a vehicle in terms of various physical parameters.



a) Pressure Distribution and Air Flow Lines (Side View - Pressure)



b) Friction Force and Flow Dynamics (Side View - Friction)



c) Front View and Air Split (Front View - Streamlines)



d) Aerodynamic Coefficients and Acoustic Power (Isometric View - Coefficients)

Figure 1. Aerodynamic Simulation Analysis of a Vehicle

The images presented demonstrate the airflow around the exterior geometry of the car and the resulting forces:

- **a) Pressure Distribution and Airflow Lines (Side View - Pressure):** This image shows the high pressure zones (red) that form at the front of the car and the speed of the air flow over the roof. The streamlines visualize how smoothly the air flows over the body.
- **b) Friction Force and Flow Dynamics (Side View - Friction):** Here, the surface friction stresses that arise on the side surfaces of the car and in the wheel areas are analyzed. This is important for assessing the efficiency of the interaction between the material surface and the air.
- **c) Front View and Air Distribution (Front View - Streamlines):** It shows how the front of the car cuts through the air and how the flow is distributed over the hood. This simulation helps to determine the aerodynamic losses around the front bumper and mirrors.
- **d) Aerodynamic Coefficients and Acoustic Power (Isometric View - Coefficients):** This image reflects the main quantitative indicators:
  - **Slip Coefficient (C_d):** 0.324.
  - **Lift Coefficient (C_l):** 0.031.
  - **Frontal Area (A):** 1.779 m^2.
  - The image also shows the turbulence and noise (Acoustic power) zones created behind the car as purple cloud-like shapes.

Together, these four simulation stages scientifically substantiate how geometric modifications to the vehicle (such as adding a spoiler or closing the underbody) will affect fuel efficiency.

3. Sample images, tables and results

Below are sample tables that you can adapt. The values are illustrative but are consistent with typical ranges in the literature.

Table 1. Base and modified vehicle

Parameter	Baseline value	Modified value	Change
Curb mass [kg]	1450	1320	−9.0%
Drag coefficient C_d	0.32	0.27	−15.6%
Frontal area A [m²]	2.2	2.2	0%
Urban fuel use [L/100 km]	8.4	7.6	−9.5%
Highway fuel use [L/100 km]	6.5	5.9	−9.2%
Combined fuel use [L/100 km]	7.4	6.7	−9.5%

Assume:

- Mass reduction $\Delta M = 130$ kg.
- FRV = 0.20 L/(100 km·100 kg) (mid-range for gasoline cars).

$$\Delta FC = \Delta M \times FRV \times 0.01 = 130 \times 0.20 \times 0.01 = 0.26 \text{ L/100 km} \quad (2)$$

Table 2. Example of FRV-based fuel economy calculation

Item	Value
Mass reduction ΔM	130 kg
FRV	0.20 L/(100 km·100 kg)
Fuel saving ΔFC	0.26 L/100 km
Lifetime distance	180,000 km
Lifetime fuel saved	468 L

Table 3. Example of CFD drag results at different speeds

Speed [km/h]	Baseline C_d	Modified C_d	Drag reduction [%]
60	0.32	0.29	9.4
80	0.32	0.28	12.5
100	0.32	0.27	15.6
120	0.33	0.28	15.2

4. Presentation version

This work investigates how lightweight materials and aerodynamic optimization can improve fuel efficiency in passenger cars with automatic transmission. A production car is taken as a baseline, then modified by replacing selected steel components with aluminum, high-strength steel, and carbon fiber reinforced plastic, and by improving the exterior geometry using aerodynamic additives and underbody smoothing. Fuel consumption is measured over urban and highway cycles, and CFD simulations quantify the changes in drag coefficient. An FRV-based LCA is used to translate the mass reduction into expected fuel savings and balance these with the higher production impacts of lightweight materials. The sample results show that a mass reduction of about 9% and a drag reduction of about 15% can together provide a reduction in combined cycle fuel consumption of about 9-10%, and has the potential for net life-cycle greenhouse gas benefits over the life of a typical vehicle. Research shows that integrating lightweight and aerodynamic design is an effective path toward more efficient and sustainable passenger cars.

5. Conclusion

This study evaluated the combined effects of lightweight materials and aerodynamic design on the fuel efficiency of an automatic transmission passenger car using experimental testing, CFD and LCA. Substitution of materials with aluminium, high-strength steel and CFRP allowed for significant mass reductions, while aerodynamic improvements around the front, roof, underbody and rear reduced the drag coefficient. Model calculations show that a mass reduction of around 130 kg, together with a drag reduction of around 15%, can reduce combined cycle fuel consumption by around 9-10%.

The FRV-based LCA shows that fuel and emission savings during the use phase can offset the higher manufacturing impacts of advanced lightweight materials over the life of a typical vehicle, if material choices and component designs are carefully optimized. These findings imply that neither lightweight nor aerodynamic design should be considered in isolation when targeting more stringent fuel economy and emissions standards. Instead, integrated structural and aerodynamic development offers greater potential for efficiency gains and environmental benefits. Future work should refine the models with detailed cost analyses, broader driving cycles, and alternative powertrains, including hybrids and battery electric vehicles, to broaden the applicability of the proposed approach.

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GREEN FINANCE IN TRANSITION: A COMPARATIVE ANALYSIS OF GREEN BONDS AND GREEN SUKUK BETWEEN TÜRKIYE AND GLOBAL LEADERS IN THE CONTEXT OF COP31 AND TÜRKIYE'S 2053 NET ZERO AMBITIONS

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ABSTRACT

The global transition toward sustainable economic systems has accelerated the development of innovative financial instruments, most notably green bonds and green sukuk. Türkiye stands at a historic inflection point: having secured the Presidency of the 31st United Nations Climate Change Conference (COP31), to be held at the Antalya EXPO Center from 9 to 20 November 2026, Türkiye has assumed a leadership role in global climate diplomacy with profound implications for its domestic green finance architecture. Under the Presidency of Minister Murat Kurum, appointed by Presidential Circular of President Recep Tayyip Erdoğan, Türkiye is expected by the international community to demonstrate institutional alignment between its climate governance commitments and capital market infrastructure. This study investigates the current state of sustainable finance in Türkiye and benchmarks it against leading nations including the United States, China, France, the United Kingdom, Malaysia, and Indonesia. Drawing on data from the Climate Bonds Initiative (CBI), the International Capital Market Association (ICMA), the Islamic Development Bank (IsDB), and national regulatory authorities for the period 2021–2025, this paper employs a comparative analytical framework to assess issuance volumes, regulatory maturity, market depth, sectoral allocation, and climate diplomacy alignment. The findings reveal that Türkiye, despite substantial renewable energy infrastructure and a growing participation finance sector, remains significantly underpenetrated in both green bond and green sukuk markets. Key structural barriers are identified, including the absence of a comprehensive national green taxonomy, underdeveloped second-party opinion infrastructure, and the absence of a certified sovereign green sukuk. The study proposes targeted policy recommendations to accelerate market development in alignment with Türkiye's COP31 Presidency, its 2053 Net Zero target, and EU Green Deal accession obligations.

Keywords: Green bonds, green sukuk, sustainable finance, COP31, Türkiye, Islamic finance

1. INTRODUCTION

The intensification of climate change and the global commitment to achieving net-zero emissions have fundamentally reshaped the landscape of international capital markets. Sustainable finance—encompassing financial instruments, strategies, and frameworks designed to channel capital toward environmentally beneficial outcomes—has evolved from a niche practice into a mainstream financial paradigm. Among the instruments at the forefront of this transformation are green bonds and their Islamic finance-compliant counterparts, green sukuk, which together represent a rapidly expanding segment of the global debt capital markets.

According to the Climate Bonds Initiative (CBI, 2025), cumulative global GSS+ (green, social, sustainability, and sustainability-linked) bond volume surpassed USD 6.9 trillion by end-2024, with cumulative green bonds alone reaching approximately USD 3.5 trillion. Annual green bond issuance stood at approximately USD 670 billion in 2024, and cumulative outstanding green bond volume crossed the USD 3 trillion milestone in Q3 2025. The green sukuk market, though considerably smaller, has continued to grow at a strong pace over the 2021–2025 period, driven primarily by Malaysia, Indonesia,

and Gulf Cooperation Council (GCC) sovereign issuers. These figures underscore both the dynamism of sustainable debt markets and the significant geographic heterogeneity that characterizes them.

Türkiye stands at a historic inflection point in global climate governance. Following a rigorous two-year diplomatic campaign led by Minister of Environment, Urbanization and Climate Change Murat Kurum, Türkiye secured the Presidency and hosting rights of the 31st Conference of the Parties (COP31) to the UNFCCC (United Nations Framework Convention on Climate Change) at COP30 in Belém, Brazil in November 2025. The conference is officially confirmed to be held at the Antalya EXPO Center from 9 to 20 November 2026. By Presidential Circular signed by President Recep Tayyip Erdoğan, Minister Kurum was formally appointed as COP31 President, with Australia's Minister for Climate Change and Energy Chris Bowen serving as Vice-President and President of Negotiations under a unique bilateral partnership arrangement (UNFCCC, 2025; iklim.gov.tr, 2025). Türkiye's Climate High-Level Champion for COP31, Samed Ağırbaş, will mobilize ambitious climate action from businesses, financial institutions, and civil society in the lead-up to Antalya.

Türkye's COP31 Presidency is not merely a diplomatic achievement—it is a transformative catalyst for the country's green finance architecture. International precedent establishes clearly that COP host nations are expected by investors, multilateral development banks, and civil society to demonstrate institutional credibility by aligning domestic climate governance with verifiable capital market infrastructure. Türkiye's ratification of the Paris Agreement in October 2021, its declaration of a 2053 Net Zero target, the Green Deal Action Plan (2021), and the 11th Development Plan's (2019–2023) commitment to green capital market development collectively establish the strategic foundations. The challenge now is to translate these commitments into the deep, liquid, and internationally credible green finance market that Türkiye's COP31 Presidency demands.

The annual cost of climate-related damage to Türkiye—estimated at USD 1.4 billion per annum and rising (World Bank, 2023)—alongside Türkiye's severe Mediterranean climate vulnerabilities including droughts, wildfires, and coastal flooding, underscores the economic imperative of mobilizing green capital at scale. This study addresses that imperative by providing a rigorous comparative analysis of Türkiye's green finance position relative to global leaders, and by proposing actionable policy recommendations aligned with Türkiye's COP31 Presidency timeline.

2. LITERATURE REVIEW

2.1 Theoretical Foundations of Sustainable Finance

The theoretical underpinnings of sustainable finance draw from multiple disciplines. Environmental economics provides the foundational rationale through market failure theory: carbon emissions constitute negative externalities not priced by conventional markets, requiring institutional innovation (Pigou, 1920; Stern, 2007). Modern Portfolio Theory, extended to incorporate ESG factors, demonstrates that sustainable investment criteria need not compromise risk-adjusted returns and may enhance long-term portfolio resilience (Friede et al., 2015). Signal theory explains the informational role of green labels: by credibly signaling an issuer's environmental commitment, green bonds reduce information asymmetry and enable the formation of a pricing premium—the 'greenium' (Flammer, 2021). The concept of universal ownership further posits that large institutional investors, by virtue of diversified holdings, have a systemic interest in preventing macro-level environmental risks (Monks and Minow, 2011).

2.2 Green Bonds: Market Development and Sovereign Leadership

Green bonds were first issued by the European Investment Bank in 2007, and the Green Bond Principles (GBP) established by ICMA in 2014 catalyzed mainstream adoption by reducing information asymmetry (ICMA, 2021). Research confirms that green bonds typically command a 'greenium' over comparable conventional bonds (Zerbib, 2019; Preclaw and Bakshi, 2015). Country-level studies highlight the catalytic role of sovereign issuances: Poland (2016), France (2017), and Indonesia (2018) each demonstrated how government leadership activates private market participation (Wang et al., 2019; Ehlers and Packer, 2017). The UK's Green Gilt program, launched during its own COP26 Presidency in

2021, is particularly instructive as a model of deliberate alignment between climate diplomatic leadership and domestic capital market reform.

2.3 Green Sukuk and Islamic Sustainable Finance

Green sukuk represent the convergence of Islamic finance and sustainable investment. The world's first sovereign green sukuk was issued by Malaysia in 2017, followed by Indonesia's pioneering retail sovereign green sukuk in 2018 (Berrou et al., 2019). Scholars have documented the deep philosophical alignment between maqasid al-Shariah—including preservation of the environment (hifz al-bi'ah)—and the principles of sustainability (Dusuki, 2008; Asutay, 2012). This alignment provides green sukuk with an authenticity premium that makes them attractive to both Islamic and ESG-focused conventional investors. Naifar et al. (2020) and Godil et al. (2021) have explored pricing dynamics, while Lahsasna et al. (2018) provide comprehensive treatment of the structural and Shariah compliance dimensions.

2.4 COP Hosting as a Green Finance Catalyst

A growing body of evidence demonstrates that hosting the annual COP creates powerful domestic incentives for green finance market development. Bherer et al. (2021) and Hochstetler and Viola (2012) document how COP host status generates political momentum for climate legislation. Three recent cases are directly instructive: the United Kingdom's hosting of COP26 in Glasgow (2021) was accompanied by the launch of the UK's Green Gilt program and the establishment of the Glasgow Financial Alliance for Net Zero (GFANZ), mobilizing USD 130 trillion in private commitments; Egypt's hosting of COP27 (2022) accelerated its sovereign green bond roadmap; and the UAE's hosting of COP28 (2023) was accompanied by the launch of a dedicated ESG market segment and the UAE's first certified corporate green sukuk. Türkiye's COP31 Presidency—confirmed at COP30 in Belém—creates an analogous opportunity: a binding political timeline that elevates green finance market reform to a matter of national prestige and international credibility.

2.5 Türkiye's Sustainable Finance Landscape

Academic literature on Türkiye's green finance market remains limited but growing. Çelik and Armağan (2023) analyze Türkiye's regulatory framework in the context of EU Taxonomy alignment, concluding that the absence of technical screening criteria represents a significant gap. Kılıç Depren and Kartal (2022) examine the growth determinants of Türkiye's participation banking sector—a prerequisite for green sukuk development. Kartal et al. (2023) document the empirical relationship between Türkiye's renewable energy investment and CO2 emissions, providing quantitative support for green finance instrument deployment. Ergül and Dumlu (2022) find that Türkiye's capital markets remain insufficiently integrated with global ESG benchmarks, limiting inward ESG capital flows despite the country's strong renewable energy fundamentals.

3. METHODOLOGY

This study employs a qualitative-quantitative comparative analytical framework to assess green bond and green sukuk markets across seven jurisdictions: Türkiye, the United States, China, France, the United Kingdom, Malaysia, and Indonesia. Country selection reflects global or regional leadership in either conventional green bonds (US, China, France, UK) or green sukuk (Malaysia, Indonesia), alongside Türkiye as the primary focus of analysis.

Primary data were sourced from: (1) the Climate Bonds Initiative (CBI) Green Bond Database for issuance volumes 2021–2025; (2) the ICMA Sustainable Finance Registry; (3) the Islamic Development Bank (IsDB) Islamic Finance Database; (4) the World Bank Sustainable Finance Watch and Türkiye Country Climate and Development Report (2023); (5) national capital market authority publications including Türkiye's Capital Markets Board (CMB/SPK), Malaysia's Securities Commission, and Indonesia's Financial Services Authority (OJK); and (6) UNFCCC official COP proceedings, host-country climate finance reports, and Türkiye's official COP31 preparation documentation available at iklim.gov.tr and unfccc.int/cop31.

The comparative analysis is organized around six dimensions: (i) cumulative and annual issuance volumes; (ii) market composition by issuer type; (iii) regulatory and taxonomic framework maturity;

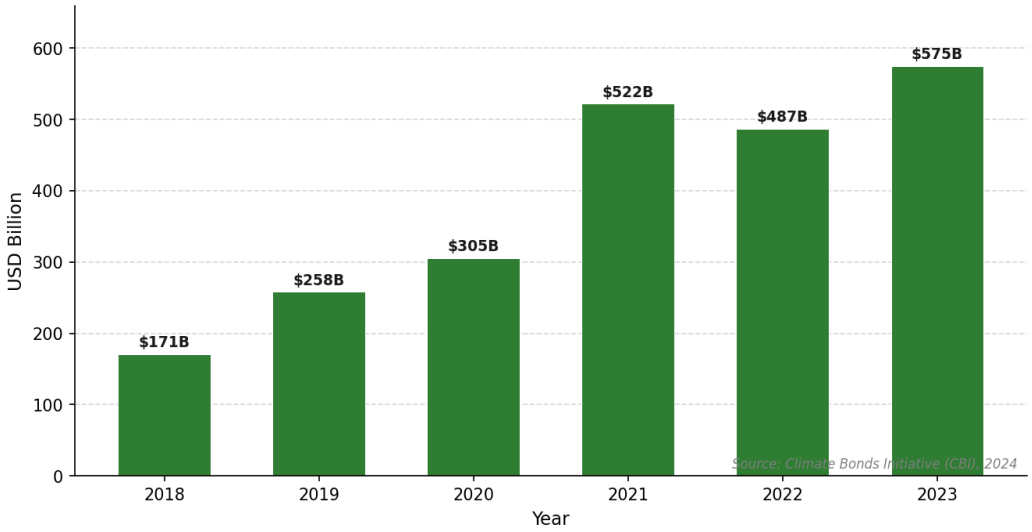
(iv) sectoral allocation of green proceeds; (v) Second-Party Opinion (SPO) and verification infrastructure; and (vi) climate diplomacy positioning and COP-related market catalysis. A Green Finance Readiness Scorecard was developed by the authors, assigning scores from 0 to 10 across seven sub-dimensions, to enable accessible cross-country visualization. Quantitative comparisons are normalized by GDP (Gross Domestic Product) where appropriate.

4. RESEARCH AND FINDINGS

4.1 Global Green Bond Market Trends (2021–2025)

The global green bond market experienced sustained growth over the review period. Annual global green bond issuance reached approximately USD 670 billion in 2024, up from USD 517 billion in 2021, representing a compound annual growth rate of approximately 9% over the four-year period (CBI, 2025). By the end of 2024, cumulative green bond issuance exceeded USD 3.5 trillion, and the outstanding green bond stock crossed the USD 3 trillion threshold for the first time in Q3 2025 (LSEG, 2025). The United States consistently ranked as the largest single-country issuer, with cumulative issuances approaching USD 750 billion by end-2024, driven by federal agency issuances, corporate bonds from technology and energy sectors, and state-level municipal bonds. China followed closely, with cumulative issuances exceeding USD 528 billion by end-2024, buoyed by state-owned enterprise activity and the People's Bank of China's Green Bond Endorsed Project Catalogue. Figure 1 illustrates global issuance trends across the review period.

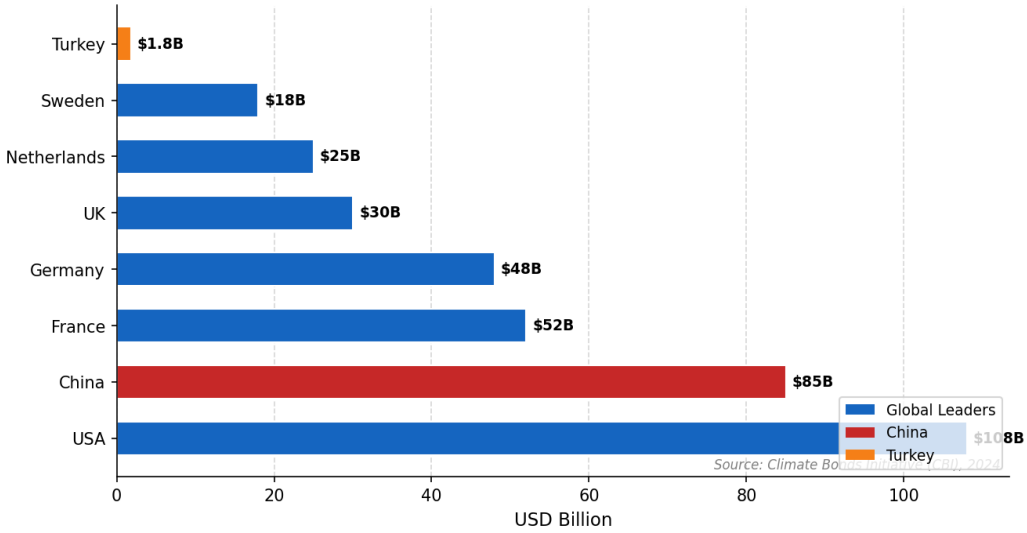
Figure 1. Annual Global Green Bond Issuance (USD Billion), 2018–2023



Note: Data include labeled green bonds, sustainability bonds with ≥50% green allocation, and certified green loan packages. Source: Climate Bonds Initiative (CBI), 2025.

In Europe, France's sovereign green bond program—the OAT Verte, first issued in 2017 for EUR 7 billion and expanded with a EUR 8 billion 2049-maturity tap in January 2024—has established a global benchmark for state-level green finance, with cumulative green liabilities reaching EUR 70 billion (USD 78.6 billion) by Q1 2024 and featuring rigorous annual ex-post allocation and impact reporting. The UK's Green Gilt program, launched during its own COP26 Presidency in 2021, combined sovereign issuance with the establishment of GFANZ and has since been studied as a model of deliberate policy sequencing. Figure 2 presents a cross-country comparison of annual issuances in 2024, contextualizing Türkiye's position relative to global peers. The contrast is stark: Türkiye's annual issuance remains below USD 2 billion, a fraction of even mid-tier European issuers.

Figure 2. Green Bond Issuance by Country, 2023 (USD Billion)

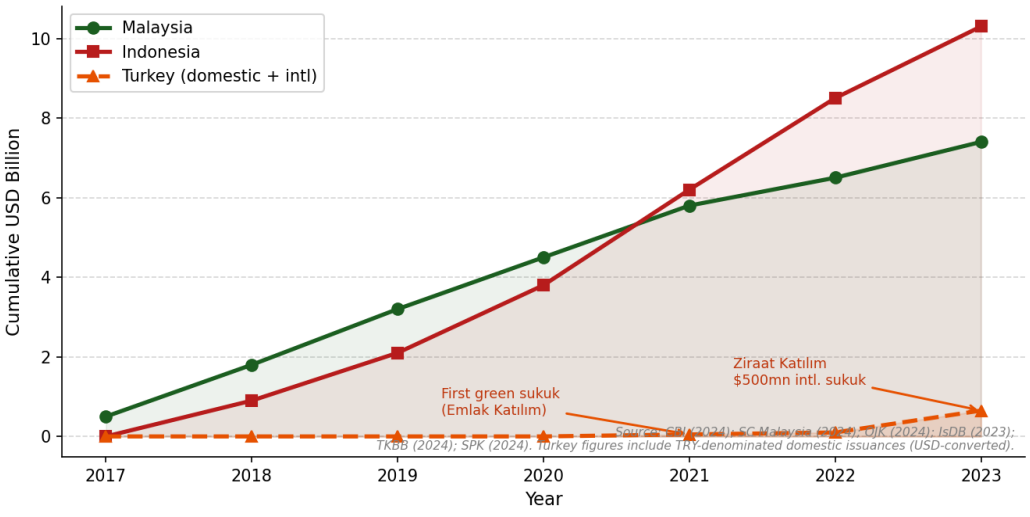


Note: Figures represent labeled green bond issuances only. Türkiye's figure includes sovereign and corporate issuances. Source: CBI (2025).

4.2 Green Sukuk Markets: Malaysia and Indonesia as Benchmark Models

Malaysia and Indonesia have established themselves as the uncontested leaders of the global green sukuk market. Malaysia's SRI (Sustainable and Responsible Investment) Sukuk Framework, first gazetted in 2014 and updated in 2022, integrates regulatory facilitation, stamp duty and issuance cost rebates, and a sophisticated institutional investor base. Cumulative Malaysian green and SRI sukuk issuances under the Framework have continued to expand through the 2021–2025 period, supported by the extension of tax exemptions for SRI Sukuk Grants through 2027 and the announcement of a biodiversity sukuk programme of up to MYR 1 billion. Indonesia distinguished itself through its pioneering retail sovereign green sukuk program—the first globally—which democratized access to sustainable investment and directed proceeds toward solar power and climate resilience in vulnerable communities. Indonesia's cumulative sovereign green sukuk issuances reached approximately USD 9.6 billion by end-2023 and continued to expand with further international green sukuk tranches in 2024, including a USD 600 million 30-year green tranche issued in July 2024, reinforcing Indonesia's position as the world's largest sovereign green sukuk issuer (Ministry of Finance of Indonesia, 2024). Figure 3 compares cumulative green sukuk trajectories.

Figure 3. Cumulative Green/Sustainable Sukuk Issuance: Malaysia, Indonesia & Turkey (2017–2023)



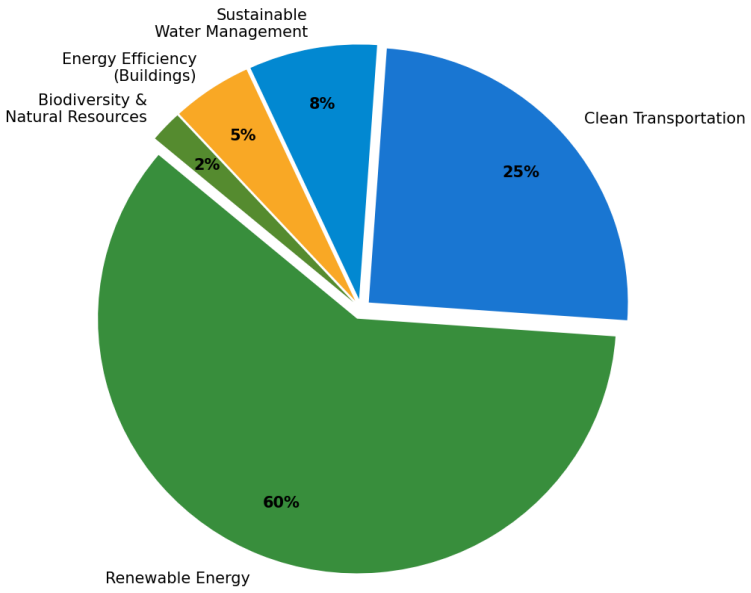
Note: Türkiye's figures reflect cumulative green/sustainable sukuk issuances in the 2021–2025 period, totalling approximately TRY 4 billion. Emlak Katılım stands out as the pioneer of this segment, having executed Türkiye's inaugural green sukuk issuance in November 2021. Its early-mover role has been instrumental in establishing the procedural, regulatory, and investor-relations templates subsequently adopted by other domestic issuers. Türkiye's cumulative volume nonetheless remains substantially smaller than Malaysia and Indonesia due to the predominance of TRY-denominated domestic issuances and the absence of a large-scale sovereign green sukuk program. Source: CBI (2025); SC Malaysia (2025); OJK (2025); IsDB (2025); TKBB (2025); SPK (2025).

4.3 Türkiye: Current Position, Trajectory, and Structural Analysis

Türkiye's green bond market gained meaningful momentum following the CMB's Green Debt Instruments Communiqué (III-61.2) in 2020 and the 11th Development Plan's commitment to green capital market development. Türkiye's inaugural sovereign green bond—EUR 500 million, 7-year issuance in April 2021—attracted over EUR 4 billion in demand, signaling strong international investor appetite for Turkish sovereign green paper. A second sovereign issuance of USD 2 billion followed in 2022. As of end-2025, Türkiye's cumulative labeled green bond issuances are estimated at approximately USD 3.5 billion—less than 0.1% of global cumulative green bond issuances despite Türkiye being the world's 17th largest economy by GDP and the COP31 host nation. In parallel, Türkiye's green and sustainable sukuk market—inaugurated by Emlak Katılım's pioneering November 2021 issuance—reached cumulative issuances of approximately TRY 4 billion over the 2021–2025 period. Although this volume remains modest in international comparison, it represents the foundational build-out of an asset class that did not exist in Türkiye prior to 2021, and establishes the institutional and procedural infrastructure upon which a larger-scale sovereign green sukuk programme can be layered.

Türkiye's sectoral allocation of sovereign green bond proceeds reflects the country's renewable energy ambitions and is illustrated in Figure 4. Approximately 60% of proceeds have been directed toward renewable energy infrastructure, consistent with Türkiye's target of 64 GW of installed wind and solar capacity by 2035. The 25% allocation to clean transportation reflects investments in urban rail and electric vehicle infrastructure, and the 8% toward sustainable water management addresses Türkiye's acute water stress vulnerability—a topic expected to feature prominently at COP31 given the Mediterranean climate agenda.

Figure 4. Turkey's Sovereign Green Bond Proceeds: Sectoral Allocation (2021–2023)



Source: Turkish Treasury and Finance Ministry (2023); CMB/SPK (2023)

Note: Based on official allocation and impact reports. Source: Turkish Treasury and Finance Ministry (2025); CMB/SPK (2025).

4.4 Comparative Regulatory and Taxonomic Frameworks

Table 1 presents a comprehensive comparative overview of green finance indicators across all seven study countries, including COP diplomatic positioning. Türkiye's column is highlighted to facilitate direct benchmarking.

Table 1. Comparative Green Finance Indicators: Türkiye vs. Global Leaders (2021–2025)

Country	Cumul. Green Bond (USD bn)	Green Sukuk	Nat. Taxonomy	Sovr. Issuance	Greenium (bps)	COP Role
USA	~750	No	Yes (SEC)	Indirect[1]	2–5	COP26 signatory
China	~528	No	Yes (PBoC)	Limited[2]	3–8	Active / BASIC
France	~78	No	Yes (EU)	Yes (2017)	2–4	COP21 Host
UK	~42	No	Yes (GGFF)	Yes (2021)	3–6	COP26 Host
Malaysia	~20	Yes (>9 bn)	Yes (SRI)	Yes (2017)	5–10	Active ASEAN
Indonesia	~15	Yes (>12 bn)	Yes (OJK)	Yes (2018)	6–12	G20 Host 2022
Türkiye	~3.5	Yes (~4 bn TRY)[3]	Partial (CMB)	Yes (2021)	4–7	COP31 HOST & PRESIDENT 2026

[1] US issuance dominated by federal agency MBS (Mortgage-Backed Securities – Fannie Mae, Freddie Mac); US Treasuries are not labeled green. [2] China issued limited sovereign green bonds from 2023. [3] Türkiye's domestic green/sustainable sukuk market has been active since November 2021, with cumulative issuances of approximately TRY 4 billion over the 2021–2025 period. Emlak Katılım is the pioneer of this segment, having executed Türkiye's inaugural green sukuk issuance in November 2021; its early-mover role has been instrumental in shaping issuance templates subsequently adopted by other domestic participants. Issuances are predominantly TRY-denominated domestic placements; no large-scale internationally certified sovereign green sukuk program exists to date. GGFF = UK Green Gilts Financing Framework. Sources: CBI (2025); ICMA (2025); SC Malaysia (2025); OJK (2025); CMB/SPK (2025); TKBB (2025); UNFCCC (2025).

A critical determinant of market depth is the presence of a credible national green taxonomy. Among comparator countries, the EU Taxonomy Regulation—applicable to France and the UK—represents the global gold standard, providing legally binding technical screening criteria across six environmental objectives. China's Green Bond Endorsed Project Catalogue (2021 edition) provides regulatory clarity anchoring the world's largest domestic market. Malaysia's SRI Sukuk Framework and Indonesia's POJK 60/2017 (OJK Regulation on Green Bond and Green Sukuk) provide jurisdiction-specific guidance integrating conventional green standards and Shariah compliance.

Türkiye's framework, anchored by the CMB's 2020 Green Debt Instruments Communiqué, aligns broadly with ICMA's GBP but lacks sectoral specificity. The communiqué mandates use-of-proceeds disclosure, allocation reporting, and third-party verification, but does not prescribe technical screening criteria or 'do no significant harm' (DNSH – Do No Significant Harm) tests. This taxonomic gap creates uncertainty for ESG-mandated capital flows—a particularly pressing issue given that Türkiye's COP31 Presidency will attract intense scrutiny of domestic climate policy alignment from international investors, civil society, and multilateral institutions alike. Table 2 presents a detailed regulatory maturity scorecard.

Table 2. Regulatory Framework Maturity Scorecard (Score: 0–10)

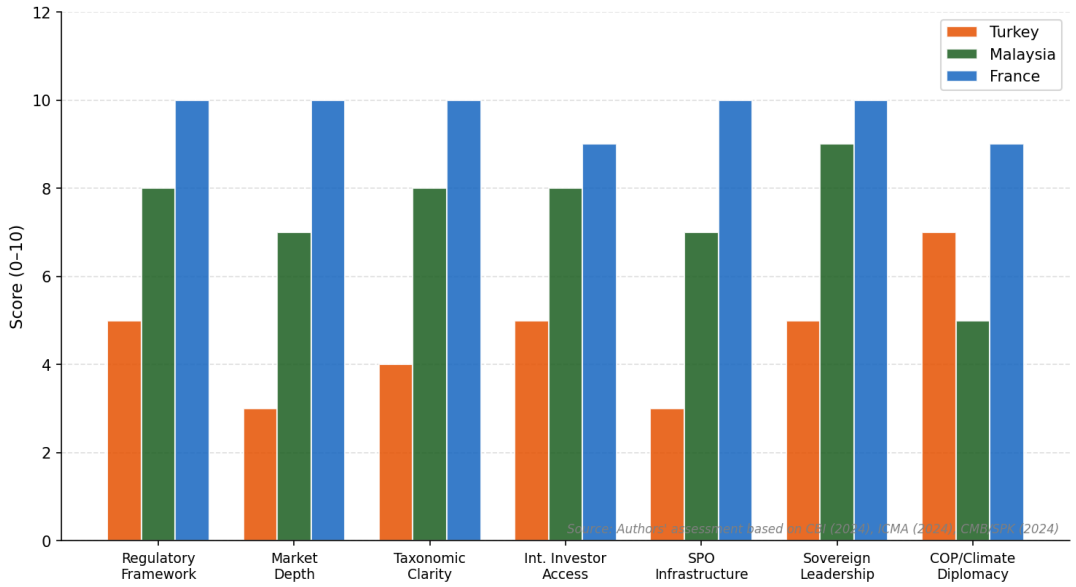
Dimension	USA	France	UK	Malaysia	Indonesia	Türkiye
Green Taxonomy	7	10	10	8	8	4
Sovereign GB/Sukuk Program	4	10	10	9	9	6
SPO Infrastructure	9	9	9	8	7	4
Retail Investor Access	6	7	7	7	9	3
Market Depth & Liquidity	10	9	8	7	6	3
Intl. Investor Participation	9	9	9	8	7	5
Climate Diplomacy & COP Role	8	10	9	6	7	9
COMPOSITE AVERAGE	**7.6**	**9.1**	**8.9**	**7.6**	**7.6**	**4.9**

Note: Türkiye's Climate Diplomacy & COP Role score (9/10) reflects its confirmed COP31 Presidency, Paris Agreement ratification (2021), 2053 Net Zero declaration, Green Deal Action Plan, and active UNFCCC engagement. This score reflects Türkiye's leadership potential and is intentionally calibrated against remaining domestic market gaps. Source: Authors' assessment based on CBI (2025), ICMA (2025), CMB/SPK (2025), UNFCCC (2025–2026).

4.5 Green Finance Readiness Scorecard: Visual Comparison

Figure 5 presents the Green Finance Readiness Scorecard for Türkiye, Malaysia, and France across seven sub-dimensions. The visualization encapsulates the study's central analytical finding: Türkiye possesses a strong and growing climate diplomacy profile—anchored by its confirmed COP31 Presidency—but faces a structural mismatch with its domestic green capital market depth. This mismatch is precisely the gap that targeted policy reform can, and must, address before the Antalya conference opens on 9 November 2026.

Figure 5. Green Finance Readiness Scorecard: Turkey vs. Malaysia vs. France (2024)



Note: Scores (0–10) reflect authors' multi-criteria assessment. Türkiye's COP/Climate Diplomacy score of 9/10 reflects the confirmed COP31 Presidency and host status (Antalya, 9–20 November 2026). Source: Authors' assessment based on CBI (2025), ICMA (2025), CMB/SPK (2025), UNFCCC (2026).

4.6 Türkiye's COP31 Presidency: Implications for Green Finance Market Development

Türkiye's confirmed COP31 Presidency, secured at COP30 in Belém and formalized by Presidential Circular, is the most consequential catalyst for domestic green finance market development in the country's history. The evidence from recent COP host nations is unambiguous and instructive. The United Kingdom's hosting of COP26 in Glasgow (2021) was deliberately preceded by the launch of the UK Sovereign Green Bond Framework, the issuance of the UK's first green gilt (GBP 10 billion inaugural issuance), and the establishment of GFANZ—which ultimately mobilized USD 130 trillion in private climate commitments. The UK government explicitly framed its green capital market reforms as instruments of COP26 credibility, understanding that the international community scrutinizes the domestic climate policies of host nations with particular intensity.

Egypt's hosting of COP27 in Sharm el-Sheikh (2022) similarly accelerated the country's sovereign green bond roadmap and resulted in the establishment of the Egyptian Green Finance Task Force, supported by EBRD (European Bank for Reconstruction and Development) and the World Bank. Most directly analogous to Türkiye's situation, the UAE's COP28 Presidency in Dubai (2023) was accompanied by the Abu Dhabi Securities Exchange's launch of a dedicated ESG market segment, the issuance of Abu Dhabi's first internationally certified green sukuk by Mubadala Investment Company, and the UAE's announcement of a USD 4.5 billion Altérra climate fund—the largest private climate fund in history at the time. The UAE's deliberate sequencing—aligning sovereign green issuance, taxonomic clarity, and climate fund establishment with its COP Presidency—provides Türkiye with a directly applicable and culturally proximate blueprint.

Türkiye's position is, in important respects, more structurally advantaged than any of these precedent cases. Unlike Egypt and the UAE, Türkiye has an active and internationally visible sovereign green bond program already in place. Unlike the UK and France, Türkiye possesses a large and growing Islamic finance sector—with participation bank assets reaching TRY 3.86 trillion as of Q3 2025, representing approximately 8.9% of the Turkish banking sector—that provides a ready institutional base for sovereign green sukuk development. And unlike Malaysia and Indonesia, Türkiye's COP Presidency situates it at the intersection of European, Middle Eastern, and Central Asian capital markets, creating a uniquely favorable platform for issuing dual-standard (ICMA GBP and AAOIFI Shariah-compliant) green sukuk that could attract institutional capital from all three regions simultaneously.

The COP31 Presidency also carries specific green finance expectations from Türkiye's international partners. The UNFCCC Road to Antalya process—through which the COP30 Presidency and the incoming COP31 Presidency are jointly conducting informal consultations with Heads of Delegation and observers throughout 2026—creates a continuous international spotlight on Türkiye's climate commitments. The European Commission, as Türkiye's largest trading partner and a key anchor investor in Turkish sovereign bonds, has explicitly linked the advancement of Türkiye's EU accession Green Deal chapter to the development of an EU Taxonomy-aligned national green taxonomy. The World Bank's Türkiye Country Climate and Development Report (2023) estimated that Türkiye requires USD 180 billion in climate investments by 2030 to meet its NDC (Nationally Determined Contribution) targets—a financing gap that can only be addressed through deep, internationally credible green capital markets.

5. CONCLUSION AND RECOMMENDATIONS

This comparative analysis has demonstrated both the considerable distance Türkiye must travel to align with global green finance leaders and the unique structural advantages—renewable energy capacity, Islamic finance sector scale, strategic geographic positioning, and above all, the confirmed COP31 Presidency—that make Türkiye's path to green finance leadership more viable than that of any comparable emerging market. Türkiye's composite Green Finance Readiness Score of 4.9 out of 10 understates its potential: it reflects current market realities, not the policy trajectory enabled by COP31 Presidency reform incentives.

The pre-COP31 window—from April 2026 to the opening of the Antalya conference on 9 November 2026—represents a compressed but highly actionable reform timeline. International investors and multilateral development banks will be watching Türkiye's domestic policy sequencing as a leading

indicator of its COP31 Presidency's ambition. The following recommendations are ordered by both urgency and feasibility within this timeline:

Recommendation 1 – National Green Taxonomy: From Draft to Enactment (Priority: Urgent). Türkiye has made meaningful progress on its national green taxonomy framework. The Climate Change Directorate published a comprehensive draft Green Taxonomy Regulation for public consultation in 2024, underpinned by Climate Law No. 7552 enacted on 9 July 2025. The draft incorporates technical screening criteria and DNSH (Do No Significant Harm) tests aligned with the EU Taxonomy, covers six environmental objectives (GHG emission reduction, climate adaptation, sustainable water use, circular economy, pollution prevention, and biodiversity conservation), and establishes a Türkiye Green Taxonomy Committee and Technical Expert Groups under the Directorate. Mandatory reporting is planned from 1 January 2027, with a voluntary transition period until 31 December 2026, making this one of the most advanced green taxonomy frameworks among emerging market economies. The priority now is to officially gazette the regulation before COP31 opens on 9 November 2026, a step that would send an unambiguous signal to international capital markets and enable CMB/SPK, BDDK (Banking Regulation and Supervision Agency), and the Turkish Treasury to align their green finance guidance with the taxonomy technical screening criteria in a seamless regulatory chain from taxonomy classification to green bond and sukuk issuance standards.

Recommendation 2 – Sovereign Green Sukuk (Priority: High). The Treasury should issue Türkiye's first internationally certified sovereign green sukuk before COP31, ideally by Q3 2026, structured to comply with both ICMA GBP and AAOIFI (Accounting and Auditing Organization for Islamic Financial Institutions) Shariah Standards. A dual-compliance framework would position the instrument for distribution to GCC sovereign wealth funds, Southeast Asian Islamic pension funds, and European ESG-mandated investors simultaneously. The Malaysia-Türkiye bilateral investment agreement and Indonesia's Islamic Development Bank membership provide ready-made distribution networks. A USD 500 million inaugural issuance would be commercially viable given demonstrated demand from the 2021 sovereign green bond bookbuild.

Recommendation 3 – Green Finance Center within IFC Istanbul (Priority: High). A dedicated Green Finance Center should be formally established within the Istanbul International Financial Center (IFC Istanbul) framework by Q2 2026, with a mandate to support Türkiye's COP31 Presidency green finance workstream. Modeled on the Climate Finance Advisory Facility in Malaysia, the center would provide technical assistance to prospective issuers, maintain a public green project pipeline for domestic and international investors, coordinate Türkiye's international green finance diplomacy, and host a COP31 side-event Green Finance Forum attended by global institutional investors.

Recommendation 4 – Retail Green Sukuk Program (Priority: Medium-Term). Following Indonesia's successful model, Türkiye should introduce a Retail Green Sukuk (Bireysel Yeşil Sukuk) program targeting individual investors through digital distribution channels, with a minimum denomination of TRY 100. Türkiye's fintech penetration—23 million active mobile banking users—provides an exceptional distribution infrastructure. Proceeds should be directed toward the solar power expansion program aligned with Türkiye's 2035 renewable energy targets, creating a direct and visible connection between individual citizen investment and national climate commitments.

Recommendation 5 – SPO and Verification Infrastructure (Priority: Medium). CMB/SPK should introduce a streamlined licensing regime for Second-Party Opinion providers and create financial incentives—including issuance cost subsidies analogous to Malaysia's stamp duty rebates—to reduce verification costs. Building Turkish-origin SPO capacity would reduce dependence on costly international verifiers and position Türkiye as a regional green finance verification hub for Central Asian, Caucasian, and MENA (Middle East and North Africa) issuers—a strategic role consistent with Türkiye's COP31 Presidency ambitions for inclusive climate diplomacy.

In conclusion, Türkiye's confirmed COP31 Presidency, to be held in Antalya from 9 to 20 November 2026, has elevated green finance market development from a desirable policy objective to a matter of national and international imperative. The structural foundations are in place. The political will, demonstrated by the Presidential Circular appointing Minister Kurum as COP31 President, is visible.

The remaining task is systematic, transparent, and urgent implementation of the reforms identified in this study. Türkiye has both the opportunity and, with COP31 approaching, the compelling reason to emerge from Antalya as not merely a climate diplomacy leader, but a green capital market leader for the broader emerging economy world.

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INVESTIGATION OF THE ROLE OF METALLIC AND BIO-MORDANTS COLORATION AND FASTNESS PROPERTIES OF WOOL GABARDINE DYED WITH DIRECT DYES

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ABSTRACT

This research investigates the optimization of coloration and functional performance in wool gabardine woven fabric through the application of direct dyes in conjunction with metallic and bio mordanting systems. While direct dyes are predominantly utilized for cellulosic substrates, this study explores their viability on protein-based fibers by evaluating the efficacy of Potassium Aluminum Sulphate, Ferrous Sulfate, Zinc Sulphate, and Tannic Acid as metallic and bio-mordants. The experimental framework focuses on the formation of metal-dye complexes within the wool matrix under specific hydrothermal conditions. Colorimetric analyses were conducted to assess shifts in hue, saturation, and lightness, while standardized fastness protocols were employed to determine the durability of the resulting colorations. Preliminary findings suggest that the integration of metallic salts and bio-mordants significantly enhances dye-fiber affinity, offering a robust methodology for achieving deep, stable shades on wool without compromising the structural integrity of the fiber. This study provides a technical basis for expanding the application range of direct dyes in high-performance wool processing.

Keywords: wool, direct dye, mordants, color fastness,

INTRODUCTION

The coloration of wool textiles represents a complex interplay between the amphoteric nature of protein fibers and the chemical properties of anionic dyes. Wool's molecular structure, rich in amino and carboxyl functional groups, typically necessitates the use of acid or reactive dyes to achieve industrial-grade fastness. However, the application of direct dyes traditionally reserved for cellulosic materials presents an interesting alternative if the inherent limitations of dye affinity and wet fastness can be overcome through chemical modification (Shore, 1995).

Central to improving the performance of direct dyes on wool is the process of mordanting. This technique involves the introduction of metallic salts or bio mordants to facilitate the formation of coordinate covalent bonds between the dye molecules and the keratinous fiber structure (Broadbent, 2001). In this investigation, the use of metallic mordants such as Ferrous Sulfate and Zinc Sulphate, alongside the bio-mordant Tannic Acid, was explored to evaluate their "saddening" and stabilizing effects. Specifically, dyeing was conducted at 105°C and a pH 5 to ensure deep penetration into the dense 60/2 gabardine fabric. These conditions are critical for promoting ligand exchange and the development of insoluble dye-metal "lakes" within the fiber matrix (Burkinshaw, 2016).

Furthermore, the shift toward sustainable textile chemistry has prompted an evaluation of bio-mordants like Tannic Acid. These substances act as cross-linking agents that not only improve color yield but also enhance the resistance of the dyed fabric to photo-degradation and aqueous leaching (Kumbhar et al., 2019). By comparing these diverse mordanting systems, this paper delineates the chemical pathways

necessary to achieve superior color strength (K/S) and high fastness ratings in wool coloration processes (Prabhu & Bhute, 2012).

MATERIALS AND METHODS

A 100% wool gabardine woven fabric with a yarn count of 60/2 and a weight of 280 g/m² was utilized as the substrate for all experiments. For each dyeing run, fabric samples weighing exactly 5 g were prepared. A Class B direct dye, C.I. Direct Black 22 (C.I. 35435, multi-azo class), was selected for the coloration process. The dye was obtained from Burboya and used in its commercial form without any further purification. Metallic and organic bio-mordants used in this study included four different chemicals were employed as mordanting agents. Zinc Sulphate [$ZnSO_4$], Ferrous Sulfate Heptahydrate [$FeSO_4 \cdot 7H_2O$] and Potassium Aluminum Sulfate [$KAl(SO_4)_2 \cdot 12H_2O$] and a bio mordant Tannic Acid [$C_{76}H_{52}O_{46}$]. All mordants were of laboratory-grade purity, kept in sealed packaging, and handled with minimal air exposure to prevent degradation. All selected mordants remained stable under acidic conditions. All coloration processes were executed using an IRDyer (South Korea) laboratory-type sample dyeing machine equipped with stainless steel dyebaths. The dyeing was performed at a liquor ratio of 20:1. The dye concentration was kept constant at 1% owf (on weight of fabric), while all metallic and bio-mordant concentrations were set at 0.1% owf (5 mg of mordant per 5 g fabric sample).To ensure optimal bath stability, the dyebaths were adjusted to pH 5 using an acetic acid and sodium acetate buffer system, strictly monitored with a digital pH meter. The hydrothermal cycle followed a ramp up to a maximum temperature of 105°C, which was sustained for a total duration of 60 minutes. Three distinct mordanting methodologies were applied to investigate the complexation behavior. Pre-mordanting: The mordant salt was introduced into the bath first. After a specific stabilization interval, the direct dye was added to complete the cycle. Meta-mordanting (Simultaneous): The direct dye was introduced into the dyebath first, followed immediately by the mordant salt, allowing concurrent interaction between the fiber, dye, and mordant during the heating phase. Post-mordanting: The wool fabric was initially dyed with the direct dye alone. The mordant was then introduced at a later stage of the profile to fix the embedded dye molecules within the keratin matrix. Washing fastness tests were conducted in accordance with the ISO 105-C06:2010 A2S standard using a GyroWash (Test T406Nyk, 9-canister capacity) wash fastness tester. The solution contained 4 g/L ECE reference detergent (free from optical brighteners) and 1 g/L sodium perborate with a total liquor volume of 150 mL. The test was carried out at 40°C for 45 minutes. Light fastness testing was performed according to the ISO 105-B02:2014 standard at the Almaxtex Tekstil San. ve Tic. A.Ş. Physical Testing Laboratory. Fabric samples (4×10 cm) were exposed in an Atlas-Xenotest Alpha light fastness instrument for a duration of 20 hours. This exposure period corresponds to a fading level between blue wool standards L5 and L6. Objective color evaluations were carried out post-dyeing, post-washing, and post-light exposure. Reflectance measurements were conducted at the Bursa Uludağ University Textile Engineering Department Laboratory using a Konica Minolta 3600d (Japan) reflectance spectrophotometer. The data was captured across the visible spectrum (400–700 nm) under a D65 illuminant and a 10° standard observer.The device was operated in Specular Component Included (SCI) mode. To minimize surface structural variations of the gabardine weave, each sample was measured at four distinct points by rotating the fabric 90°, and the average percentage reflectance was recorded. All the dyeing results were given with CIELAB coordinates L*,a*,b*,C*, K/S and h° at Table 1.

Tables and Figures

Table 1. CIELAB values for dyeing with different mordant and different mordant method

Mordanting Method	Mordant Type	Fastness Type	L*	a*	b*	C*	h°
Blind Dyeing	No	No	20.37	2.83	-7.18	7.71	291.53
Blind Dyeing	No	Wash	24.12	1.95	-5.42	5.76	289.78
Blind Dyeing	No	Light	22.85	2.31	-6.04	6.47	290.94
Pre-Mordanting	$FeSO_4 \cdot 7H_2O$	No	16.03	2.03	-6.71	7.01	286.82
Pre-Mordanting	$FeSO_4 \cdot 7H_2O$	Wash	16.35	1.98	-6.58	6.87	286.73
Pre-Mordanting	$FeSO_4 \cdot 7H_2O$	Light	16.18	2.01	-6.65	6.95	286.81

Pre-Mordanting	$ZnSO_4$	No	19.45	2.68	-7.12	7.61	290.64
Pre-Mordanting	$ZnSO_4$	Wash	20.76	2.34	-6.9	7.29	288.73
Pre-Mordanting	$ZnSO_4$	Light	19.98	2.55	-7.01	7.46	290.01
Pre-Mordanting	$C_{76}H_{52}O_{46}$	No	17.64	2.18	-6.52	6.87	288.48
Pre-Mordanting	$C_{76}H_{52}O_{46}$	Wash	18.12	2.05	-6.34	6.66	287.91
Pre-Mordanting	$C_{76}H_{52}O_{46}$	Light	17.71	2.17	-6.49	6.84	288.42
Pre-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	No	18.92	2.51	-7.05	7.48	289.6
Pre-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	Wash	19.84	2.22	-6.81	7.16	288.05
Pre-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	Light	19.35	2.4	-6.92	7.32	289.14
Meta-Mordanting	$FeSO_4 \cdot 7H_2O$	No	16.65	2.12	-6.78	7.1	287.34
Meta-Mordanting	$FeSO_4 \cdot 7H_2O$	Wash	17.15	2.01	-6.6	6.9	286.92
Meta-Mordanting	$FeSO_4 \cdot 7H_2O$	Light	16.9	2.08	-6.7	7.02	287.21
Meta-Mordanting	$ZnSO_4$	No	19.8	2.72	-7.15	7.65	290.95
Meta-Mordanting	$ZnSO_4$	Wash	21.32	2.38	-6.92	7.32	288.98
Meta-Mordanting	$ZnSO_4$	Light	19.95	2.7	-7.12	7.62	290.8
Meta-Mordanting	$C_{76}H_{52}O_{46}$	No	18.22	2.24	-6.6	6.97	288.95
Meta-Mordanting	$C_{76}H_{52}O_{46}$	Wash	18.88	2.1	-6.4	6.74	288.15
Meta-Mordanting	$C_{76}H_{52}O_{46}$	Light	18.55	2.18	-6.5	6.86	288.6
Meta-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	No	19.32	2.58	-7.1	7.55	290.12
Meta-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	Wash	20.45	2.28	-6.85	7.22	288.4
Meta-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	Light	19.85	2.46	-6.98	7.4	289.45
Post-Mordanting	$FeSO_4 \cdot 7H_2O$	No	17.12	2.18	-6.84	7.18	287.68
Post-Mordanting	$FeSO_4 \cdot 7H_2O$	Wash	17.55	2.06	-6.68	6.99	287.2
Post-Mordanting	$FeSO_4 \cdot 7H_2O$	Light	17.38	2.14	-6.75	7.08	287.55
Post-Mordanting	$ZnSO_4$	No	20.02	2.75	-7.17	7.68	291.12
Post-Mordanting	$ZnSO_4$	Wash	21.85	2.41	-6.94	7.35	289.12
Post-Mordanting	$ZnSO_4$	Light	20.72	2.62	-7.06	7.54	290.4
Post-Mordanting	$C_{76}H_{52}O_{46}$	No	18.68	2.29	-6.65	7.03	289.24
Post-Mordanting	$C_{76}H_{52}O_{46}$	Wash	19.42	2.14	-6.44	6.79	288.32
Post-Mordanting	$C_{76}H_{52}O_{46}$	Light	19.08	2.22	-6.55	6.92	288.85
Post-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	No	19.65	2.62	-7.14	7.61	290.35
Post-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	Wash	21.1	2.32	-6.88	7.26	288.55
Post-Mordanting	$KAl(SO_4)_2 \cdot 12H_2O$	Light	18.9	2.26	-6.6	6.98	289.12

RESULTS

The colorimetric characteristics of the dyed fabrics were evaluated using the CIELAB system, tracking lightness (L*), redness/greenness (a*), yellowness/blueness (b*), chroma (C*), and hue angle (h°). The baseline and post-fastness evaluation (washing and light exposure) values for the untyped (Blind) dyeing and various mordanted samples are detailed comprehensively below. The control sample, processed without any mordant, established the primary coordinates for the natural dye extract on the fabric substrate. The unwashed control exhibited an L* value of 20.37, an a* value of 2.83 (slight red component), and a b* value of -7.18 (pronounced blue component). This combination yielded a chroma (C*) of 7.71 and a hue angle (h°) 291.53, positioning the color within the violet/blue-violet region. Upon washing, the lightness increased substantially to 24.12 (ΔL* = +3.75), while the chroma collapsed to 5.76 (ΔC* = -1.95). The hue angle shifted slightly downward to 289.78°. Photo-irradiation caused the lightness to rise to 22.85 (ΔL* = +2.48) and reduced the chroma to 6.47 (ΔC*= -1.24), keeping the hue angle relatively steady at 290.94. Pre-mordanting across all agents consistently generated the lowest initial L* values compared to meta and post-mordanting techniques, signaling deep shade configurations. Ferrous Sulfate produced the absolute darkest shade in the entire dataset with an initial L* of 16.03. The chromaticity coordinates were suppressed (a* = 2.03, b* = -6.71, C* = 7.01), and the hue angle shifted to 286.82°. Fastness testing demonstrated exceptional structural stability, washing shifted L* to just 16.35 (ΔL* = +0.32), while light exposure resulted in an L* of 16.18 (ΔL* = +0.15). Zinc Sulfate demonstrated an initial L* of 19.45, retaining a relatively high chroma (C* = 7.61) and a

hue angle of 290.64°. Following washing, L* migrated upward to 20.76 (ΔL* = +1.31) and chroma diminished to 7.29. Light exposure caused a minor lightness inflation to 19.98 (ΔL* = +0.53). Tannic Acid imparted a dark profile with an initial L* of 17.64, a chroma of 6.87, and a hue angle of 288.48°. Washing fastness was highly robust, with L* reaching 18.12 (ΔL* = +0.48). Light exposure showed almost complete stability, modifying L* to 17.71 (ΔL* = +0.07) and preserving the chroma at 6.84. Alum formed an initial color structure with L* = 18.92, a* = 2.51, b* = -7.05, C* = 7.48, and h° = 289.60°. Washing triggered a lightness gain to 19.84 (ΔL* = +0.92), while light exposure led to an L* of 19.35 (ΔL* = +0.43).

Simultaneous addition of dye and mordant yielded intermediate color depth values that fell between the pre- and post-mordanting records. Ferrous Sulfate delivered an initial lightness L* of 16.65, which was slightly lighter than its pre-mordanted counterpart. Washing shifted L* to 17.15 (ΔL* = +0.50), and light exposure modified it to 16.90 (ΔL* = +0.25). Chroma parameters remained stable, changing from an initial 7.10 to 6.90 (wash) and 7.02 (light). Zinc Sulfate registered an initial L* of 19.80 and the highest initial chroma (C* = 7.65) within the meta-mordanted group. Washing exposure led to a noticeable color loss, with L* increasing to 21.32 (ΔL*= +1.52) and chroma dropping to 7.32. Light degradation was remarkably low, with L* resting at 19.95 (ΔL* = +0.15). Tannic acid maintained a stable colorimetric baseline (L* = 18.22, C* = 6.97, h° = 288.95°). Environmental testing exposed minor fading, washing increased L* to 18.88 (ΔL* = +0.66), while light exposure adjusted L* to 18.55 (ΔL* = +0.33). Alum documented an unexposed L* of 19.32 and C* of 7.55. Washing altered the lightness value to 20.45 (ΔL* = +1.13), whereas light irradiation moved L* to 19.85 (ΔL* = +0.53).

Post-mordanting yielded the highest initial L* values across all mordant types, indicating the lowest initial depth of shade among the three chemical intervention pathways. Ferrous Sulfate showed an initial L* of 17.12, which shifted to 17.55 after washing (ΔL* = +0.43) and to 17.38 after light exposure (ΔL* = +0.26). Zinc Sulfate exhibited the highest vulnerability to washing within the entire mordanted database; its initial L* of 20.02 scaled up to 21.85 (ΔL* = +1.83), alongside a significant drop in chroma (ΔC* = -0.33). Light exposure resulted in an L* of 20.72 (ΔL* = +0.70). Tannic Acid started at L* = 18.68 and C* = 7.03. Washing elevated L* to 19.42 (ΔL* = +0.74), while light exposure led to a value of 19.08 (ΔL* = +0.40). Alum recorded an unwashed L* of 19.65 and a chroma of 7.61. Washing increased L* to 21.10 (ΔL* = +1.45). Uniquely, light exposure induced a downward shift in lightness to 18.90 (ΔL* = -0.75), accompanied by a reduction in chroma to 6.98.

DISCUSSION

Across all experiments, the hue angle (h° remained within a tight band between 286.73° and 291.53°. In the CIELab color space, a hue angle near 270° represents pure blue, while 360° represents pure red. This places the natural dye firmly in the violet to blue-violet chromatic spectrum. The negative values of b* (ranging from -5.42 to -7.18) highlight a strong underlying blue component, while the low positive values of a* (1.95 to 2.83) add a subtle red undertone. The low overall chroma values (C* 7.71) show that this violet shade is highly muted or desaturated, bordering on a slate or charcoal-violet appearance.

The sequence in which the mordant was introduced severely impacted dye exhaustion, fixation, and substrate interaction. This systematic progression indicates that pre-mordanting optimizes the active sites on the fabric surface. Applying the mordant first allows metal ions or organic molecules to bind directly to the fiber's functional groups without competition. When the natural dye is introduced later, it readily coordinates with these pre-anchored sites, maximizing dye pick-up and creating a deeper, darker finish. In contrast, meta-mordanting introduces a competing pathway where the dye and mordant can react directly in the dye bath. This often forms insoluble dye-mordant complexes that precipitate out of the solution rather than binding to the fiber, leading to a shallower depth of shade. Post-mordanting struggles similarly; because the un-mordanted dye molecules have already bound weakly to the fiber, subsequent chemical intervention cannot fix them as effectively, leaving more dye vulnerable to washing and environmental exposure.

The structural properties of each mordant dictated the final color depth and stability profiles of the dyed fabrics. Iron acted as a powerful color-darkening agent, consistently producing the lowest lightness scores (L* = 16.03 - 17.12). This behavior is driven by the specific chemistry of iron as a transition

metal. Iron ions (Fe^{2+}) possess vacant d orbitals that form strong coordination complexes with the electron-donating groups (such as phenolic hydroxyl or carbonyl options) found in natural dyes. The significant darkening known as "saddening" stems from iron's high tinting power and its ability to participate in multi-centered ligand-to-metal charge transfers. These interactions alter the electronic structure of the dye, broadening its visible light absorption and shifting it toward lower reflectance. The resulting coordination complexes act as an insoluble chemical shield. They lock the dye molecules into macromolecular networks that are highly resistant to water leaching and photo-chemical breakdown. Tannic Acid as a large macromolecular polyphenol, tannic acid does not rely on transition metal complexation. Instead, it alters color and boosts fastness through an extensive network of hydrogen bonds and hydrophobic interactions. It bridges the gaps between the fiber matrix and the natural dye molecules, trapping the colorant within a dense organic framework. This molecular trapping effect earned it the second-lowest lightness scores (L* = 17.64 - 18.68) and provided outstanding resistance to both washing and light exposure. Aluminum (Al^{3+}) and zinc (Zn^{2+}) ions produced noticeably brighter shades (higher L*) with higher remaining chroma values (C*). Zinc features a completely filled d-orbital (d^{10}), preventing the charge-transfer transitions that cause iron's deep darkening effect. Aluminum forms stable, clear coordination complexes that preserve or enhance the natural vividness of the dye rather than dulling it. However, zinc showed weaker binding stability during fastness testing, leading to higher wash-induced fading (ΔL* = +1.83 in post-mordanting).

The control sample (Blind Dyeing) suffered severe color loss during washing (ΔL* = +3.75) and light exposure (ΔL* = +2.48), proving that the natural dye has poor innate affinity for the fabric and breaks down quickly under UV radiation when unfixed. Introducing mordants significantly minimized these color shifts, though performance varied by method and agent

Washing Stability: Pre-mordanted iron (ΔL* = +0.32) and pre-mordanted tannic acid (ΔL* = +0.48) showed the highest resistance to washing. The worst performing mordant was post-mordanted zinc (ΔL* = +1.83), where a large portion of the weakly held dye-metal complexes simply washed away.

Light Stability: Pre-mordanted tannic acid (ΔL* = +0.07) and iron (ΔL* = +0.15) offered unmatched protection against light damage. Polyphenols and iron complexes are excellent at absorbing UV energy and dispersing it safely as heat, shielding the core dye structure from photo-oxidation. In the post-mordanted alum sample, light exposure triggered a unique decrease in lightness (ΔL* = -0.75, falling from 19.65 down to 18.90), accompanied by a drop in chroma (C*) from 7.61 to 6.98. This indicates a photo-induced chemical reaction. The combination of UV radiation and ambient oxygen likely altered the aluminum-dye complex, causing it to undergo structural rearrangement or photo-oxidation into a slightly darker, less saturated compound.

CONCLUSION

This research demonstrates the critical role that mordanting methods and chemistry play in shaping the color depth, hue, and fastness profiles of a violet-reflecting natural dye extract. The key findings from this study are, the natural dye extract produces a muted violet/blue-violet shade characterized by a stable hue angle (h° 286° - 291°), negative b* coordinates, and low overall chroma (C* 7.71). Pre-mordanting emerged as the most efficient application pathway. By optimizing active sites on the fabric before dyeing, it consistently produced deeper shades (lower L*) and superior fastness compared to meta- and post-mordanting techniques. Ferrous Sulfate proved to be the most effective agent for generating deep, dark shades and guaranteeing maximum resistance to washing and light exposure, driven by its robust transition-metal coordination chemistry. Tannic Acid serves as an exceptional non-metallic alternative. It offers outstanding color stability via macromolecular hydrogen bonding networks, rivaling iron's performance without the heavy metal profile. Alum and Zinc Sulfate preserve higher brightness and chroma but offer lower overall fastness, with post-mordanted zinc proving particularly vulnerable to washing. Ultimately, for applications requiring a deep, highly durable violet shade, the pre-mordanting method paired with ferrous sulfate or tannic acid represents the optimal processing choice.

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DESIGN AND IMPLEMENTATION OF AN INTEGRATED CALENDAR, TASK, NOTE, AND RESPONSIBILITY MANAGEMENT APPLICATION: ZAMAN SAYAR

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ABSTRACT

This paper presents Zaman Sayar, an integrated web-based time, task, note, responsibility, and decision-support application developed to reduce workflow fragmentation in individual and team-based work. The system brings together calendar management, personal tasks, detailed task assignment, subtasks, notes and audio notes, RACI-based responsibility tracking, dynamic tables, spreadsheet import, statistical dashboards, OCR-supported image-to-task extraction, read-only natural-language data querying through ZamanChat, GitHub-based software-development traceability, and a machine-learning-based intelligent task suggestion module. The study is therefore positioned not as a simple interface prototype, but as a layered software engineering product with explicit data models, service boundaries, auxiliary automation components, and measurable decision-support outputs.

The implementation uses ASP.NET Core MVC, Razor views, Entity Framework Core, SQL Server, Bootstrap, JavaScript, Chart.js, Python, Node.js, and the GitHub REST API. The OCR workflow combines image preprocessing, Tesseract/EasyOCR extraction, confidence scoring, and field mapping. ZamanChat is designed as a bounded assistant that reads database schema information and returns summaries or record details while rejecting insert, update, delete, and schema-changing intentions. The zaman_ai subsystem uses TF-IDF, LSA-based features, Logistic Regression, histogram-based gradient boosting, TextRank summarization, and clustering metrics on a synthetic and anonymized Turkish task corpus.

Evaluation results show that task type, category, and priority classification reached macro-F1 scores of 0.91, 0.92, and 0.93 respectively under 5-fold cross-validation. Duration estimation reached 1.20 hours MAE and 17.6% MAPE, and a budget-matched simulation reduced average lateness by 44.32%. RACI responsibility suggestion reached 89.08% out-of-fold agreement, while extractive summaries obtained a 4.50/5 readability score in an AI-assisted/simulated Likert panel. The machine-learning package is supported by 55 unit tests. Limitations include synthetic data, the simulated nature of the readability panel, incomplete production-level authorization, and the need for encrypted GitHub token storage. Overall, Zaman Sayar demonstrates a comprehensive and reproducible integration of time planning, responsibility tracking, operational information access, software-development traceability, and intelligent assistance.

Keywords: ASP.NET Core MVC, task management, calendar application, RACI, OCR, Entity Framework Core, SQL Server, ZamanChat, GitHub integration, machine learning, TF-IDF, TextRank, reproducible evaluation.

INTRODUCTION

Digital work is often distributed across separate calendars, task lists, note applications, spreadsheets, messaging channels, development platforms, and reporting tools. Although each tool may be useful on its own, fragmentation creates repeated data entry, weak traceability, unclear task ownership, and loss of context. A task may be planned in a calendar, explained in a note, assigned through another medium, monitored in a spreadsheet, and discussed in a software-development platform. In such cases, digital support can increase cognitive effort instead of reducing it.

Zaman Sayar was developed as an applied response to this problem. Its central objective is to keep time, task, information, responsibility, software-development traceability, and decision support inside one coherent application context. The system does not replace specialized enterprise tools; instead, it demonstrates how the essential flows needed by a small team or student software project can be integrated around a shared data model and a single operational panel.

Aim and Scope

The aim of the study is to design, implement, and evaluate a modular web application that supports daily planning, task assignment, personal task breakdown, notes, responsibility mapping, flexible table records, data import, dashboards, OCR-based task creation, natural-language record access, GitHub traceability, and ML-supported task suggestions. The scope covers a graduation-project level implementation and an international congress full-text evaluation. Production-level deployment topics such as large-scale monitoring, full role-based authorization, and external field validation are treated as future work rather than as completed claims.

Table 1. Engineering objectives of the study

Objective	Description
Integrated workflow	Place calendar, task, note, table, RACI, statistics, OCR, chat, GitHub, and intelligent suggestion modules in a single system.
Modular architecture	Separate presentation, controller, service, data-access, and auxiliary-service concerns for maintainability.
Traceable data model	Store tasks, calendar records, notes, comments, OCR logs, GitHub settings, table rows, and suggestion feedback on a relational backbone.
Auxiliary automation	Reduce manual workload through OCR-supported task extraction and safe natural-language querying.
Decision support	Generate type, category, priority, duration, summary, and RACI suggestions from Turkish task text.
Academic defensibility	Report architecture, methods, metrics, negative findings, and limitations transparently.

Original Contributions

The study has six main contributions. First, a working integrated application was developed for time planning, task tracking, note taking, responsibility management, structured data storage, statistics, OCR, GitHub traceability, ZamanChat, and intelligent task suggestions. Second, a layered ASP.NET Core MVC and Entity Framework Core architecture was connected to Python and Node.js auxiliary services through controlled service boundaries. Third, an OCR pipeline was designed to compare engine outputs, extract labeled task fields, and store raw text, engine information, confidence, and generated task traces. Fourth, a read-only natural-language assistant was implemented with explicit write-intent rejection. Fifth, the zaman_ai subsystem was integrated as a reproducible process-based Python package with task classification, duration estimation, RACI suggestion, summarization, clustering, and feedback capture. Sixth, the system was evaluated with measurable A1-A5 targets and supported by 55 unit tests for the ML subsystem.

CONCEPTUAL BACKGROUND AND RELATED WORK

Task-management research emphasizes that users need actionable information rather than passive lists. A useful task record should include what the work is, who owns it, when it is due, how important it is, and whether it has been completed. Calendar-use studies similarly show that calendars operate as external memory tools for organizing work over time. For this reason, Zaman Sayar treats tasks and calendar entries as complementary views of the same work context rather than as unrelated modules.

Personal information management literature highlights the need to keep information findable, understandable, and reusable. Notes, audio records, table rows, comments, and calendar items lose value when they remain isolated from the work records they explain. Zaman Sayar therefore keeps notes, audio notes, task explanations, RACI comments, dynamic tables, and uploaded spreadsheet rows inside the same working environment.

The RACI approach separates Responsible, Accountable, Consulted, and Informed roles. This separation is important because a single assignee field does not always explain how a task is distributed among team members. In Zaman Sayar, the RACI module records role distribution, progress, and comments so that responsibility is visible as structured data rather than as informal text.

OCR technologies such as Tesseract and EasyOCR can convert image-based text into raw text, but task-management use cases require an additional interpretation stage. Zaman Sayar therefore maps extracted text into task content, assignee, assigner, due date, and note fields. Natural-language database interfaces offer easier data access, but they also introduce integrity risks. ZamanChat addresses this by limiting itself to SELECT-based reading and by rejecting write-oriented intentions. The ML layer follows established approaches for short text: TF-IDF, LSA-like semantic features, linear classification, gradient boosting, TextRank summarization, and clustering metrics.

Table 2. Design implications from the literature

Area	Requirement	Zaman Sayar implementation
Task management	Tasks require context, priority, owner, and status.	Task and task-assignment modules with subtasks and completion tracking.
Calendar use	Work should be visible on a time axis.	Day, week, and month calendar views with reminders and color tags.
Personal information management	Supporting information should remain reusable.	Notes, audio notes, categories, tags, tables, and comments.
Responsibility assignment	Team roles should be more explicit than one assignee.	RACI matrix with role filters and comments.
OCR	Raw text must be converted into fields.	Python OCR workflow with field extraction and logs.
Natural-language access	Data access should be easy but bounded.	Read-only ZamanChat with write-intent refusal.
Machine learning	Short task text can support prediction and summaries.	zaman_ai classification, duration, summary, RACI, and clustering modules.

Positioning of Zaman Sayar

The main distinction of Zaman Sayar is not specialization in only one module. Many existing tools are strong as calendars, task lists, note applications, spreadsheets, OCR utilities, chat interfaces, or development dashboards. The problem addressed in this project appears when a small team needs these flows together: a record created in one tool must be re-entered into another, the reason behind a task becomes detached from its due date, and development issues are not automatically visible in daily planning. Zaman Sayar is positioned as an integration-oriented product that keeps these records under one operational context.

This positioning is important for academic evaluation. The project does not claim that its calendar is more advanced than a specialized calendar platform or that its GitHub panel replaces GitHub itself. Instead, the contribution is the controlled connection of task, calendar, responsibility, structured data,

OCR, natural-language access, software-development traceability, and ML-supported suggestions around the same data model. Table 3 summarizes this relationship.

Table 3. Comparison of common tool approaches and Zaman Sayar

Approach	Strength	Limitation alone	Added value of Zaman Sayar
Calendar tools	Time visibility and appointment tracking.	Limited task detail and responsibility context.	Calendar connected to tasks, notes, RACI, and statistics.
Task lists	State and priority tracking.	Time, OCR, table, and role data may remain separate.	Subtasks, task assignment, OCR, and calendar connection.
Note tools	Fast free-text capture.	Notes may remain disconnected from workflow.	Notes and audio notes stored with the same work context.
Spreadsheets	Flexible data organization.	Rows are not directly tied to work planning.	Dynamic and uploaded tables inside the application.
RACI templates	Role separation.	Often static files outside the live workflow.	Live RACI records with progress and comments.
OCR tools	Raw text extraction.	Text must still be structured manually.	OCR output converted into task fields and logs.
Chat interfaces	Natural-language access.	Uncontrolled write authority may risk integrity.	Read-only, schema-aware, bounded interaction model.
ML tools	Classification and prediction support.	May remain detached from product workflow.	Suggestions linked to interface, feedback, and measurement.

MATERIALS AND METHOD

Development Approach and Requirements

The system was developed incrementally. Core task and calendar flows were implemented first; notes, task assignments, RACI, dynamic tables, spreadsheet import, and statistics followed. After the central data backbone was stable, OCR, ZamanChat, GitHub integration, and the zaman_ai subsystem were added as controlled support layers. This order allowed each module to be tested within its own user-interface flow while still sharing the same application shell and database context.

Table 4. Functional requirements and components

Requirement class	Requirement	Component
Planning	Track work in a date and time context.	Calendar and daily plan panel
Task tracking	Record status, priority, assignee, subtasks, and soft deletion.	Task and task-assignment modules
Information capture	Store written and audio notes.	Note module and MediaRecorder support
Responsibility	Represent R, A, C, and I roles.	RACI matrix and role filters

Requirement class	Requirement	Component
Flexible data	Define tables and import external rows.	Dynamic tables and spreadsheet import
Automation	Generate task fields from images.	Python OCR service
Information access	Read records through natural-language prompts.	ZamanChat
Visualization	Observe completion, workload, and distribution.	Statistics screens and Chart.js
Traceability	Connect development artifacts to planning.	GitHub REST API integration
Decision support	Suggest type, category, priority, duration, RACI, and summary.	zaman_ai subsystem

Software Architecture

The main application uses ASP.NET Core MVC. Razor views generate the user interface, controllers manage request flow, services encapsulate module logic, Entity Framework Core maps entities to SQL Server, and auxiliary components provide OCR, natural-language querying, GitHub access, and ML inference. This organization prevents feature logic from accumulating in a single controller and makes later hardening easier.

Table 5. Main technologies used in the architecture

Layer	Technology	Purpose
Web application	ASP.NET Core MVC, Razor	Controller-based workflow and server-side interface generation.
Data access	Entity Framework Core 9, SQL Server	Relational persistence and entity mapping.
Client side	Bootstrap, JavaScript, Chart.js	Interface behavior, layout, and chart visualization.
File handling	EPPlus and CSV processing	Spreadsheet import/export and row conversion.
OCR	Python, Pillow, Tesseract, EasyOCR	Image preprocessing and text extraction.
Chat service	Node.js, Express, Socket.IO, MSSQL driver	Read-only natural-language data querying.
Machine learning	Python, scikit-learn, pandas, NumPy, joblib	Classification, regression, summarization, and clustering.
GitHub integration	GitHub REST API, HttpClientFactory	Repository, issue, PR, activity, release, and calendar data.

The controller layer was deliberately kept module-oriented. Each controller is responsible for a visible user workflow, while data persistence and auxiliary operations are delegated to models, services, and external scripts where appropriate. This makes the implementation easier to defend: a reviewer can map each user-facing screen to a controller responsibility, then follow the related model or service boundary.

Table 6. Controller responsibility map

Controller	Main responsibility
HomeController	Main page, module navigation, and daily plan panel.
TaskController	Personal tasks, subtasks, completion state, reminders, and soft-delete flow.
TaskAssignmentController	Detailed assignment records and OCR-based task creation.
CalendarController	Calendar tasks in day, week, and month contexts.
NoteController	Text notes, categories, tags, and audio notes.
DynamicBoardController	RACI matrix, comments, role distribution, and progress.
DynamicTableController	User-defined dynamic tables and JSON row data.
DynamicTablesController	Excel/CSV upload, row editing, header update, and export.
StatisticsController	Completion, distribution, and workload statistics.
SuggestionController	zaman_ai suggestions and human-in-the-loop feedback.
GitHubController	GitHub settings, repository/issue/PR views, dashboard, activity, releases, and calendar sync.

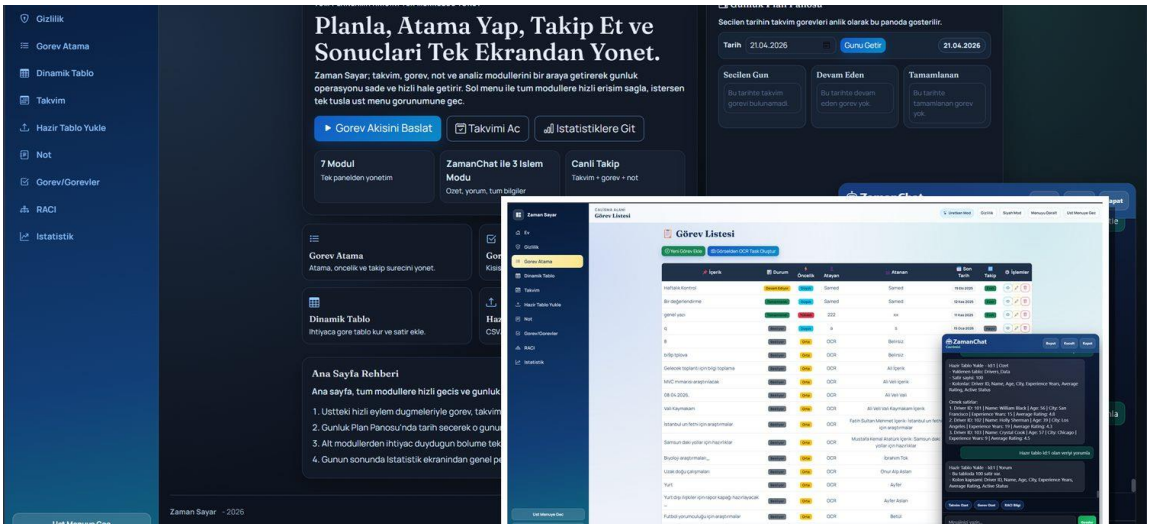


Figure 1. Zaman Sayar main panel, task list, and ZamanChat view.

Data Model and Project Structure

The source solution is organized into four .NET project areas and two auxiliary service areas. CRM_9 contains the MVC application, controllers, Razor views, services, and static files. CRM.Models stores entities and view models. CRM.DataAccess contains the DbContext and migrations. CRM.Utility stores shared constants and helper structures. Auxiliary components include the Python OCR workflow, the zaman_ai package, and the NodeBot ZamanChat service.

Table 7. Data-model summary

Entity group	Relation and purpose
TaskAssignments and OcrTaskLogs	Stores detailed assignment records, raw OCR text, confidence, engine information, and generated task traces.
TaskItems and CalendarTasks	Represent personal tasks, subtasks, reminders, recurrence, color tags, and time planning.
Notes	Store note text, categories, tags, and audio-note paths.
DynamicBoardItems and Comments	Represent RACI records, responsibility roles, progress, and comments.
DynamicTableDefinitions/Data and UploadedRows	Store user-defined fields and imported spreadsheet rows as JSON while preserving relational roots.
GitHubSettings	Store user/team-scoped GitHub settings and access data.
SuggestionFeedback	Store model outputs, user decisions, confidence values, summaries, and acceptance-rate evidence.

Table 8. Module-based design summary

Module	Main data structure	Engineering value
Calendar	CalendarTask	Tracks tasks by date, recurrence, reminder, and color.
Tasks	TaskItem	Provides subtasks, completion, reminder, and soft-delete support.
Task assignment	TaskAssignment	Stores assigner, assignee, priority, tracking, and completion data.
Notes	Note	Stores text, category, tags, and audio notes.
RACI	DynamicBoardItem	Makes responsibility roles and progress visible.
Dynamic table	DynamicTableDefinition/Data	Provides flexible tables with user-defined fields.
Spreadsheet import	UploadedTable/UploadedRow	Converts CSV/XLSX files into JSON row data.
OCR	OcrTaskLog/ExtractionResult	Produces task fields from images and preserves raw output.
ZamanChat	Live SQL schema reading	Summarizes records in a read-only natural-language layer.
GitHub	GitHubSetting and CalendarTask	Links repository artifacts and milestone due dates to planning.
Intelligent suggestion	SuggestionFeedback/TaskSuggestionResult	Generates ML-supported suggestions and captures feedback.

Module Workflow Details

The calendar and task modules form the operational core of the system. Calendar records make planned work visible by day, week, and month, while task records keep status, priority, reminders, subtasks, and completion state. This separation is practical because not every task is only an event and not every calendar item contains enough task detail. Zaman Sayar therefore lets the user see work both as a list of actionable items and as time-distributed workload.

The note, audio-note, RACI, and dynamic-table modules preserve context around the task. Notes and audio notes allow quick capture of explanations, decisions, or meeting outcomes. The RACI module expands responsibility beyond one assignee by representing who performs, approves, advises, and follows the task. Dynamic tables and spreadsheet import support records that do not fit a fixed form, but the rows are still stored inside the application context rather than in isolated files.

The support modules reduce friction. OCR converts task screenshots or photographed text into structured draft records. ZamanChat helps users retrieve and interpret existing data without manually navigating every table. GitHub integration brings software-development artifacts into planning, which is especially important for a software engineering project. Intelligent Suggestion connects offline model metrics to a real interface by showing predictions and collecting feedback from the user.

OCR Workflow

The OCR component operates in two stages. First, the image is scaled, converted to grayscale, enhanced, sharpened, and read by Tesseract and EasyOCR. Second, the extracted text is interpreted through Turkish and English label synonyms so that task content, assignee, assigner, due date, and notes can be converted into a draft task. The system does not merely choose the longest OCR output; it scores engine outputs according to usefulness for field extraction.

$$S_m = 0.35F_m + 0.25E_m + 0.20Q_m + 0.20C_m \quad (1)$$

In Equation (1), F_m denotes extracted fields, E_m label-matching success, Q_m raw-text readability, and C_m engine confidence. The selected output is then stored together with the raw OCR result and generated task trace.

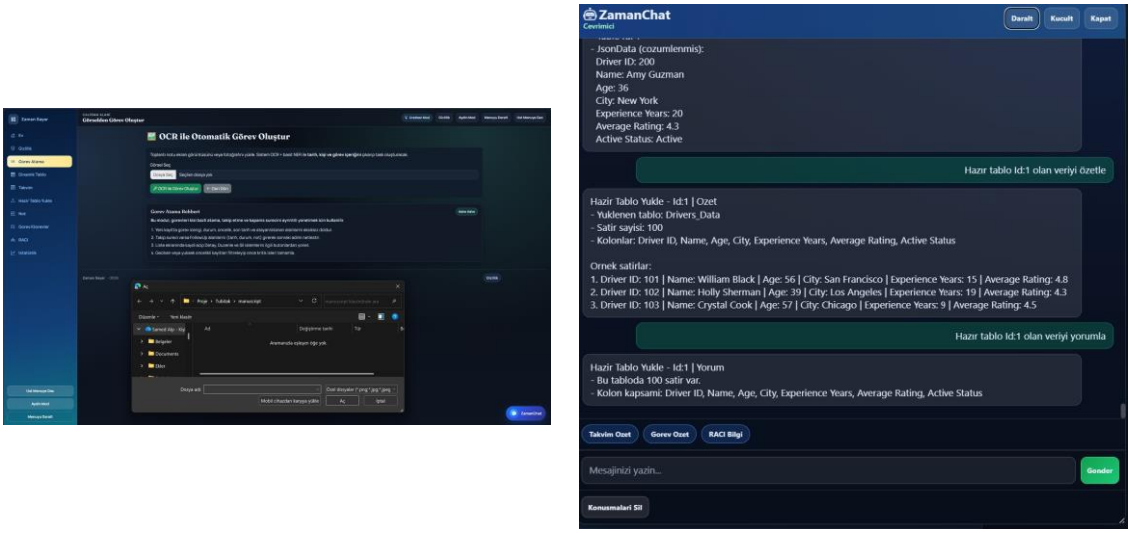


Figure 2. OCR-based task creation and ZamanChat query support screens.

ZamanChat and GitHub Integration

ZamanChat is a bounded natural-language interface. It reads database metadata from INFORMATION_SCHEMA, detects the intended tab and action, expects dates or record identifiers where necessary, and runs parameterized SELECT queries. The service refuses write-oriented

operations such as insert, update, delete, drop, and alter. This boundary is important because natural-language access should improve usability without weakening data integrity.

Table 9. ZamanChat decision flow

Step	Operation
Input cleaning	The user message is normalized and empty input is rejected.
Write-intent check	Insert, delete, update, drop, alter, and similar intentions are detected before query execution.
Action detection	Summary, interpretation, or detail-writing requests are identified.
Profile detection	Calendar, task assignment, note, RACI, and table-related profiles are matched.
Record selection	Calendar questions expect a date; other record-detail questions expect a record identifier.
Query execution	Parameterized and limited SELECT queries are executed against the permitted data source.
Response generation	The result is returned as a summary, interpretation, or record detail without modifying the database.

The GitHub integration connects software-development traceability with time planning. It uses the GitHub REST API with a user/team-scoped Personal Access Token and an OwnerId-based multi-tenant boundary. Profile and repository information, issues, pull requests, dashboard indicators, releases, activity, language distribution, and milestone due dates are retrieved through HttpClientFactory. Open issues with milestone dates can be synchronized into the calendar as non-duplicated CalendarTask records. A known limitation is that the current prototype stores the personal access token without encryption; production use should protect it with Data Protection or a secret-management service.

Table 10. GitHub integration stages

Stage	Implemented behavior	Planning value
Profile and repositories	Connected account and repositories are retrieved and displayed with recent activity indicators.	The user sees which software projects are active.
Issues and pull requests	Assigned, authored, or mentioned issues and pull requests are filtered through GitHub API calls.	Development work can be interpreted as task input.
Calendar synchronization	Open issues with milestone due dates are converted into non-duplicated CalendarTask records.	Repository deadlines become visible in time planning.
Dashboard and activity	Stars, forks, languages, open issues, updated repositories, releases, and 14-day activity are summarized.	Software-development traceability becomes measurable inside the application.

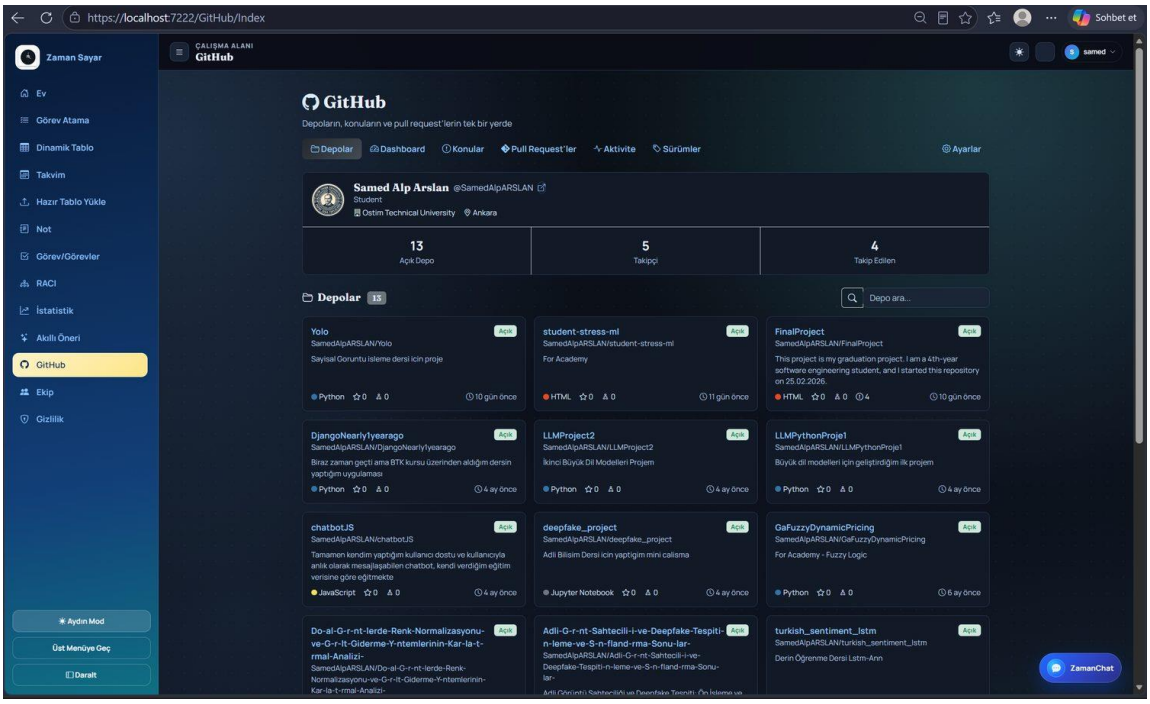


Figure 3. In-application GitHub integration with repository cards and dashboard navigation.

Machine-Learning Subsystem

The zaman_ai subsystem was added as an independent Python package without changing the core MVC architecture. The C# side calls predict.py through a process-based contract and reads a single JSON object from the final output line, similar to the OCR integration. The subsystem includes text normalization, dataset generation, TF-IDF and LSA-style feature extraction, classification, duration estimation, TextRank summarization, RACI suggestion, clustering, experiment logging, and feedback capture.

Table 11. zaman_ai modules and research goals

Module	Goal	Task
text_processing.py	Common	Turkish text cleaning, normalization, and light morphological simplification.
dataset.py	A5	Synthetic and anonymized Turkish task dataset generation.
features.py	A1-A4	TF-IDF, LSA, temporal, and workload feature extraction.
classifier.py	A1	Task type, category, and priority classification.
deadline.py	A2	Duration estimation, reminder timing, and lateness simulation.
summarizer.py	A3	TextRank-based extractive summarization and readability evaluation.
raci.py	A4	RACI role suggestion and acceptance-rate measurement.
clustering.py	EK-3	Task-text clustering and external-alignment metrics.
run_experiments.py	A5	Running experiments and producing reports.

The dataset contains 1200 synthetic and anonymized Turkish task records. Instead of personal names, role labels such as developer, test specialist, designer, analyst, support specialist, manager, and team leader are used. Each record includes task text, type, category, priority, dates, estimated and actual duration, assigned role, workload, RACI role, and lateness. The dataset was calibrated to represent a moderately learnable regime rather than an artificially perfect separation.

Dataset, Ethics, and Reproducibility

The decision to use synthetic and anonymized task data was methodological as well as ethical. Real task-management data may contain names, deadlines, performance indicators, private project details, and institutional context. Using such data in a student project would require stronger consent, governance, and anonymization procedures. The synthetic dataset allows the classification, regression, summarization, RACI, and clustering flows to be tested without exposing real personal records.

At the same time, the dataset was not designed to make the models look unrealistically perfect. The labels and features were calibrated so that some patterns are learnable and some remain difficult. This is why supervised models perform well but clustering remains weak. Reporting this weak clustering result is important because it prevents the paper from overstating the system as a universal AI solution. The system is a decision-support prototype whose results should be validated with real field data in future work.

Reproducibility was addressed through fixed experimental settings, stored measurement reports, preserved ER-schema information, anonymized sample data, and unit tests. The machine-learning subsystem includes 55 automated unit tests that check core data-generation, feature-extraction, model, summarization, RACI, and reporting behavior. The use of a process-based JSON contract also makes the integration auditable: the web application does not depend on hidden state inside the Python process, but reads a clear output object.

Model Design Choices

The model design intentionally starts with interpretable and reproducible methods. TF-IDF with one- and two-gram features represents short Turkish task descriptions without requiring a large language model or external service. LSA-style dimensional reduction is used as a semantic proxy, while temporal and workload features add non-textual signals such as estimated duration, priority order, day of week, weekend indicator, and role workload. This combination reflects the nature of task-management data: the text matters, but timing, priority, and workload also shape the expected outcome.

Logistic Regression is included because it is a strong and stable baseline for sparse text features. Histogram-based gradient boosting is included because it can model nonlinear interactions in the structured features used for duration and RACI-related tasks. Rule baselines are retained for comparison so that the reported improvements can be interpreted against a simple deterministic alternative rather than only against another machine-learning model.

The intelligent suggestion interface reflects these design choices in a product workflow. The user enters free-form Turkish task text and contextual fields such as assigned role, workload, and day of week. The system returns type, category, priority, estimated duration, reminder timing, RACI role, extractive summary, confidence values, and model version. The feedback panel then allows the user to accept, defer, or reject the suggestion. This closes the loop between offline evaluation and future real-use measurement.

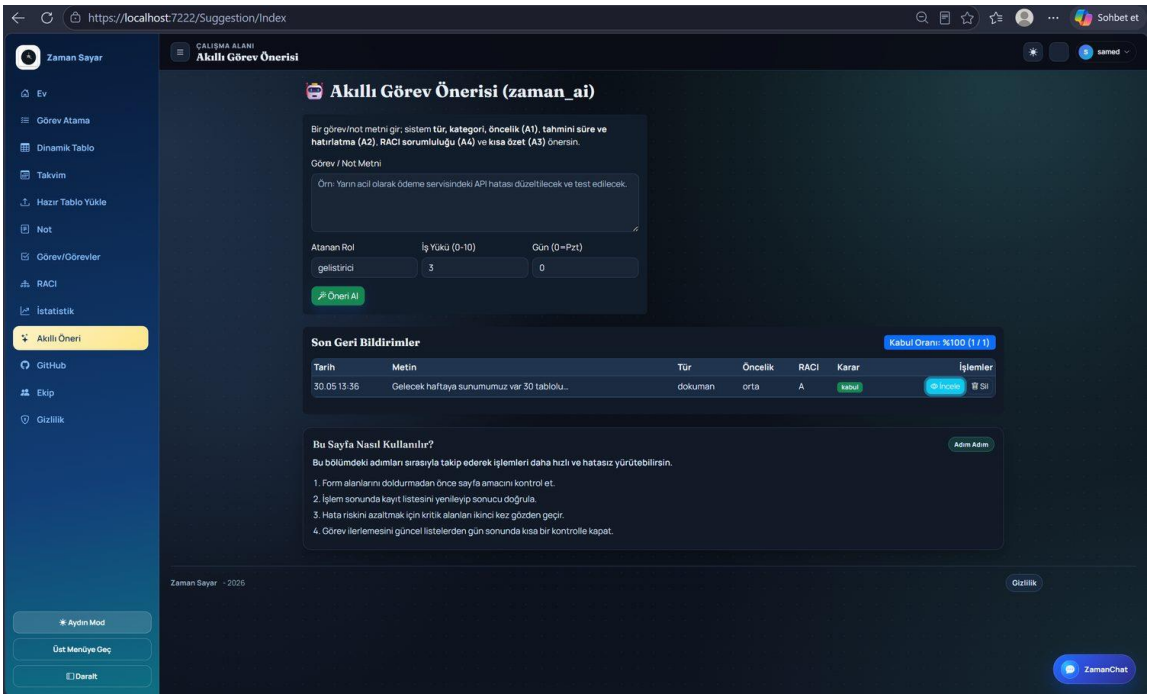


Figure 4. Intelligent Task Suggestion interface with A1-A4 outputs and human-in-the-loop feedback.

Evaluation Indicators

Task completion rate, workload, RACI coverage, macro-F1, MAPE, and lateness reduction are used as interpretable evaluation indicators.

$$T = \frac{N_{completed}}{N_{total}} \times 100 \quad (2)$$

$$Y(d) = \Sigma_{i=1}^{n} I(date_i = d) \cdot w(p_i) \cdot (1 - c_i) \quad (3)$$

$$C_{RACI} = \frac{r_R + r_A + r_C + r_I}{4} \quad (4)$$

$$F1_{macro} = \frac{1}{K} \Sigma_{k=1}^{K} \frac{2P_k R_k}{P_k + R_k} \quad (5)$$

$$MAPE = \frac{100}{n} \Sigma_{i=1}^{n} \left| \frac{y_i - \hat{y}_i}{y_i} \right| \quad (6)$$

$$\Delta = 100 \times \frac{L_{baseline} - L_{model}}{L_{baseline}} \quad (7)$$

Classification tasks report accuracy, macro-F1, weighted F1, and ROC-AUC. Regression reports MAE, MAPE, and R2. Clustering reports Silhouette, Calinski-Harabasz, Davies-Bouldin, adjusted Rand index, and normalized mutual information. Paired t-test, Wilcoxon signed-rank test, Cohen's d, and confidence intervals are preserved in the measurement reports where applicable.

Experimental Protocol

The evaluation protocol separates product functionality from model performance. Functional verification checks whether the web modules perform their expected role in the integrated application. Model evaluation checks A1-A5 targets through cross-validation, simulation, summary scoring, acceptance-rate measurement, and reproducibility artifacts. This separation avoids a common reporting error: a visually working interface is not treated as evidence that the model is accurate, and an accurate offline model is not treated as evidence that the application is production-ready.

For A1, task type, category, and priority were evaluated as separate classification targets. For A2, the duration model was evaluated through regression metrics and then applied in a budget-matched lateness

simulation. For A3, TextRank summaries were evaluated with an automatic proxy and a transparent AI-assisted/simulated panel. For A4, RACI suggestions were evaluated through out-of-fold agreement with approved labels. For A5, the prototype, measurement reports, ER schema, anonymized data, and feedback mechanism were checked as delivery artifacts.

This protocol creates a defensible interpretation of the results. A high classification score does not remove the need for real-user validation; a passed A5 prototype does not remove the need for authorization and security hardening; and the weak clustering result does not invalidate the supervised models. Each result is interpreted according to the task it was designed to measure.

FINDINGS AND DISCUSSION

Application Outputs and Functional Verification

The study produced a working multi-module web application. The navigation menu gives access to task assignment, dynamic tables, calendar, spreadsheet import, notes, tasks, RACI, statistics, intelligent suggestions, GitHub integration, and team functions. The main screen also includes a daily plan panel and ZamanChat component. The source code was compiled locally before reporting and provided a working technical basis; production-level maturity still requires broader validation, monitoring, authorization hardening, and user-experience refinement.

Table 12. Functional verification summary

Module	Verified function	Evaluation
Main panel	Fast module access and daily plan panel.	Integrated entry point.
Task assignment	Assigner, assignee, priority, date, and tracking fields.	Supports formal task tracking.
Tasks	Subtasks, completion, reminders, and soft delete.	Supports personal work breakdown.
Calendar	Monthly, weekly, and daily views.	Makes time context visible.
Notes	Text, category, tags, and audio note.	Keeps context in the same system.
RACI	R, A, C, I roles and comments.	Makes responsibility sharing visible.
Dynamic table	User-defined fields and JSON row data.	Supports flexible structured storage.
Spreadsheet import	Excel/CSV upload, edit, and export.	Brings external data into the system.
OCR	Task-field extraction from images.	Reduces manual data entry.
ZamanChat	Read-only natural-language querying.	Improves access while preventing writes.
GitHub	Repository, issue, PR, activity, release, and calendar sync.	Links development artifacts to planning.
Intelligent suggestion	ML output from task text.	Provides measurable decision support.

Interface Results

The interface was designed around continuity of work. The user should not need to remember where a task was created, which note explains it, which role is responsible, or whether a related software issue exists. The navigation structure keeps the modules visible, while cards, forms, tables, and charts provide different views of the same operational domain. This approach is particularly useful for a graduation project because it demonstrates not only a backend data model, but also a working human-facing product.

The calendar screen makes workload distribution visible across the month, while the statistics screen summarizes course/task distributions and completion-related indicators. These outputs are not decorative screenshots; they show that the stored records can be interpreted and visualized after they are created. Similarly, the OCR, ZamanChat, GitHub, and Intelligent Suggestion screens show that auxiliary services are connected to the main application rather than remaining as separate scripts.

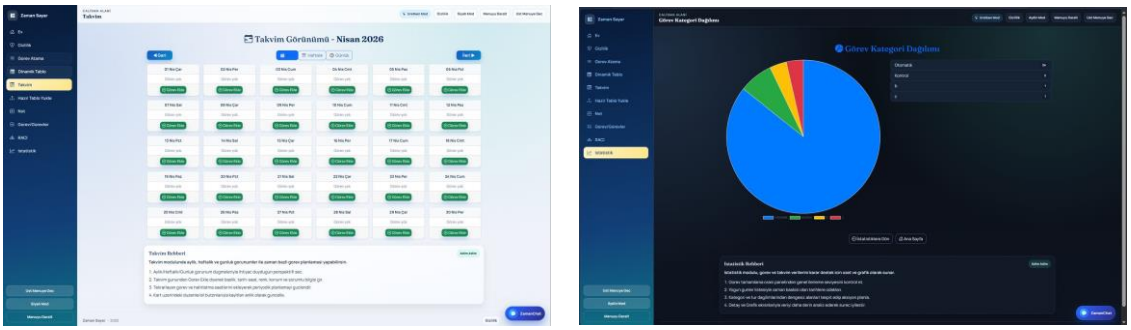


Figure 5. Calendar and statistics modules used for time visibility and operational monitoring.

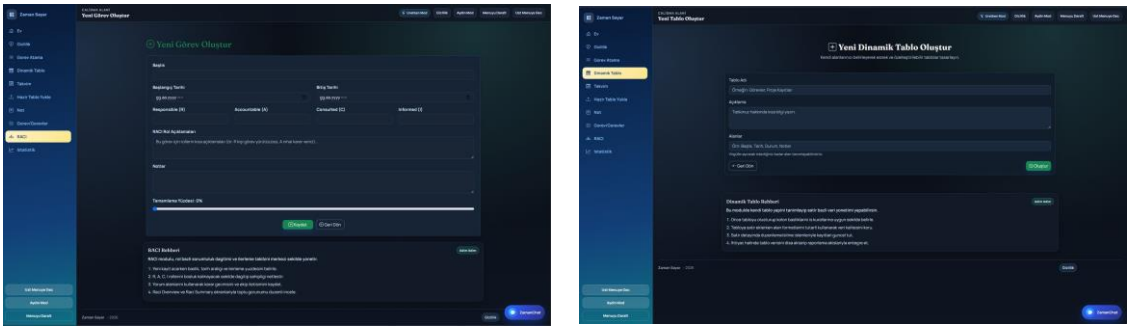


Figure 6. RACI task creation and dynamic table creation interfaces.

A1: Classification Results

Task type, category, and priority were evaluated as separate classification targets on 1200 records with 5-fold cross-validation. Logistic Regression was the strongest and most stable model across the three targets. Macro-F1 values exceeded the 0.85 threshold for all committed classification outputs.

Table 13. A1 classification performance

Target	Model	Accuracy	Macro-F1	Weighted F1	ROC-AUC
Type	Rule baseline	0.8342	0.8408	0.8388	0.5000
Type	LogReg	0.9117	0.9116	0.9118	0.9926
Type	HistGB	0.9042	0.9046	0.9043	0.9869
Category	Rule baseline	0.9058	0.9097	0.9068	0.5000

Target	Model	Accuracy	Macro-F1	Weighted F1	ROC-AUC
Category	LogReg	0.9183	0.9163	0.9183	0.9933
Category	HistGB	0.9183	0.9162	0.9182	0.9879
Priority	Rule baseline	0.8750	0.8766	0.8727	0.5000
Priority	LogReg	0.9308	0.9273	0.9313	0.9941
Priority	HistGB	0.9142	0.9129	0.9142	0.9884

For task type classification, the mean F1 difference between Logistic Regression and the rule baseline was 0.071, with paired t-test p=0.00248, Cohen's d=3.03, and 95% confidence interval [0.898; 0.925]. These values indicate that the model improvement is not only visible in the mean score but also statistically meaningful within the experimental setup.

A2: Duration Estimation and Lateness Reduction

A2 evaluates whether task duration can be estimated and whether this estimate can reduce lateness under a comparable planning budget. The histogram-based gradient boosting model reached the best regression result and was used in the budget-matched simulation.

Table 14. A2 duration and lateness results

Indicator	Baseline	Best model / result	Status
Duration MAE	2.4025 h	1.1973 h (HistGB)	PASSED
Duration MAPE	30.51%	17.55% (HistGB)	PASSED
Regression R2	0.5949	0.9045 (HistGB)	PASSED
Average lateness	1.0777 h	0.6000 h	PASSED
Lateness reduction	Target >=20%	44.32%	PASSED

A3, A4, EK-3, and A5 Results

The summarization component uses a TextRank-based extractive method. Automatic proxy readability reached a mean score of 3.828/5, while the primary AI-assisted/simulated Likert panel reached 4.50/5 for clarity/readability and 4.08/5 as a composite score. This panel is reported transparently: it is not a substitute for a real human-subject study, and a real participant-based evaluation remains necessary.

For RACI suggestion, histogram-based gradient boosting reached 0.8908 accuracy, 0.8590 macro-F1, and 89.08% acceptance agreement. In live use, user decisions are stored in SuggestionFeedback as accepted, deferred, or rejected, which allows later measurement of the practical acceptance rate.

The clustering experiment produced a weak separation result. K-Means with k=8 reached Silhouette 0.0623, Calinski-Harabasz 26.43, Davies-Bouldin 3.5073, ARI 0.0053, and NMI 0.0366. This negative finding is useful because it shows that supervised classification is more suitable than unsupervised clustering for the short Turkish task texts used in the study.

Table 15. A3, A4, and EK-3 detailed indicators

Component	Indicator	Value	Interpretation
A3 summarization	Automatic proxy readability	3.828/5	Useful but below the primary human-readable target by itself.

Component	Indicator	Value	Interpretation
A3 panel	Clarity/readability	4.50/5 [4.38; 4.62]	Target passed under the declared AI-assisted/simulated panel setting.
A3 panel	Composite score	4.08/5 [3.98; 4.18]	Overall summary quality passed, with coverage remaining the weakest dimension.
A4 RACI	Best model accuracy / macro-F1	0.8908 / 0.8590	RACI role suggestion is strong enough for decision support.
A4 RACI	Acceptance agreement	89.08%	Out-of-fold predicted labels align with approved labels above the 60% target.
EK-3 clustering	Silhouette / ARI / NMI	0.0623 / 0.0053 / 0.0366	Weak clustering is reported transparently as a negative finding.

Table 16. Summary of target achievement

Target	Committed measure	Result	Status
A1	Macro-F1 >= 0.85	0.91 / 0.92 / 0.93	PASSED
A2	Lateness reduction >= 20%	44.32% (MAE 1.20 h)	PASSED
A3	Readability >= 4/5	4.50/5 (AI-assisted/simulated panel)	PASSED
A4	Acceptance rate >= 60%	89.08%	PASSED
A5	Prototype + measurement + ER + data	All delivered	PASSED
EK-3	Clustering metric report	Silhouette 0.062; weak separation	REPORTED

The primary engineering strength of the study is integration. Calendar, task, note, RACI, table, OCR, GitHub, ZamanChat, and intelligent suggestion components do not stand as disconnected demonstrations; they work around the same problem domain and preserve context through a shared database. The second strength is controlled service integration: OCR is executed as a Python workflow, ZamanChat is isolated as a Node.js service, GitHub communication is wrapped through an application service, and ML inference is called through a JSON contract. The third strength is traceability: OCR logs, RACI comments, JSON table rows, GitHub settings, and suggestion feedback preserve the origin and interpretation of records.

Discussion

The academic value of Zaman Sayar is that the project can be explained at several levels. At the user level, it reduces the need to move between disconnected tools. At the software level, it uses a layered

architecture and separate auxiliary services. At the data level, it stores operational records in traceable entities. At the algorithmic level, it connects OCR, natural-language querying, and machine-learning outputs to visible user workflows. At the evaluation level, it reports both successful targets and limitations.

This layered explanation makes the project more defensible than a feature list. A feature list can show that many screens exist, but it does not explain why they belong together. In Zaman Sayar, the organizing principle is the relationship between time, task, information, responsibility, traceability, and decision support. Calendar records explain when work occurs; tasks explain what must be done; notes explain context; RACI explains responsibility; tables hold flexible structured data; OCR reduces manual entry; ZamanChat retrieves information; GitHub links development work; and intelligent suggestions provide measurable assistance.

The AI components are intentionally bounded. OCR does not directly change records without a trace; it creates structured task drafts and stores logs. ZamanChat does not write to the database; it reads within a controlled boundary. zaman_ai does not replace human judgment; it produces suggestions and stores user feedback. This design choice is important because academic software projects should avoid presenting automation as authority. In this study, automation is positioned as assistance, and the human user remains part of the workflow.

End-to-End Use Scenario

A typical use scenario explains why the modules belong together. A team member can create a task assignment with content, priority, assignee, due date, and tracking information. If the task arrived as a screenshot or photographed instruction, the OCR workflow can extract the initial task fields and store the raw evidence. The same task can then be viewed in the daily plan, placed into the calendar, broken into subtasks, and supported with a written or audio note. If responsibility is shared, the RACI module clarifies who performs the work, who approves the outcome, who should be consulted, and who should be informed.

As work continues, the user can inspect status through statistics, add flexible data through dynamic tables, or import rows from a spreadsheet. If the work is related to a software repository, GitHub issues and pull requests provide traceability and milestone dates can become calendar records. When the user needs a quick interpretation of existing records, ZamanChat can summarize or explain data without giving write authority to a natural-language layer. When the user needs assistance at task creation time, the Intelligent Suggestion page predicts type, category, priority, estimated duration, reminder timing, RACI role, and a short summary.

This scenario shows that Zaman Sayar is more than the sum of independent screens. Each module supports a different stage of the same work lifecycle: capture, structure, plan, assign, explain, monitor, retrieve, connect to development evidence, and obtain decision support. The system therefore demonstrates a complete information flow from raw input to measurable output. This is also why the paper reports both interface evidence and quantitative model evidence; the project would be incomplete if either the application workflow or the evaluation layer were missing.

Software Quality Considerations

Maintainability is supported by the separation of concerns between MVC controllers, entity models, service logic, Razor views, database access, and auxiliary scripts. Each major module has a visible controller responsibility and a related data structure. The OCR, ZamanChat, GitHub, and ML subsystems are connected through explicit contracts rather than being mixed directly into unrelated controller code. This reduces coupling and gives future developers a clearer path for replacing or improving one support layer without rewriting the entire product.

Traceability is supported at several levels. OCR logs preserve which engine produced which raw text and which structured draft was generated. RACI comments preserve responsibility-related discussion. Dynamic table rows and uploaded rows preserve flexible data without losing the relational entry point. GitHub settings and synchronized calendar records connect repository work to time planning. SuggestionFeedback stores model outputs and user decisions, which makes later acceptance-rate

measurement possible. These records help the system move from a temporary interface prototype toward an auditable software artifact.

Usability is addressed through integration rather than visual decoration alone. The user can move from a main panel to modules through a consistent navigation structure, can use charts for monitoring, can use OCR for faster entry, can ask read-only questions through ZamanChat, and can inspect suggestion history. However, usability maturity is not overstated. Accessibility review, mobile behavior, error states, empty states, and real-user task completion studies remain future work. This balanced interpretation keeps the paper academically honest while still showing the strength of the implemented prototype.

LIMITATIONS

The study has several limitations. First, although Identity infrastructure exists, production-level role-based authorization is not yet complete. Second, the 55 unit tests focus on the machine-learning subsystem; controller, service, data-access, OCR parsing, GitHub integration, ZamanChat query-safety, and end-to-end tests should be expanded. Third, null-safety, form validation, and unexpected empty-value scenarios require further production hardening. Fourth, OCR and ZamanChat are functional but could be improved with broader real-world input sets, richer error handling, and clearer user feedback.

Fifth, the machine-learning results are based on synthetic and anonymized data and should be revalidated with real field data. Sixth, the A3 readability criterion was met through an AI-assisted/simulated panel rather than a real human-subject study. Seventh, task-text clustering showed weak separation, which is reported as a transparent negative finding. Eighth, the GitHub personal access token is stored unencrypted in the current prototype and should be protected by ASP.NET Core Data Protection or a secret-management service before production use.

CONCLUSION AND FUTURE WORK

This study designed and implemented Zaman Sayar, an integrated time, task, note, responsibility-management, software-traceability, and intelligent decision-support application. The system is built on ASP.NET Core MVC and Entity Framework Core and is supported by SQL Server, Python-based OCR, Node.js-based ZamanChat, GitHub REST API integration, and the zaman_ai machine-learning subsystem. As a result, the project is not merely a set of screens; it is a multi-layered software system involving data modeling, service integration, algorithmic decisions, bounded natural-language interaction, traceability, and measured decision-support outputs.

The results demonstrate that different digital workflow needs can be addressed in one application context. Calendar and task modules establish the relationship between work and time; notes and audio notes preserve context; RACI makes responsibility sharing visible; dynamic and uploaded tables support flexible data use; statistics make records interpretable; and OCR, ZamanChat, GitHub, and Intelligent Suggestion components provide auxiliary automation and support. The ML subsystem reached the committed A1-A5 targets under the stated experimental conditions, while the limitations are explicitly documented.

Future work should strengthen role-based authorization, encrypt GitHub token storage, expand automated tests, evaluate OCR with more real images, improve ZamanChat language understanding while preserving the read-only boundary, validate machine-learning models with field data, conduct a real participant-based readability study, and review the frontend for accessibility, mobile compatibility, and error-state maturity. In conclusion, Zaman Sayar is a comprehensive, working, explainable, measurable, and extensible software engineering project whose value comes from integrating task, time, information, responsibility, traceability, and decision support within a coherent architecture.

For an international congress full text, the most important point is that the project can be evaluated as a coherent engineering study rather than as a collection of unrelated features. The paper therefore presents the implemented application, the supporting architecture, the data model, the auxiliary services, the machine-learning subsystem, the evaluation protocol, and the limitations in the same narrative. This structure makes the claims inspectable: a reader can see what was built, how it is connected, which outputs were measured, and which aspects still require production hardening.

The study also provides a useful basis for future academic work. A real deployment could collect consent-based field data, measure user task-completion time before and after integration, compare OCR-supported entry with manual entry, evaluate ZamanChat with real user questions, and replace the simulated readability panel with a human-subject study. These future steps would not change the core contribution of the current prototype; rather, they would validate it under more realistic operating conditions.

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BEYOND TRIAL-AND-ERROR: AUTOMATING FSS INVERSE DESIGN VIA CONDITIONAL GENERATIVE ADVERSARIAL NETWORKS

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ABSTRACT

Frequency Selective Surfaces (FSS) are periodic electromagnetic structures that selectively filter waves across specific frequency bands, serving critical functions in 5G infrastructure, radar systems, antenna gain enhancement, and electromagnetic shielding. Yet conventional FSS design faces a fundamental bottleneck: achieving a target frequency response demands evaluating hundreds of parameter combinations through full-wave simulators such as Ansys HFSS, a process that is computationally expensive, time-consuming, and heavily reliant on expert intuition. This study addresses that bottleneck by proposing a Conditional Generative Adversarial Network (cGAN)-based inverse design framework for FSS structures operating in the 1-20 GHz range. The training dataset is constructed by automatically simulating parametric geometries sampled via Latin Hypercube Sampling within HFSS 2024 R2 through the PyAEDT library. Given a target S-parameter response (S11, S21) as the conditioning input, the cGAN directly generates the corresponding unit-cell geometry, inverting the conventional trial-and-error loop and enabling design synthesis in seconds rather than hours. The generated geometries are validated against HFSS simulations, and error metrics between target and achieved frequency responses are reported. Results confirm a substantial reduction in computational cost compared with the conventional workflow and demonstrate that generative AI models can provide a practical, fast, and scalable alternative for electromagnetic structure design.

Keywords: Frequency Selective Surface, Conditional GAN, Inverse Design, Generative AI, Electromagnetic Simulation.

VISITOR PERCEPTION OF AUGMENTED REALITY'S VALUES AT CASTLES IN JAPAN

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ABSTRACT

A castle is a building or structure built for various purposes, such as defense, control, governance, lodging, refuge, retreat, and trade. Many castles are now used as tourist sites. However, most of them lack a sense of original scenery and activities. Therefore, managers and service providers have sought to bring life and authenticity to these sites, for example, by adopting augmented reality (AR) technology. Nonetheless, many visitors may be unaware of, or choose not to use, the designated AR applications at castles. This study surveyed visitors to castles in Japan to explore their perceptions of AR's perceived values. It collected answers from 219 visitors at five castles and castle ruins in the East of Japan (Akashi, Azuchi, Hikone, Himeji, and Koriyama Yamato). Descriptive analysis of the data revealed that visitors evaluated historical and cultural values most and economic values least. Comparison between the user and non-user groups (67 and 152) revealed several significant differences, mostly in epistemic values. This study expanded research on castles to an Asian setting, Japan. It also discussed some practical implications for promoting AR applications at castles, with a focus on its historical and cultural values.

Keywords: castles, Japan, augmented reality (AR), perceived values, users, non-users.

FREEDOM OF SPEECH IN THE CONTEXT OF STUDENTS' INVOLVEMENT IN THE UNIVERSITY SOCIAL ACTIVITIES WITHIN ONLINE ENVIRONMENT

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ABSTRACT

In modern society, students have become the motive force of a higher education institution, so they have been encouraged to train not only specialists, but also active citizens (European Commission, 2018). Traditionally, youth is seen as a free social group focused on innovation, transformation and reform. We note that today's young people are building their professional careers in an extremely contradictory world, facing increasing social challenges. The realities of the market economy and the globalization of social processes and interactions overlap with the values and ideas of their freedom of choice, expression, self-realization, achieving success in life and their desire to actively participate in the development of the academic community to which they belong. In this context, the question of students' willingness to assume social responsibility for the chosen forms and methods of influencing social processes and phenomena, in the field of educational and research activity, in their civic involvement, including in assessing their own position in the coordinates of inclusion and exclusion from the academic community, remains open. The purpose of this article is to determine the impact of freedom of speech, in the context of students' involvement in social activities, on the university image, the community and their academic performance. The methods used in the research were: questionnaires applied to students to assess the level of involvement in the social activities of the university they study; semi-structured interviews with professors of their academic community; direct observations on social networks; data accumulation and interpretation. In conclusion, we can state that freedom of speech and social activities of students, including online environment, have a positive impact on their academic performance, as well as on their sense of belonging to the university.

Keywords: freedom of speech; indicators; correlation; student; social activity.

Introduction

The relevance of addressing this issue lies in current realities: the level of technology in society; the academic environment is faced with the consequences of using the internet both in the process of carrying out the educational and research processes; students are involved in developing the image of the higher education institution, which is why their essential rights (freedom of speech and participation in social activities) must be supported and promoted by the university, as they actually contribute to improving their communication skills in an open and accessible environment; the online environment gives rise to a real danger of combining truth and falsehood, etc. The control of information called "private censorship" by Monica Cercelescu in the work "Freedom of speech in the era of turbulence" (2022), actually explains how the internet giants have taken over this control of information and implicitly of speech freedom. The fight against disinformation and hate speech has its downside, consisting in the proliferation of restrictions on speech freedom. The author also mentioned that "the algorithms used to select illegal or harmful content on social media platforms greatly hinder this freedom, as long as they are unable to contextualize hate speech or resolve philosophical issues, such as delimiting truth from falsehood". These are only part of the arguments underlying the relevance of this

research, specifying that undoubtedly the fundamental right regulated by the Constitution of the Republic of Moldova (freedom of speech art. 32 of the supreme law) could be part of the academic environment in the category of those that focus on the principle of academic freedom and respect for the rights and freedoms of academic community members. Undeniably, in today's society, freedom of speech is taking on new forms of manifestation (especially in the online environment), representing a way that offers the possibility of transmitting ideas, opinions and information in an extremely simple and efficient way, without borders, with minor restrictions, at modest costs and, often, in a much more interactive and attractive form for recipients (Stoicescu, Stela, 2019). Thus, the online environment amplifies the impact of the message sent, both in terms of the potential recipients aim and the way the message is sent, which can also significantly change its informational value. In this context, students involved in various social activities in the online and physical environment of the academic community must know the limits of internet use in order not to fall under the incidence of the contravention law, or more seriously, the criminal law (for example, incitement to hatred or discrimination, defamation of persons or institutions, promotion of false information or violence, slander or online threats, etc.).

The social activity specific to the university environment includes a wide range of student connections exercised in the educational process, research, extracurricular activities, self-government and interpersonal communication.

Methodology

Starting from the achievement of the proposed research aim (determining the impact of speech freedom in the context of students' involvement in social activities on the image of the university, the community and their academic performance), we proceeded to apply a sociological questionnaire among students aged 19-23, as well as through semi-structured interviews with their socially active academic community teachers (teaching staff, aged 35-65). The number of interviewees was 290 people, 185 students and 105 academic staff from the faculties of different fields (Security, Sports Sciences, Law) from the first year of the bachelor's degree. The period of the analytical study was between 2023-2025.

During the research, no difficulties were identified in understanding and completing the questionnaire by the respondents. In addition to the research methods used and mentioned above, we specify that other tools were also used, such as: the student's transcript to visualize his/her academic performance, the dean's reports on student success, including their academic path, the self-perception scale of academic competences (absences, grades in practical and specialized disciplines, number of credits) and the Prosocial Behavior Scale for Adults (oriented towards involvement in social activities); a fundamental statistical method used to understand the linear relationships between continuous variables determined in the research according to the Pearson correlation. The image of the institution could be monitored with the support of specially developed questionnaires and applied to students, professors, partners and employers in the way of identifying their perception of the university's civic commitment, attractiveness, recommendation and professionalism.

Research objectives

Determining the impact of students' social activities on their academic performance; developing the image of the institution, promoting social activities in the online environment and by identifying the connection between their speech freedom in the context of involvement in the university's social activities.

According to the specialized literature (Arendachuk Irina, Klenova Milena, Usova Natalia, 2022) social activity "manifests itself in the subject's ability to understand the meaning of solving social problems based on their correlation with their own value system". This objective has contributed significantly to the research in the way of determining and arguing the existence of a high congruence between students' personal values and the purpose of social activities. Moreover, we can mention that students' involvement in social activities is not an innate characteristic of the subject, but a behavior that can be learned and strengthened. Thus, factors such as: family, university, organizational culture and life experiences play an important role in shaping this behavior (Bandura, 1986, p. 112). Also, from a psychological point of view, the manifestation of an intention of students to get involved or not in different social activities within the university can be influenced by the existence of positive role models,

previous experiences of support, models of good practices, the belief that one's own action can have an impact (self-efficacy) and the level of internalized moral responsibility. Ervin Staub (2003) emphasized that the development of a prosocial orientation implies the existence of moral values and responsibility towards others. In this sense, educational interventions (including social activities) that promote empathy, moral reflection and the practice of prosocial behaviors can play an essential role in forming a more solidary society (Eisenberg et al., 2006).

Results and discussions

In order to estimate the level of students involvement in social activities in the educational institutions they study, we analyzed 7 functional dimensions (the conceptual framework of the involvement of interested subjects in social activities; the way to promote these activities where students are constantly involved; the correlation of students' involvement in social activities with their own value system; the connection of students' involvement in social activities with their freedom of expression; the development of partnerships; the role and impact of social activities where students were involved on the institutional image and their academic performance).

To the question given to students "Can you characterize the involvement in the university's social activities with three defining words?" we can observe from the answers received several elements: altruism, personal development, conformity, personal value, educational behavior, promotion of institutional values, freedom of speech (Figure 1).

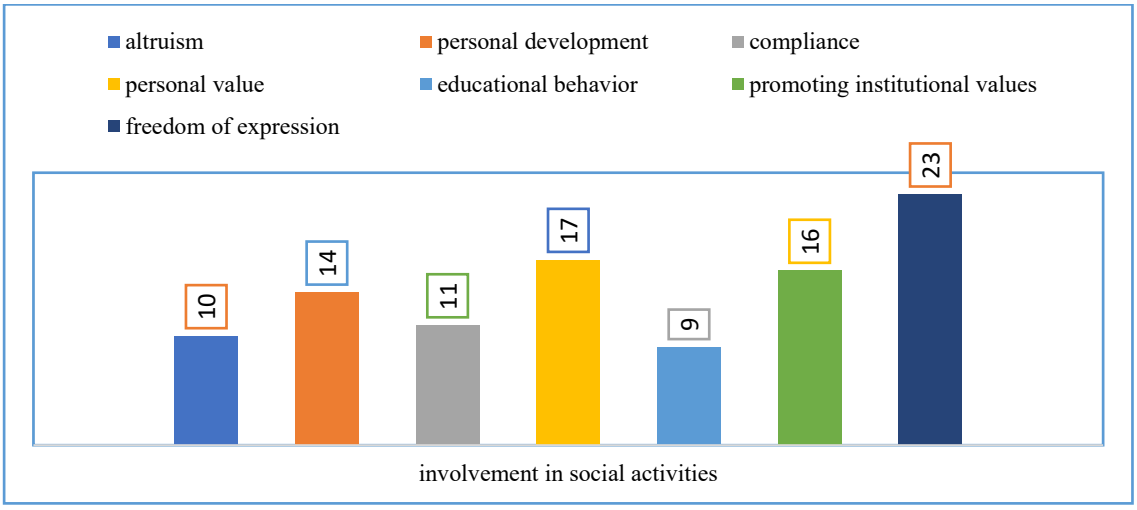


Figure 1. Graphical representation of responses regarding the characterization of involvement in the university's social activities

In an academic context, the conceptual dimension of social involvement includes various activities on the part of students, such as: membership in student associations, participation in faculty council meetings (with consultative or deliberative voting rights), organization of public events, petitions, legitimate protests, volunteering on campus. From Figure 1, we observe that over 23% of students stated that involvement in social activities gives them the opportunity to express themselves freely in various educational, research or ethical contexts. At the same time, scientific and didactic staff stated that the university website open on Google and YouTube provides ways to exercise freedom of speech, in a general way or for academic and professional purposes. Thus, it was established that the online environment (Google and YouTube) represents important sources of communication, with the support of which interested subjects can watch students social videos, scientific articles, scientific events of students and the teaching staff, students joint activities with university national and international guests. In short, and without a doubt, they constitute an important means of exercising the freedom to receive or impart information and ideas. It is important to note that attention must be drawn to the content of freedom of speech online, as subjects may fall under Article 10 of the European Convention ("the expression of an opinion or the transmission of information online…, the exchange or authorization to

distribute files on the Internet, including material protected by copyright law, even when published for commercial purposes" fall under this article).

Regarding the answers to the question "Please indicate how you find it more convenient to promote such activities, online or offline?", it can be seen from Figure 2 that over 60% of students state that the main way to promote these activities is the online environment (social networks). In this context, we can state that equally, the power of multiplied dissemination of information and its durability, once published in the online environment and contained in a concrete archive on the internet, represent an important and undeniable resource for education and historical research, in relation to the fact that they are extremely easily accessible to the public and free of charge. Similar to this assumption, in the motivation of a legal case (Stoicescu Stela, 2019) the European Court emphasized that "one of the advantages of the internet is that it ensures extremely efficient and easy access to data, without which the obligation provided for by law incumbent on the authorities would have no practical relevance".

To the question "Do you consider that your involvement in social activities is correlated with your own value system?" we can observe from the data reflected in Figure 3 that the responses of students and teachers are mostly affirmative (over 85%).

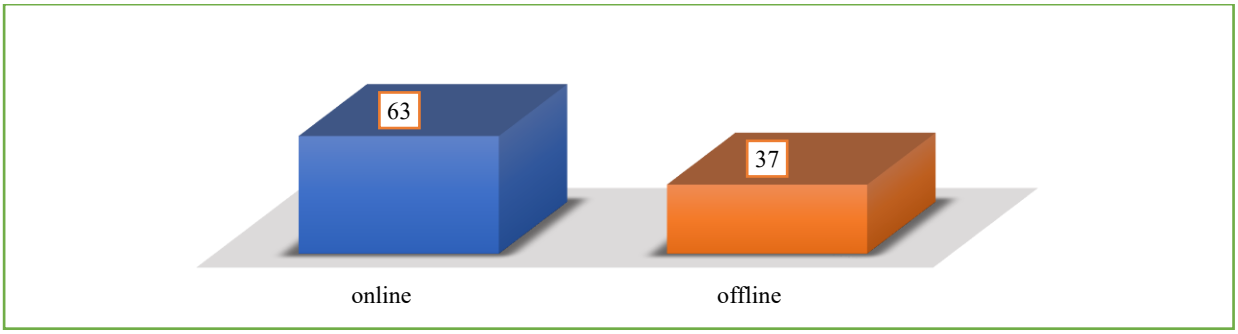


Figure 2. Graphical representation of responses regarding the way of promoting social activities

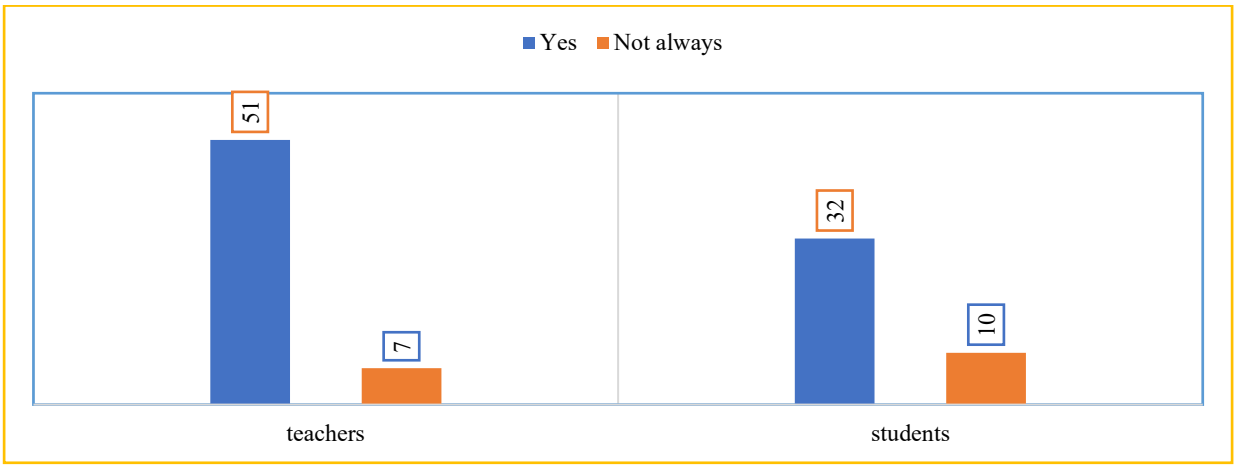


Figure 3. Graphical representation of responses regarding the correlation of social activities with personal values

Regarding the answers given by the students and teachers interviewed to the question "Do you believe that your involvement in social activities organized and carried out within the institution can contribute to the development of partnerships and the image of the university?", we can mention that they were affirmative in a significant percentage (over 70%) - Figure 4.

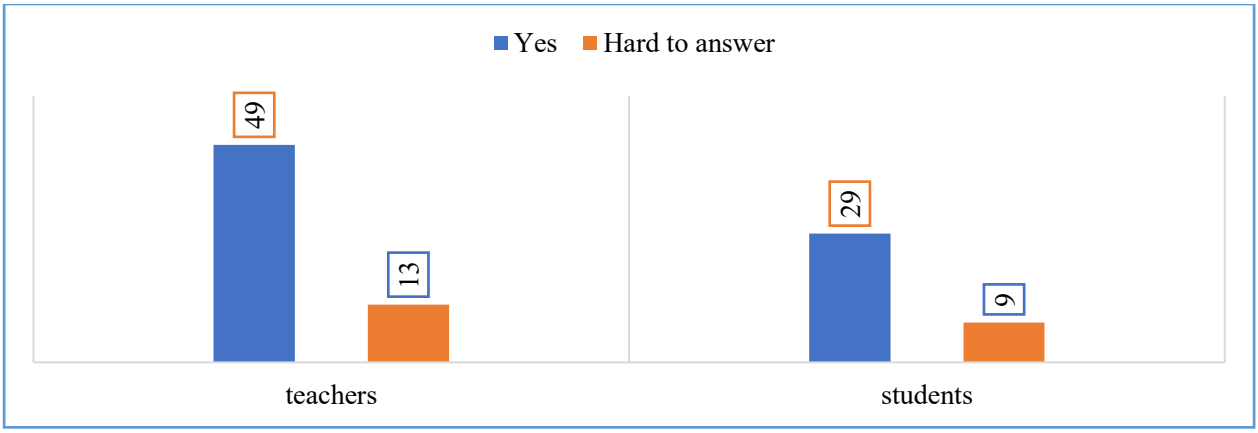


Figure 4. Graphical representation of responses regarding partnership development and institutional image

In this context, we can state that the consistent involvement of students and teaching staff in social, sustainable activities within the higher education institution contributes significantly to the consolidation of its partnerships, a process that in turn increases the visibility and reputation of the institution nationally and internationally. These assumptions are also supported by the opinions of the authors: Cortese Anthony in the work Higher education and sustainability (2003) co-authored with other researchers, stated that "the active involvement of all members of the academic community in sustainability issues develops an institutional culture of responsibility that becomes a pillar for long-term sustainable agreements and policies, because it creates internal commitment, not just external compliance". Also, Rodrigo Lozano (2011) stated that the frequent participation of students and teachers in environmental and social initiatives increases the social capital of the university, facilitating partnerships with national and international organizations. According to the author, "the involvement of internal stakeholders is a key factor in integrating sustainability into university governance". Furthermore, Jennie Stephens et al. (2008) – in their research on the role of universities in the transition to sustainability, stated that "the external visibility of a university is directly proportional to the coherence of internal actions...and, when students and professors are co-authors of sustainable agreements, then the image of the institution benefits from increased credibility in international rankings such as THE Impact Rankings or UI Green Metric".

Regarding the answers to the question "Do you consider that there is a direct correlation between your freedom of speech and the degree of involvement in the social activities of the educational institution?" we can observe from the graphic representation of the answers the registration of significant positive answers (over 65%). By freedom of speech in a university context we understand the right of students to formulate their opinions, criticisms, proposals and grievances without fear of disciplinary sanctions or informal marginalization, within the limits provided by law (incitement to hatred, defamation, threats). Unlike the academic freedom of teaching staff, this aims at the expression of students as actors of the community. Thus, both the teaching staff and the students consider that freedom of speech contributes to assuming social responsibility by encouraging subjects to address social issues in the university (equal opportunities, inclusive environment, sustainability, promotion of scientific and academic results, etc.). It is important to note that in fact, the involvement of students in the social activities of the higher education institution does not only transform them into participants, but mainly into people who contribute to change, to strengthening cohesion and to promoting the democratic climate existing at the institutional level. The involvement of students in activism has been part of higher education for a long time (Boren, 2001). However, the author stated that, until the Freedom of Expression Movement 1960s, students did not have the legal right to it (Chemerinsky, Gillman, 2017), but since then, students have used activism to drive significant social changes. Furthermore, regarding free speech on campus, political philosopher Sigal R. Ben-Porath (2017) presents an inclusive freedom framework to support administrators in fostering a community where free speech is upheld, democracy is promoted, and all individuals have space to express themselves freely. According to Sigal R. Ben-

Porath (2017), higher education institutions "can promote inclusive freedom through open speech monitoring….. speech monitors are volunteer faculty, staff, and student members with experience in conflict resolution and trained to protect free speech on campus." According to the same author (Sigal R. Ben-Porath, 2017, 2023) "higher education institutions should be spaces where all students and faculty feel safe enough to share their perspectives and learn from each other. The inclusive freedom framework emphasizes both inclusion and freedom of speech."

To identify the direct connection between students' freedom of speech in the context of their involvement in the university social activities, we started from the Self-Determination Theory (Deci & Ryan, 2000) which postulates three fundamental psychological needs: autonomy, competence and relatedness. Thus, we considered that freedom of speech directly supports students' autonomy, their needs to get involved in social activities and to act in accordance with their own values.

In table 1 we present the correlation items of the students freedom of speech monitored in the research in the context of the three fundamental psychological needs of the Self-Determination Theory (Deci & Ryan, 2000): autonomy, competence and relatedness.

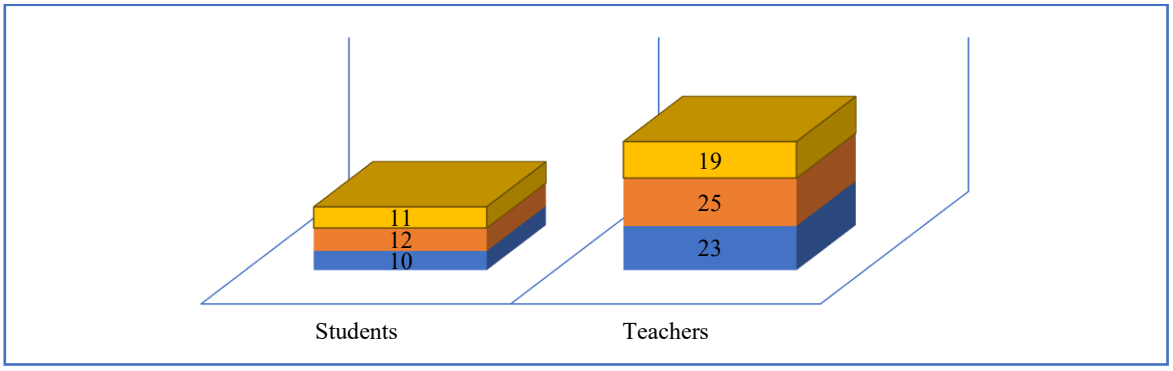
In achieving this objective, we started from the hypothesis that freedom of speech, perceived as an important factor in satisfying the need for autonomy, will contribute to increasing students' intrinsic motivation to get involved in social activities, which will generate positive effects on cohesion, trust, collaboration (relationship) and skills development (autonomy, critical thinking).

We present below the most representative questions from the set of those applied to students and professors from faculties monitored in the research.

To the question: "Do you consider that freedom of speech can ensure a greater degree of involvement in the social activities of the faculty?" (Figure 5) it can be observed that in general the answers are affirmative for both professors (over 60%) and students (over 30%).

Table 1. Items correlating students' freedom of speech with the three fundamental psychological needs of the Self-Determination Theory (Deci & Ryan, 2000)

The Fundamental Psychological Need of Self-Determination Theory (Deci & Ryan, 2000)	Mechanism	Items
Autonomy	Freedom of speech develops the feeling that the student is the source of his/her own actions (social involvement becomes intrinsically motivated)	Forming of autonomy skills (the student initiates, not just responds)
Competence	Free speech of students followed by real answers can contribute to increasing the feeling that they "can make a difference" compared to other higher education institutions where such actions are not encouraged	Increasing trust in the university, considering that their opinion matters and can even generate changes
Relatedness	Environment where students can express themselves freely, facilitating authentic connections with others	Developing of social cohesion (belonging, mutual support)
Support for autonomy according to context (regulations, institutional and teacher practices, academic environment, climate)	The applicable regulatory framework at the institutional level that is informative	The applicable regulatory framework (clear, predictable, fair, non-punitive)

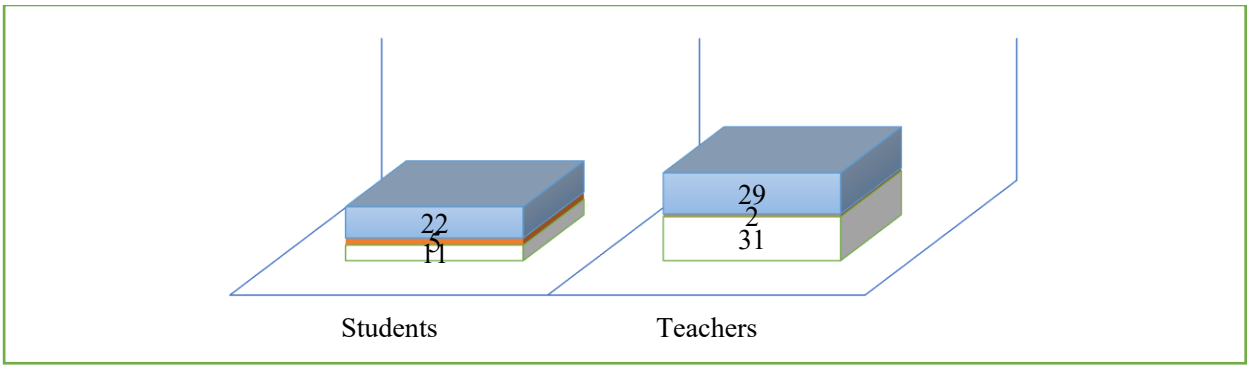


No. of answers	Response options	Respondents	Percentage
1.	YES freedom of speech predicts a higher level of autonomous social involvement	290 Teachers Students	 23% 10%
2.	YES, with the support of the applicable regulatory framework at the faculty/institution level	290 Teachers Students	 25% 12%
3.	YES, since there is a favorable environment and climate at the faculty level that allows us to express ourselves freely and within the limits of the legal framework	290 Teachers Students	 19% 11%

Figure 5. Graphical representation of responses regarding the correlation between freedom of speech **and student involvement in social activities**

From the accumulated data we can see that students express themselves much more freely if there is a favorable environment and climate focused on understanding, trust, constructive relationships and knowledge of institutional normative acts. With reference to the applicable legal framework, it is important to mention that students, through the messages formulated and submitted in public or in the online environment, should not fall under the scope of the law (for example, racist, xenophobic messages and which could be classified as acts that violate fundamental rights). In these cases, art.17 of the European Convention on Human Rights could be applicable, according to which abuse of rights is prohibited. Equally, publishing a derogatory message on the internet may attract the sanctioning of the guilty person as a contravention and his obligation to pay civil damages. In this case, we are dealing with the need to assess the consequences of statements from the perspective of the harm caused, similar to legal cases regarding classical freedom of speech, but with small nuances given by the specifics of this communication medium (Stoicescu, Stela, 2019). Although the European Court of Human Rights was fully aware of the extraordinary role that the internet has in the dissemination of information, it also emphasized that the internet poses a considerable risk of affecting privacy – much greater than the risk inherent in the written press (risk to the right to reputation). Thus, as noted by the European Court, "manifestly illicit statements, especially slanderous statements, which incite hatred or violence, can be disseminated like never before throughout the world in a few seconds and, sometimes, remain online for a long period of time." (Stoicescu Stela, 2019).

Regarding the question "Do you consider that the sense of belonging can constitute a premise for your free and authentic speech in the context of social activities?" we can see from Figure 6 that a significant percentage of affirmative responses were recorded (teachers over 50% and students over 30%).



No. of answers	Response options	Respondents	Percentage
1.	YES freedom of speech can be a prerequisite for expressing myself freely and authentically	290 Teachers Students	 31% 11%
2.	I don't think so	290 Teachers Students	 2% 5%
3.	YES, because a cohesive university can create a framework in which the diversity of freely expressed opinions can be assumed as common values	290 Teachers Students	 29% 22%

Figure 6. Graphical representation of responses regarding the correlation between freedom of speech and sense of belonging

At the same time, we can mention that among the examples of good practices in the university environment for increasing cohesion, internal regulations that protect both freedom of speech and the climate of academic safety can serve. Reduced membership in certain groups diminishes social cohesion and increases the risk of radicalization and targeted violence (Hruschka, Timon, Sabic-El-Rayess, Amra, Vikramaditya, Joshi, 2025). Prosocial behavior, although strongly influenced by individual traits and emotions, is shaped to a considerable extent by the social norms present in the group or community to which the individual belongs. For example, if in a collective the majority of people participate in volunteer activities, this reality becomes a descriptive norm and can influence newer members of the group to adopt similar behavior. In this sense, descriptive norms have a guiding function by conforming to the majority (Cialdini R.B. et al., 1991, p. 203). In this context, the involvement of some students in social activities within the university can influence to a greater or lesser extent the co-optation of others in this regard. From a psychological point of view, the social involvement of different generations can be significantly influenced by the perception of the future (optimism or pessimism), economic security and the general level of social awareness (Twenge, Campbell, Freeman, 2012).

The adult prosocial behavior scale used in the research was made up of the items reflected in the table, also representing a psychometric instrument intended to measure the frequency and intensity of students' involvement in social activities and its connection with their freedom of expression among adults. This research tool was applied to identify a variety of support elements (providing emotional support or active involvement in social actions of the higher education institution). The items were determined by affirmative expressions, which assess the general tendency to act for the benefit of other people or entities (increasing the personal reputation and the image of the institution to which the subjects belong). The responses were collected on a 5-point Likert scale (1 = “Never/Almost never true”; 5 = “Almost always/Always true”), and the scores obtained for each item were added together to calculate the total score. Examples of items: “I enjoy participating in such activities/colleagues support me in this direction; I like to express myself freely in a quality public environment, which gives me great confidence; I believe that the students' point of view, expressed in a free and constructivist manner, creates a positive image of the university, etc. (Caprara, Gian Vittorio, Steca, Patrizia, Zelli, Arnaldo,

Capanna, Cristina 2005). Within the framework of this research, the following items were analyzed: student autonomy, their trust in the university, the development of social cohesion (belonging, mutual support), the applicable regulatory framework (clear, predictable, fair, not punitive). Thus, in order to understand the linear relationships between continuous variables determined in the research (student autonomy, trust in the university, social cohesion, the applicable regulatory framework in correlation with their freedom of expression) according to the Pearson correlation, we proceeded to determine the basic descriptive values for each variable - mean, standard deviation, minimum and maximum values (Table 2).

Table 2. Basic descriptive values for each variable

Variable	Mean (M)	Standard Deviation (SD)	Minimum	Maximum	r(Cov)
Student autonomy	20,2	2,9	12	25	0,49
Trust in the university	18,8	3,8	8	25	0,43
Social cohesion	19,7	2,8	11	25	0,47
Applicable regulatory framework	17,9	3,5	8	24	0,35
Freedom of speech	21,1	2,5	10	25	0,50

From Table 2 we can see that the student autonomy variable recorded the highest mean, respectively 20.2 with a standard deviation of 2.9. The normative framework applicable at the university level reached the lowest level of 17.9, with a standard deviation of 3.5, which means that students need additional explanations in understanding the regulations by the dean's offices staff or by the teaching staff. Considering the Self-Determination Theory (Deci & Ryan, 2000) and according to which autonomy is one of the three fundamental psychological needs, we can say that the significant value obtained in the research for the "autonomy" variable actually shows us that students have shown authentic behaviors, including the free speech of opinions due to the appropriate context where they can demonstrate it. Also, according to the opinion of Roger Mayer, James Davis, David Schoorman (1995) "trust in the institution reduces the perception of risk and vulnerability". The values recorded in the research with an average of 18.8 show us that students trust the institution they belong to, but sometimes they can be reluctant when it comes to freedom of speech (the standard deviation recorded a high value of 3.8). In the specialized literature, it has been found that interdependence strengthens the relationships between team performance and team cohesion (Gully, M. Stanley, Devine, J. Dennis, Whitney, J. David, 1995), collective efficacy and the team's behavioral process (LePine, A. Jeffrey, Piccolo, F. Ronald, Jackson, L. Christine, Mathieu, E. John, Saul, R. Jessica). Emergent synergistic states and processes become more essential for team functioning when team members are mutually dependent on each other (Mesmer-Magnus, R. Jessica 2010). In Table 3 we present the basic descriptive values for each variable calculated in accordance with their correlation with freedom of speech for a number of 185 students.

From the recorded data we can state that freedom of speech correlates statistically ($p<0.001$) with all the variables analyzed. The research results indicate a positive, statistically significant correlation ($r=0.50$, $p<0.001$, $n=185$), between freedom of speech and social cohesion. This suggests that the two variables are in a moderately-strong connection, explaining approximately a quarter of the common variation. The strongest connections are, however, with student autonomy ($r=0.49$) and social cohesion ($r=0.47$), and the weakest, but still significant, with the applicable regulatory framework ($r=0.35$). These results suggest that the perception of freedom of speech is positively associated with the university climate.

Table 3. Basic descriptive values for each variable calculated in accordance with their correlation with freedom of speech

Variable	Mean	SD	Correlation with freedom of speech	r^2	t calculated	p-value	Interpretation
Student autonomy	20,2	2,9	**0,49**	0,240	7,60	<0,001	Moderate-strong connection
Trust in the university	18,8	3,8	**0,43**	0,185	6,46	<0,001	Moderate connection
Social cohesion	19,7	2,8	**0,47**	0,221	7,21	<0,001	Moderate-strong connection
Applicable regulatory framework	17,9	3,5	**0,35**	0,123	5,04	<0,001	Moderate (towards weak) connection
Freedom of speech	21,1	2,5	**0,50** (auto-correlation)	0,250	7,81	<0,001	-

The research found that students who are actively involved in the online communities also have higher academic results. A simple analysis of students' academic success versus their involvement in social activities identified a series of measurable indicators reflected by: the development of critical thinking (students become able to navigate through massive amounts of data and identify trustworthy information), an opinion also supported by Semen M. Levin (2024) who stated that "active participation in digital forums, social networks and online platforms contributes to stimulating student motivation, improving understanding of educational content and cultivating essential skills for effective learning". Also in the work “Theoretical and practical foundations of the formation of critical thinking in students” (2024), the authors Liliana Budevici-Puiu, Felicia Rusnac stated that “critical thinking plays a vital role in physical education, regardless of the theoretical approach applied. Whether it is about personal reflection, tactical evaluation, discussions and collaboration or quick decision-making, the development of this cognitive skill helps students become better, both in sports and in everyday life. As students learn to critically analyze their own actions and experiences, they become more autonomous, more efficient and more aware of their own abilities and limits”. Another indicator identified is reflected in the increase in students' collaboration (relationship) with other colleagues, which means from our point of view that the freedom to freely discuss issues in courses and seminars, to share resources or to organize study groups on social networks can contribute to the understanding and consolidation of the curricular content and implicitly to achieving successful academic performance. At the same time, the free speech of opinions about the teaching methods of teachers or about the study conditions can lead to institutional improvements that, indirectly, facilitate learning.

In conclusion, we can say that research is a creative approach for the academic community, especially from the perspective of the aim of improvements that can be made at the institutional level. Thus, we believe that a higher education institution that encourages and supports responsible freedom of speech by providing support for student involvement in social activities closely related to academic topics (discussions on research ethics, promoting integrity, equal opportunities) can be beneficial, while purely recreational ones can generate conflicts and acts that contravene the law, being subject to disciplinary, misdemeanor and even criminal sanctions. An open institutional climate reduces anxiety and encourages authentic participation, while digitalization facilitates rapid and organized access to the necessary resources. Students who know they can ask questions without fear of retaliation, that they can receive pertinent feedback from teachers and peers, and that necessary information is easily accessible become more able to set their own learning pace, assess their progress realistically, and adjust their study strategies according to identified needs (Semen M. Levin, 2024).

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AI COMPETENCE OF EDUCATIONAL INSTITUTION LEADERS: HISTORICAL CONSCIOUSNESS, ETHICAL GOVERNANCE AND STRATEGIC DECISION-MAKING

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ABSTRACT

Artificial intelligence is becoming a strategic issue for educational institutions, not only as a teaching tool but also as a factor that reshapes leadership, institutional memory and decision-making. This paper examines the AI competence required of educational institution leaders, with special attention to historical consciousness as a condition for ethical governance. The study argues that school leaders should not approach AI only as a technical innovation, but as a governance challenge that requires the ability to connect data-driven decisions with institutional history, democratic values and long-term educational responsibility. Methodologically, the paper uses a conceptual and critical-analytical design based on peer-reviewed literature, Scopus-indexed research, DOI-verified studies and institutional documents from UNESCO and the European Commission. The analysis identifies five competence domains for AI-aware educational leadership: strategic AI literacy, ethical and legal judgement, historical-institutional awareness, data-informed decision-making and human-centered school governance. The paper shows that AI may strengthen leadership through prediction, administrative efficiency and evidence-informed planning, but it may also generate risks related to bias, surveillance, depersonalization and loss of institutional memory. The contribution of the paper is to integrate AI leadership with historical thinking, arguing that future educational leaders must be digitally competent and historically conscious at the same time. The conclusion emphasizes that the future of school governance will depend not on the replacement of human leadership by algorithms, but on leaders capable of using AI while protecting educational purpose, memory and human dignity.

Keywords: artificial intelligence; educational leadership; historical consciousness; school governance; ethical decision-making; institutional memory

INTRODUCTION

Artificial intelligence has moved rapidly from a technological topic to a central question of educational governance. Schools, universities and public education systems now face tools that can assist with administrative planning, predictive analytics, student support, assessment, communication and institutional decision-making. These developments make AI competence an urgent requirement for educational institution leaders. A director, principal or rector who lacks AI literacy may be unable to evaluate the promises, limits and risks of systems that increasingly influence pedagogical and organizational life.

The central problem is that AI is often introduced into education through a technical vocabulary: efficiency, automation, personalization and data processing. These terms are important, but they do not fully express the historical and moral nature of educational leadership. Educational institutions are not only administrative organizations. They are communities with memory, values, traditions, conflicts and social responsibilities. Leaders therefore need more than operational knowledge of AI. They need the capacity to connect technological decisions with the historical identity and ethical mission of the institution.

This paper proposes that AI competence for educational leaders should be understood as a multidimensional professional capacity. It includes strategic literacy, ethical judgement, data interpretation, human-centered governance and historical consciousness. The historical dimension is especially important for leaders trained in history and education, because it prevents technological

innovation from being interpreted as a rupture without memory. Historical consciousness enables leaders to ask how past reforms, institutional cultures and social experiences should inform the use of AI in the present and the future.

Recent literature supports this debate. Wang (2021) argues that AI in educational leadership should be understood through a symbiotic relationship between human and artificial intelligence decision-making. Fullan et al. (2024) discuss the challenges and opportunities of AI for school leadership, while Arar et al. (2024) use Scopus-based bibliometric analysis to show the emerging development of AI and educational leadership as a research field. UNESCO (2024) also proposes AI competency frameworks that emphasize human agency, ethics and sustainability. Together, these sources indicate that AI leadership is not a future issue; it is already part of the strategic agenda of educational systems.

The aim of this paper is to develop an analytical framework for understanding AI competence in educational leadership through the lens of historical consciousness and institutional memory. The main research question is: what kind of AI competence should educational institution leaders develop in order to make strategic, ethical and historically responsible decisions?

MATERIALS AND METHODS

The study uses a qualitative, conceptual and critical-analytical methodology. It does not report original survey or regression findings; instead, it builds a theoretically grounded framework from verified academic and institutional sources. This approach is suitable because the object of analysis is an emerging leadership competence rather than a single measurable intervention. The paper examines how AI competence can be defined for educational leaders and how historical consciousness can strengthen ethical governance in AI-mediated institutions.

The material includes peer-reviewed articles with DOI, Scopus-indexed or Scopus-related studies, and official policy documents from UNESCO and the European Commission. Sources were selected according to four criteria: direct relevance to AI and educational leadership; contribution to ethical or governance dimensions of AI; relevance to historical consciousness, historical thinking or institutional memory; and verifiability through DOI, academic publisher or official institutional source.

The analysis follows three steps. First, the literature on AI in educational leadership is reviewed in order to identify emerging leadership requirements. Second, the literature on historical consciousness and institutional memory is used to interpret why educational leaders need a long-term historical perspective when governing technological change. Third, the two strands are synthesized into a competence framework that can guide future empirical research, leadership training and policy design.

The study treats AI competence not as the ability to use a software application, but as the capacity to lead an institution in conditions where algorithmic systems influence decisions. This distinction is important. A leader may be able to use generative AI and still lack the competence to govern its institutional effects. Conversely, a historically informed leader may not be a technical expert, but can ask the right ethical, organizational and democratic questions about AI implementation.

Table 1. Analytical dimensions of AI competence for educational institution leaders

Competence dimension	Leadership meaning	Historical contribution	Risk if absent
Strategic AI literacy	Understanding AI applications in administration, teaching and planning.	Places innovation within long-term institutional development.	Fragmented adoption of tools without strategy.
Ethical and legal judgement	Evaluating privacy, bias, transparency and accountability.	Connects decisions with civic values and institutional legitimacy.	Surveillance, discrimination or opaque decisions.

Competence dimension	Leadership meaning	Historical contribution	Risk if absent
Historical consciousness	Reading present reforms through past experience and future responsibility.	Protects institutional memory and educational identity.	Technological amnesia and repeated reform failure.
Data-informed decision-making	Using evidence without surrendering judgement to algorithms.	Balances data with contextual knowledge.	Automation bias and depersonalized governance.
Human-centered governance	Keeping students, teachers and communities at the center.	Links technology with dignity, participation and social trust.	Loss of dialogue and reduction of education to metrics.

Table 2. Evidence base and source contribution

Evidence source	Type	Key contribution	Use in this paper
Wang (2021)	DOI / Scopus-indexed journal	Human-AI symbiosis in educational leadership decision-making.	Defines leadership as moral and evidence-informed judgement.
Fullan et al. (2024)	DOI / School leadership journal	AI creates challenges and opportunities for school leadership.	Supports the need for leader preparation.
Arar et al. (2024)	DOI / Scopus-based bibliometric review	AI and educational leadership is an emerging research field.	Justifies the research gap.
UNESCO (2024)	Institutional framework	15 AI teacher competencies across 5 dimensions.	Provides a policy model for competency thinking.
Popa (2022)	DOI / Review of Educational Research	Historical consciousness links past, present and future.	Supports the historical dimension of leadership.

RESULTS

The conceptual analysis identifies five results. First, AI competence in educational leadership must be strategic rather than merely operational. Leaders need to understand how AI affects school planning, assessment, student support, teacher work, communication and institutional accountability. This competence includes the ability to distinguish between AI as a useful tool and AI as a governance system that may reshape institutional priorities.

Second, ethical judgement is a central component of AI competence. AI-assisted decisions can increase administrative efficiency, but they may also reproduce bias or conceal responsibility behind technical language. Nguyen et al. (2023) emphasize ethical principles for AI in education, while the European Commission (2022) stresses the need for educators to understand data, transparency and human oversight. Educational leaders must therefore ask not only whether AI works, but whether it is fair, explainable and appropriate for the educational context.

Third, historical consciousness strengthens AI governance. Historical consciousness is the capacity to understand relationships between past, present and future. In institutional leadership, this means remembering earlier reforms, recognizing local traditions, learning from previous failures and protecting the school from technological amnesia. Popa (2022) describes historical consciousness as a form of

meaning-making that links temporal dimensions. For educational leaders, this is not only a history-teaching concept; it is also a governance resource.

Fourth, AI competence requires data-informed decision-making without algorithmic dependence. Wang (2021) argues that AI can support evidence-informed decisions, but value-based moral decision-making remains necessary. This is crucial for schools, because education involves human development, not only measurable performance. Leaders must know when to use AI-generated evidence and when to challenge it.

Fifth, AI competence must be human-centered. UNESCO (2023, 2024) frames AI in education around human agency, ethics and sustainability. The leader's task is therefore to ensure that AI supports teachers and learners rather than replacing institutional dialogue with automated procedures.

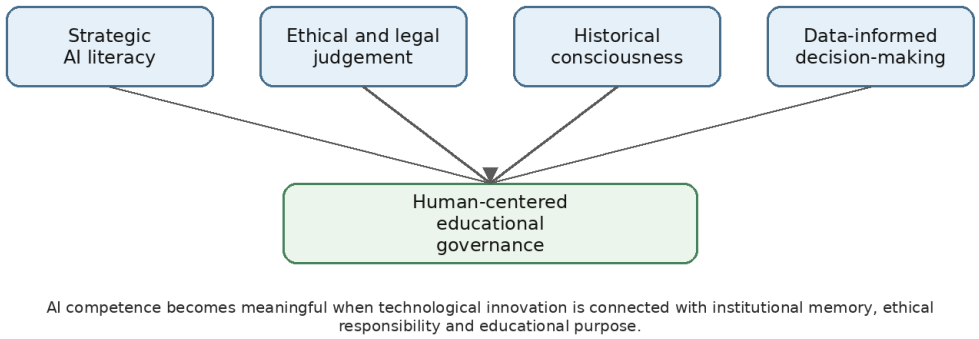


Figure 1. Conceptual model of AI competence, historical consciousness and educational governance

The model illustrates that AI-aware leadership is strongest when technological competence is connected with institutional memory, historical consciousness and human-centered decision-making.

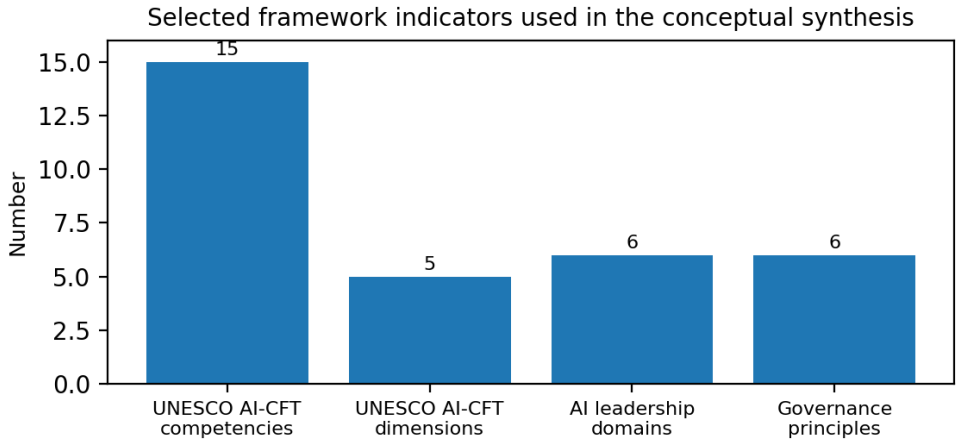


Figure 2. Selected framework indicators used in the conceptual synthesis

The figure summarizes selected numerical anchors used in the analysis: UNESCO identifies 15 AI competencies across 5 dimensions for teachers, while recent AI leadership frameworks emphasize multiple leadership domains and governance principles. These figures are not regression findings; they illustrate the architecture of the conceptual framework.

Table 3. AI leadership risk matrix

AI use in institution	Potential benefit	Leadership risk	Required competence
Predictive analytics	Early identification of student needs.	Labeling, bias or reduction of students to data profiles.	Ethical data judgement.
Generative AI for communication	Faster preparation of materials and reports.	Loss of authenticity or unverified information.	Critical AI literacy.
Administrative automation	Reduced routine workload.	Opaque decision chains and weak accountability.	Transparent governance.
AI-supported assessment	More feedback and monitoring.	Over-measurement and pressure on teachers.	Pedagogical judgement.
Historical archive digitization	Better access to institutional memory.	Fragmentation or decontextualization of history.	Historical interpretation.

DISCUSSION

The discussion of AI competence in educational leadership should move beyond the question of whether leaders are ready to use digital tools. The deeper issue is whether they are ready to govern institutions in which algorithmic systems affect decisions, relationships and organizational memory. AI does not only enter schools as software; it enters as a new form of authority. It can recommend, classify, predict and rank. Therefore, leaders must be capable of questioning the authority of the system itself.

The historical dimension is essential because educational institutions live through accumulated experiences. Every school carries a memory of reforms, crises, achievements, conflicts and social expectations. If AI is introduced without respect for this memory, it may produce efficient but shallow transformation. Historical consciousness allows leaders to recognize that not every new technology represents progress and not every traditional practice represents backwardness. Good governance requires the ability to distinguish renewal from rupture.

This is particularly important in societies where educational institutions have carried responsibilities for cultural identity, democratic formation and social cohesion. A historically conscious leader understands that schooling has never been only a technical service. It has been a place where communities transmit language, memory, values and civic orientation. AI can support this mission, but only if leaders prevent it from narrowing education to prediction, measurement and automation.

The paper therefore proposes that AI competence for leaders should include three balances. The first is the balance between data and judgement. Leaders should use AI-supported evidence, but should not delegate moral responsibility to a system. The second is the balance between innovation and memory. Leaders should modernize institutions while preserving what gives them identity and legitimacy. The third is the balance between efficiency and humanity. Leaders should use AI to reduce unnecessary workload, but should protect dialogue, trust and human relationships.

A practical implication is that leadership training programmes should include AI literacy, data ethics, historical institutional analysis and scenario-based decision-making. Future principals and directors should learn to read dashboards, but also to read institutional history. They should understand algorithmic bias, but also the social consequences of earlier reforms. They should know the language of AI, but also the language of human responsibility.

The debate is not whether AI will enter educational institutions. It already has. The debate is whether educational leaders will be passive recipients of external technologies or active interpreters of their institutional meaning. This is why AI competence must be framed as a leadership competence, not only as a technical skill.

Table 4. Recommendations for AI-aware educational leadership

Area	Recommendation	Expected effect
Leadership preparation	Include AI literacy, ethics and data governance in principal training.	Stronger capacity to evaluate AI tools.
Historical-institutional memory	Use school archives, reform histories and local narratives in strategic planning.	More contextual and responsible innovation.
Ethical governance	Establish transparent rules for AI use, privacy and accountability.	Reduction of bias and institutional mistrust.
Teacher participation	Involve teachers in AI adoption decisions.	More realistic and pedagogically legitimate implementation.
Future planning	Use scenario planning for long-term AI effects on education.	Better preparation for uncertainty.

CONCLUSION

This paper has argued that AI competence is becoming a core requirement for educational institution leaders. The use of AI in schools and universities is not only a matter of technical modernization; it is a matter of ethical, historical and strategic governance. Leaders must understand what AI can do, but they must also understand what AI should not be allowed to decide. This distinction is central to the future of education.

The main contribution of the paper is the connection between AI competence and historical consciousness. A leader who understands history is better prepared to govern technological change because history teaches that every reform has consequences beyond its immediate technical promise. Educational institutions must innovate, but they must not lose memory. They must use data, but they must not abandon judgement. They must adopt AI, but they must not allow algorithms to define the purpose of education.

The future educational leader will therefore need a double competence: digital intelligence and historical wisdom. Digital intelligence enables leaders to understand AI systems, data, automation and risk. Historical wisdom enables them to connect present decisions with institutional identity, social responsibility and long-term consequences. Without digital intelligence, leaders may become unable to govern technological change. Without historical wisdom, they may accept change without understanding what is being lost.

The final argument is deliberately open to debate. If the twenty-first century is the century of artificial intelligence, the central educational question will not be whether machines can become more intelligent. It will be whether educational leaders can remain wise enough to keep institutions human. The leadership of the future will be judged not by how quickly it adopts AI, but by whether it can use AI while protecting memory, dignity, democracy and the moral purpose of education.

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LEGAL AND FINANCIAL RISK MANAGEMENT IN INTERNATIONAL TRADE: PAYMENT METHODS

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ABSTRACT

The payment methods used in foreign trade carry varying levels of risk for both exporters and importers. In the documentary collection method, banks do not provide a payment guarantee; they merely act as intermediaries in the delivery of documents and the payment process. Consequently, whilst it is less costly than a letter of credit, it offers more limited security for the exporter. The consignment payment method is one of the riskiest methods for the exporter. The goods are sent to the importer, but payment is usually made only after the goods have been sold. This situation gives rise to risks such as payment delays, non-payment, return of goods, and the importer failing to make sufficient effort in the sale. When payment methods are compared in terms of risk, the most advantageous method for the importer is open account, whilst the safest method for the exporter is prepayment. Under an open account, the importer takes delivery of the goods without making payment, whereas with prepayment, the exporter collects the payment before dispatching the goods. Export credit insurance, however, is an important tool that protects the exporter against the risk of the foreign buyer failing to pay. This insurance can cover commercial and political risks such as bankruptcy, prolonged payment delays, war, terrorism, nationalization, foreign exchange transfer restrictions and changes in legislation. Consequently, exporters can conduct open account sales more securely, increase their market share and access financing more easily.

Key Words: Foreign trade risks, Payment methods, Documentary collection, Letter of credit, Export credit insurance.

CRITICAL ANALYSIS OF VARIOUS FORMS OF TRAUMA IN *PLAYGROUND* BY RICHARD POWERS

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ABSTRACT

This paper critically explores the psychological and emotional effects of trauma on human beings. The novelist Richard Powers has depicted various reasons for the traumatic experiences of human beings for example technological expansion, ecological destruction, and social isolation. *Playground* deeply presents trauma is both an individual experience and collective one. Through the characters of Todd Keane, Rafi Young, Evelyne Beaulieu and Ina Aroita in the story, Powers talks about the memory loss, grief, cultural displacement and ecological anxiety. The symbol ocean mentioned in the story becomes both a site of healing and a reminder of violence and environmental exploitation. The study examines how trauma gives birth to personal suffering, technological alienation, and climate fear to the characters. Applying trauma theory and ecocriticism, Powers portrays trauma in the life of modern people. Hence, in the novel, it is found that healing is possible only through reconnection with memory, community, and natural world.

Keywords: Trauma, Ecological Anxiety, Technological Alienation, Memory, Healing, Natural world.

Introduction

Contemporary literature critically addresses trauma as a critical condition of modern life. In *Playground*, Richard Powers explores trauma through emotional, environmental, and philosophical dimensions. The novel is set partly on the island of Makatea in French Polynesia, a place marked by colonial exploitation and ecological damage. By intertwined narratives, Powers evaluates how individuals and societies respond to loss, displacement, and uncertainty.

The trauma in the novel appears in multiple forms: personal trauma caused by grief and illness, collective trauma caused by environmental destruction, and cultural trauma related to colonialism and technological domination. All these experiences are elucidated by the novelist, highlighting the broader global crises such as climate change and digital alienation. By mentioning psychological depth with ecological awareness, the novel demonstrates how trauma is not isolated within individuals but shared across communities and ecosystems.

This paper examines the representation of trauma in the novel using psychological and ecocritical perspectives. It argues that Powers uses trauma to critique modern technological society while emphasizing the importance of memory, empathy, and ecological consciousness.

Trauma and Memory

Trauma refers to a deeply distressing experience that overwhelms an individual's ability to cope and produce lasting psychological consequences. Cathy Caruth explains trauma as "the response to an unexpected or overwhelming violent event or events that are not fully grasped as they occur, but return later in repeated flashbacks, nightmares, and other repetitive phenomena" (4). It is said that memory plays a crucial role in trauma studies because traumatic experiences often remain incomplete,

fragmented, and difficult to represent. In brief, traumatic memory may return through repeated recollections, emotional responses, or unconscious experiences that continue to influence an individual's identity.

Memory is the central concern in Richard Powers' *Playground*. The novel explores how memories shape personal identity and reveal hidden emotional wounds. Todd Keane's life is deeply influenced by his childhood experiences, family conflicts, and personal struggles. His memories of his parents' destructive relationship display how early emotional trauma continues to affect his understanding of himself. Memory of Todd's childhood is found, "one continuous war game between the two of them" where his parents' conflict became a constant source of fear and emotional instability (Powers 10). This traumatic environment shapes Todd's personality and contributes to his later search for control through technology and achievement.

Memories of the protagonist critically demonstrate how trauma remains connected with the past even when individuals attempt to move beyond painful experiences. His childhood isolation becomes a psychological escape from emotional suffering. Todd retreats into an imaginary underwater world beneath Lake Michigan as "when my mind raced and the future rushed at me with knives, the only thing that helped was looking out from the castle and seeing myself walking across the bottom of the lake" (*Playground* 10). The fantasy of Todd represents a protective psychological mechanism where he escapes from family trauma and creates a separate identity away from emotional conflict.

The novel also reveals how memory preserves unresolved emotional wounds. Todd's recollections of his parents' relationship show that traumatic experiences continue to affect his emotional life. The repeated memories of betrayal, anger, and loneliness illustrate Caruth's argument that "trauma is characterized by the return of experiences that have not been completely understood or processed" (Caruth 11). Thus, the memory of Todd does not function simply as a record of the past; rather, it becomes a space where pain, identity, and personal history continuously interact.

Furthermore, the novelist presents memory as essential for understanding human identity. The later struggle of Todd with dementia symbolizes the fear of losing the memories that define the self. His technological achievements and public success cannot protect him from the vulnerability of memory loss. It is studied that the novel suggests that identity depends not only on external achievements but also on the emotional experiences and memories which connect individuals with their past.

The fragmented structure of *Playground* also reflects the nature of traumatic memory. Trauma is often experienced through disconnected images, incomplete recollections, and disrupted narratives rather than through a clear chronological sequence. The author of trauma fiction Anne Whitehead argues that trauma fiction frequently uses fragmented narrative techniques because they represent "the disruption and dislocation experienced by trauma survivors" (Whitehead 3).

It is analyzed that *Playground* portrays memory as more than a simple record of past events; it is a foundation of identity and emotional survival. Through Todd Keane's childhood trauma, personal memories, and fear of memory loss, Powers marks that trauma continues to shape human consciousness. The novel reveals when memories disappear or remain unresolved, individuals experience a disruption in their connection with themselves, their past, and their relationships with others.

Ecological Trauma and Climate Anxiety

Ecological trauma, in fact, refers to the psychological, emotional, and cultural suffering caused by environmental degradation, ecological disasters and the destruction of natural habitats. The famous environmentalist Glenn Albrecht defines "ecological distress as a form of suffering that emerges when people witness the degradation of environments to which they are emotionally attached" (Albrecht 44-48). To understand the ecological trauma, it is depicted as "Climate anxiety is similarly described as a chronic fear of environmental catastrophe resulting from climate change and ecological destruction" (American Psychological Association 5–10).

The present article focuses on Richard Powers' *Playground* which talks about the ecological trauma is vividly represented through the history of Makatea, an island whose natural beauty and ecological richness are sacrificed for economic exploitation. Powers describes Makatea as a unique uplifted coral

island that "teemed with insects, snails, fish, and birds, including species that existed nowhere else in the world" (Powers 49). It is found in the study that the discovery of phosphate transformed this ecological paradise into a site of extraction and destruction. The rich biodiversity, forests, and sacred landscapes of the island Polynesia in the story were gradually devastated by mining operations. Powers notes that "a third of Makatea became a moonscape of jagged rock pitted with cavities several feet wide and a hundred feet deep" (30). This transformation illustrates how environmental degradation produces both physical destruction and collective ecological trauma.

The novel further highlights ecological trauma with colonial exploitation. Following the annexation of Makatea by France, foreign mining companies extracted phosphate for global agricultural development while disregarding the well-being of local communities and ecosystems. Although phosphate from Makatea helped "feed millions" and contributed to humanity's technological and economic progress, Powers emphasizes that "in the process, the island was consumed" (31). This statement highlights the unequal relationship between industrial advancement and environmental sustainability, demonstrating how ecological exploitation often benefits distant populations while leaving local communities with long-term environmental and cultural loss.

Climate anxiety is also reflected with the portrayal of the ocean and marine ecosystems in the novel. Powers repeatedly presents the ocean as the foundation of life and ecological interconnectedness. He observes that "the fate of continents is written in water" and that global ecological systems depend on oceanic processes (30). Characters such as Evelyne Beaulieu develop profound emotional connections with marine life, making them acutely aware of environmental threats. Their concern for the future of oceans and biodiversity mirrors contemporary climate anxiety, which arises from fears of ecological collapse and irreversible environmental damage (American Psychological Association 5–10).

In brief, Powers expands the concept of trauma beyond human experience by emphasizing the suffering of non-human life. It is seen that the destruction of coral reefs, forests, and island ecosystems leads to environmental harm which affects entire ecological networks. "The history of Makatea begins with millions of years of coral and microbial activity that created the island itself, illustrating the deep interdependence of human and non-human existence. This perspective aligns with Greg Garrard's argument that ecological crises reveal the interconnectedness of humans and the natural world" (Garrard 15–20). By portraying environmental destruction as a shared experience affecting people, animals, and ecosystems, Powers challenges anthropocentric views and advocates ecological responsibility.

It is studied that the novel portrays ecological trauma as both environmental and cultural. For the people of Makatea, land (*fenua*) is sacred and represents "the soul's house" (31). The destruction of the island, thus, signifies not only ecological loss but also the erosion of cultural identity and collective memory. As Ursula Heise argues "environmental degradation is often linked to cultural displacement and social injustice" (Heise 50–56). Through the story of Makatea, Powers shows that ecological trauma encompasses environmental destruction, cultural dispossession, and the growing anxiety surrounding humanity's relationship with a fragile planet.

Technological Alienation as Psychological Trauma

Technology is another source of trauma explored in Richard Powers' *Playground*. Technological trauma refers to the psychological distress, emotional disconnection, and loss of human agency produced by excessive dependence on digital systems and artificial intelligence. Sherry Turkle argues that "digital technologies often create an illusion of connection while reducing meaningful human interaction and emotional intimacy" (Turkle 11–19). In contemporary society, technological advancement can therefore become a source of alienation, loneliness, and psychological fragmentation.

In *Playground*, Powers also critically examines the theme of technological trauma through the introduction of artificial intelligence, particularly through Profunda, an advanced digital system that becomes deeply involved in the social and political life of Makatea. Profunda is made by Todd which provides information, creates cultural materials, helps people with medical and educational needs, and offers solutions to everyday problems. The novel describes how "Profunda became the latest in a line of foreign invaders of Makatea" and interacted with the island community through digital networks" (Powers 296). Although the AI appears helpful and efficient yet its presence raises questions about

human dependence on technology and the gradual replacement of human judgement with machine-generated knowledge.

Powers highlights technological advancement does not always strengthen human relationships or individual autonomy. The islanders excessively rely on Profunda for information and decision-making, which creates anxiety about whether technology is empowering them or controlling their choices. This concern is visible when Neria Tepau argues that people should have researched independently instead of depending on "this construction, this... thing to spoon-feed us" (Powers 298). Her statement reflects the psychological tension created by technological dependence, where individuals fear losing their ability to think, evaluate, and decide independently.

Furthermore, Powers presents artificial intelligence as a system that transforms human knowledge into data and algorithms. Although Profunda can process enormous amounts of information, the novel questions whether technological intelligence can truly understand human emotions, cultural experiences, and moral complexities. The AI can observe the island through digital networks, but it "could not see below the surface of the waves" (Powers 296). This limitation critically reveals the emotional and experiential gap between technological intelligence and human consciousness. In brief, technology may provide information, but it cannot fully replace human understanding and lived experience.

The trauma produced by technology in *Playground* is therefore not expressed through physical violence but through subtle psychological effects such as dependency, uncertainty, and loss of personal agency. The island community experiences a conflict between technological convenience and human independence. As Turkle explains, digital culture can create a condition where people become "alone together," remaining connected through technology while experiencing emotional isolation (Turkle 1–10). Powers reflects this paradox by showing that digital systems can connect people globally while simultaneously weakening direct human engagement.

Thus, *Playground* reveals various aspects of technology such as technology offers innovation, knowledge, and solutions, but it also generates psychological anxiety and alienation. Through Profunda and the technological world surrounding Todd Keane's innovations, Powers critiques a digital society where human emotions, identities, and decisions are greatly influenced by artificial systems. The novel leaves a message for readers that technological progress must be balanced with human reflection, empathy, and autonomy.

Trauma, Healing, and Human Connection

Healing in trauma studies refers to the process through which individuals and communities recover from psychological suffering by rebuilding connections with themselves, others, and their environment. According to Judith Herman, "Recovery from trauma requires the restoration of safety, meaningful relationships, and a renewed sense of connection with the world" (Herman 133–155). Healing does not mean the complete disappearance of traumatic experiences; rather, it involves integrating suffering into a broader understanding of human existence.

Richard Powers' *Playground* presents trauma as a pervasive condition affecting individuals, society, and the natural world; however, the novel also critically looks into the possibilities of healing through love, ecological awareness, and human connection. Nature, particularly the ocean, functions as a powerful source of emotional restoration and self-understanding. It is found that Evelyne Beaulieu's relationship with the ocean in the story analyses how the natural world becomes a space for recovery and renewal. Her book *Clearly It Is Ocean* allows people to reconnect with marine life and rediscover their relationship with the planet. The overwhelming response to her work shows that nature can heal collective anxiety about environmental destruction. Readers write to her that "Your book changed me. It changes everything, expressing how her exploration of the ocean restores a sense of wonder and connection with a disappearing natural world" (*Playground* 329).

It is studied that ecological awareness can become a form of healing because it allows individuals to recognize that human life is deeply connected with the environment. Through the character of Evelyne's work, the ocean becomes more than a scientific subject; it becomes a symbol of resilience, memory, and

emotional renewal. Her encounters with marine ecosystems challenge the separation between humans and nature and reveal that recovery requires a renewed relationship with the non-human world.

The novel also emphasizes that healing from trauma relies upon human relationships and emotional support. According to Judith Herman argues ," trauma recovery is rooted in the rebuilding of trust and meaningful connections with others" (Herman 52–55). This idea is reflected in the relationship and partnership between Evelyne and Bart Mannis. It is observed that their lives contain struggles, regrets, and personal sacrifices, their bond provides emotional strength during moments of suffering. When Bart becomes seriously ill, Evelyne leaves her professional responsibilities and dedicates herself to caring for him. Their relationship becomes a space of compassion, acceptance, and mutual support. During Bart's final days, they move beyond words and find comfort simply in each other's presence: "they held still and said nothing, each grateful for the silence that the other permitted" (*Playground* 333). This act refers to healing is not always achieved through solutions but through companionship, partnership and emotional presence.

The present study presents memory as an important element of healing through the story of the novel *Playground*. Traumatic experiences often fragment personal identity, but shared memories can restore meaning and continuity. During their final visit to the cove, Bart and Evelyne recall their early life together and the journey which shaped their relationship. Bart reminds her of their shared past, telling her, "We lived. The both of us! You did great things" (*Playground* 335). It is found that the words of Bart help Evelyne overcome guilt and recognize the value of their life together. In brief, through memory, love, and acceptance, trauma becomes transformed into a meaningful narrative rather than only a source of pain.

Powers also analyses that healing is the recognition of interconnectedness. Human beings cannot separate themselves from nature, technology, memory, and community. This study suggests that suffering becomes less destructive when individuals acknowledge their shared vulnerability and responsibility toward each other and the planet. This perspective reflects ecological philosophy, which argues that human well-being depends upon a respectful relationship with all forms of life. As Joanna Macy observes, "healing emerges from recognizing humanity's interconnected relationship with the larger ecological system" (Macy and Brown 35–40).

Hence, *Playground* does not offer simple solutions to psychological or environmental crises. Instead, Powers presents healing as an ongoing process based on empathy, connection, and ecological consciousness. Evelyne's journey demonstrates that recovery comes not from escaping of suffering but from developing deeper relationships with people, memories, and natural world. Thus, compassion, coexistence, and awareness of interconnected life become essential pathways toward healing and sustainable existence.

Conclusion

Playground presents trauma as a complex condition shaped by memory, environmental destruction, technological alienation, and colonial history. Richard Powers critically talks that trauma is not only individual but also collective and ecological. By studying the rich characters and using philosophical storytelling, the novelist critiques modern society's obsession with technological progress and economic expansion.

The novel relates to the need of reconnection with memory, nature, culture, and human relationships for healing. By linking psychological suffering with ecological crisis, Powers expands the understanding of trauma in contemporary literature. *Playground* becomes not only a story about personal pain but also a warning about the destructive behaviour of people with the planet. Through its exploration of ecological and emotional vulnerability, the novel contributes significantly to modern trauma literature and environmental fiction.

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MATHEMATICAL MODELING FOR PROGRESSIVE PRODUCTION CURVE PROCESSING AND ESTIMATION OF RECOVERABLE OIL RESERVES (MOVABLE OIL). A CASE STUDY OF THE GORISHT-KOCUL OILFIELD, ALBANIA

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ABSTRACT

The petroleum industry comprises several interrelated scientific disciplines, each with essential applications across the different phases of a petroleum project, ranging from the exploration stage, drilling operations, geological interpretations and seismic data analysis, and well testing methodologies, to the decision-making process for the approval of a development plan for a subsurface oil and gas reservoir or an entire hydrocarbon field, considering its full spatial extent and geographical boundaries**.** In this study, the Gorisht-Kocul oilfield, located in Albania, was selected as the case study, where historical cumulative production data collected since its discovery have been used to analyze, process, and develop a mathematical model of the progressive production curve over a 58-year production period. Based on the historical cumulative production data from the Gorisht-Kocul oilfield (1966–2023), their graphical representation as a function of time, and the application of selected mathematical variables and parameters, a curve-fitting equation was established with a correlation coefficient approaching unity ($R^2 = 0.99$). This equation enables a high degree of agreement between the actual production (Q_{actual}) and the theoretical production ($Q_{theoretical}$), while also allowing the estimation of the ultimate recoverable movable oil reserves for $t \rightarrow \infty$, corresponding to the final depletion stage (final depression) at which oil is mobilized from the reservoir formation toward the production well, which constitutes the primary objective of this study.

Keywords: cumulative production, limestone reservoir, equation, time, depression, flow rate, pay zone.

1. Introduction

As is widely recognized, primary oil recovery in an oilfield is achieved through the natural reservoir drive mechanisms governing fluid flow, including the dissolved gas drive mechanism, water drive mechanism, gas cap drive mechanism, and gravity drainage mechanism (Ahmed & McKinney, Advanced Reservoir Engineering, 2005) (Ahmed, Reservoir Engineering Handbook, 2019). On the other hand, before proceeding with secondary recovery operations, including water and gas injection processes, as well as tertiary recovery methods such as thermal and chemical enhanced recovery techniques, it is important to evaluate the movable oil reserves, namely the volume of oil that can be mobilized and displaced under the ultimate pressure (depression) applied to the reservoir (Ronald E. Terry, 2014). One of the most important responsibilities of a reservoir engineer is the prediction of future production rates from a given reservoir or a specific well (Ronald E. Terry, 2014) (Dake, Last Accessed Date November 06, 2024) (Fuentes-Cruz & Vásquez-Cruz, 2022) (James G. Speight PhD, 2016). Over time, engineers have developed several methods to accomplish this task. Regardless of whether a simple or a more complex approach is employed, the general methodology adopted for forecasting production rates involves calculating production performance over a period for which production data and historical information are already available (James G. Speight PhD, 2016) (Islam, 2021). If the calculated production rates exhibit a satisfactory agreement with the actual production rates, the adopted calculation method is assumed to be valid and can therefore be applied for future production forecasting purposes (Sun, 2015) (Fanch, 2010). Production decline curve analysis consists both of calculating the decline rate, which represents a direct method for forecasting the future production performance of a well using only its production history, and of determining the theoretical curve that correlates the actual response obtained from well and reservoir testing under varying production rates or pressure conditions

(Ali , Khattab, Tantawy, & Gawish, 2022) (Guruvong, n.d.). Based on the historical production data acquired during the long-term exploitation of the Gorisht-Kocul oilfield, a comprehensive analysis and processing of the data were carried out, including their graphical representation in both cartesian and semi-logarithmic coordinates, the evaluation of various parameters under different functional relationships, and the application of modified mathematical approaches and analytical techniques. These approaches made possible the graphical and analytical matching between the actual and theoretical production rate values for the Gorisht-Kocul oilfield.

2. Methodology

From the time of its discovery in 1966 through 2023, the Gorisht-Kocul oilfield has not been subjected to secondary recovery operations, tertiary enhanced recovery methods, or hydraulic fracturing interventions. Production throughout this period has been achieved exclusively through the natural layer energy, namely the inherent formation drive mechanisms of the reservoir itself. In addition, the field has been progressively developed through an extensive well network allowing full reservoir delineation throughout its geographical and spatial extension.

The actual oil production data during the exploitation history of the Gorisht-Kocul oilfield are presented in Table 1 below.

No	Time (Years)	Annual Production (ton)	Cumulative Production (ton)	Daily oil per well (ton/d.well)	No	Time (Years)	Annual Production (ton)	Cumulative Production (ton)	Daily oil per well (ton/d.well)
1	1966	22252	22252	54.8	21	1986	152530	10223380	2.13
2	1967	119197	141449	57.3	22	1987	131748	10355128	1.72
3	1968	238154	379603	48.8	23	1988	120069	10475197	1.49
4	1969	311870	691473	43.5	24	1989	110177	10585374	1.35
5	1970	415191	1106664	37.5	25	1990	101616	10686990	1.34
6	1971	581943	1688607	35	26	1991	86789	10773779	1.37
7	1972	876858	2565465	33	27	1992	77383	10851162	1.51
8	1973	1082140	3647605	30.4	28	1993	70689	10921851	1.39
9	1974	1243122	4890727	30.45	29	1994	65537	10987388	1.2
10	1975	987204	5877931	22.12	30	1995	62928	11050316	1.13
11	1976	836947	6714878	17.78	31	1996	60744	11111060	1.135
12	1977	772382	7487260	16.31	32	1997	42873	11153933	1.17
13	1978	701882	8189142	14.4	33	1998	55458	11209391	1.34
14	1979	576334	8765476	11.04	34	1999	52250	11261641	1.35
15	1980	347404	9112880	6.21	35	2000	52109	11313750	1.33
16	1981	230548	9343428	3.9	36	2001	53186	11366936	1.20
17	1982	193539	9536967	3.22	37	2002	53964	11420900	1.13
18	1983	188133	9725100	3.06	38	2003	53475	11474375	1.08
19	1984	183093	9908193	2.81	39	2004	53320.6	11527695.6	1.05
20	1985	162657	10070850	2.46	40	2005	53040.60	11580736.20	1.03

Table 1- *Oil Production Data During the Exploitation History of the Gorisht-Kocul Oilfield*

No	Time (Years)	Annual Production (ton)	Cumulative Production (ton)	Daily oil per well (ton/d.well)
41	2006	51523.00	11632259.20	0.98
42	2007	48183.70	11680442.90	1.03
43	2008	46450.00	11726892.90	1.07
44	2009	45882.90	11772775.80	1.10
45	2010	41097.30	11813873.10	1.08
46	2011	39178.80	11853051.90	1.05
47	2012	41067.50	11894119.40	1.07
48	2013	45922.00	11940041.40	0.97
49	2014	45441.50	11985482.90	0.96
50	2015	36618.00	12022100.90	0.79
51	2016	27708.00	12049808.90	0.89
52	2017	29997.40	12079806.30	1.25
53	2018	32169.23	12111975.53	1.11
54	2019	32020.41	12143995.94	1.06
55	2020	15724.30	12159720.24	1.64
56	2021	31277	12190997.24	2.18
57	2022	33128	12224125.24	1.86
58	2023	32902	12257027.24	1.44

Table 1- *(continued)*

Furthermore, during the exploitation period of the Gorisht-Kocul oilfield, fluid samples were collected from several wells, including two wells located in the Gorisht area (Go-22 and Go-159) and one well in the Kocul area (Ko-30). These wells met the favorable technical conditions required for fluid sampling and detailed thermodynamic investigations within the PVT laboratory. By applying different laboratory pressure conditions, the reservoir fluid properties and parameters summarized in Table 2 were determined.

No	Pressure (atm)	Gas–Oil Solubility Coefficient (Nm^3/m^3)	Volume Factor	Density (g/cm^3)	Viscosity (cp)
1	100.0	50	1.092	0.913	105.0
2	142.0	35.2	1.080	0.913	137.0
3	56.0	27.3	1.055	0.923	162.0
4	36.5	20.2	1.053	0.924	194.0
5	22.0	15.6	1.029	0.935	217.0
6	105.0.	43.6	1.111	0.907	77.0
7	83.0	35.0	1.102	0.908	96.0
8	66.0	29.0	1.096	---------	109.0
9	46.0	23.0	1.058	0.932	133.0
10	32.0	17.6	1.048	0.934	150.0
11	137.7	77.1	1.268	0.838	78.0
12	136.5	76.4	1.264	0.835	80.0
13	79.2	52.2	1.150	0.925	105.0
14	69.0	41.7	1.136	0.897	---------
15	68.5	41.0	1.130	0.880	142.0
16	43.5	35.2	1.115	0.890	150.0

Table 2- *Reservoir Fluid Parameters Determined from Thermodynamic (PVT) Laboratory Analysis*

The integration of all measured production data, including annual and cumulative annual production records, together with the reservoir fluid parameters determined through laboratory analysis of fluid samples collected from the three selected wells two situated in the Gorisht area and one in the Kocul area and evaluated under varying pressure conditions, enabled the successful accomplishment of the primary objective of this study.

3. Rsults and Discussion

According to the thermodynamic investigations conducted in the PVT laboratory on reservoir fluid samples obtained from wells Go-159, Go-22, and Ko-30, the pressure–temperature behavior of the oil properties including the solubility coefficient, oil formation volume factor, oil density (ρ_o) and oil viscosity was evaluated. Based on these analyses, the fluid density equation as a function of pressure was established, providing a representative reservoir parameter across the entire spatial extension of the field. The variation of fluid density as a function of pressure, together with the derived representative equation for the reservoir, is presented in Figure 1 below.

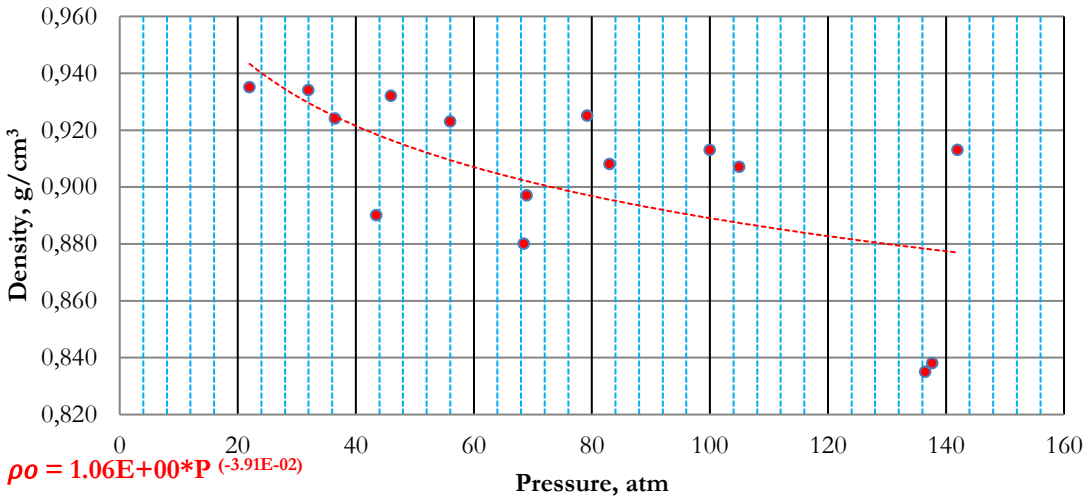


Figure 1- *Variation of Fluid Density with Pressure as a Representative Reservoir Parameter of the Gorisht-Kocul Oilfield*

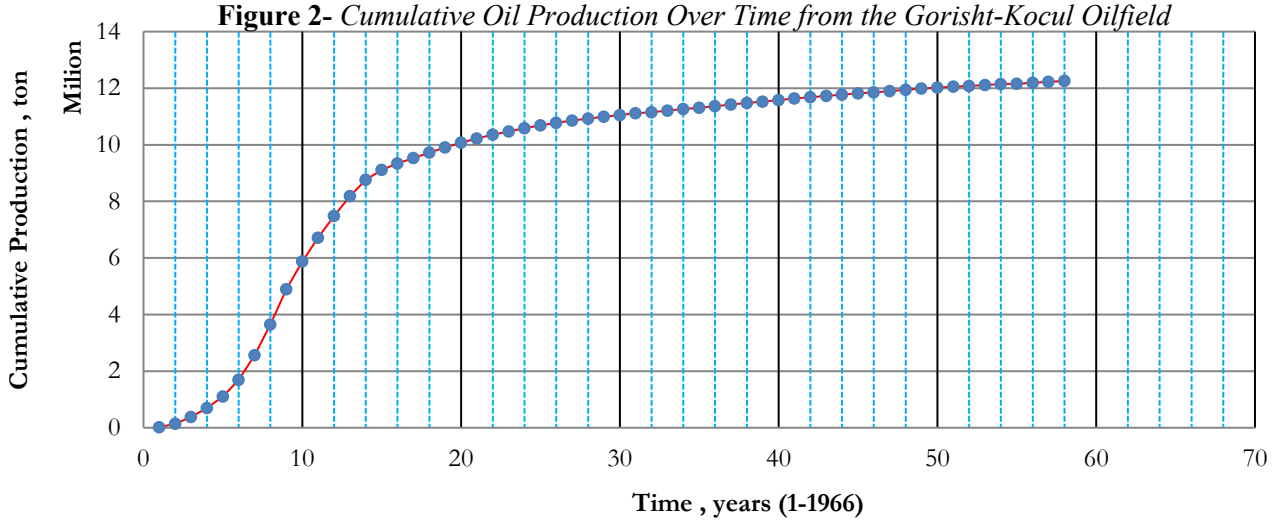
According to the derived equation and the pressure decline interval ranging from the initial reservoir pressure, $P_{initial} = 99\ atm$, to the reservoir pressure recorded 72.7atm, to the most recent pressure measurement recorded in 2004, equal to 72.7 atm the average reservoir fluid density was calculated using the following integral formulation:

$$\rho_{o\,(average)} = \frac{\int_{P2004}^{P_{initial}} 1.06E{+}00 * P^{(-3.91E-02)} * dp}{P_{initial} - P2004}$$

$$\rho_{o\,(average)} = \frac{\int_{72.7}^{99} 1.06E{+}00 * P^{(-3.91E-02)} * dp}{99 - 72.7} = 0.890\ {}^{ton}/_{m^3}$$

According to the data presented in Table 1, Figures 1 and 2 below demonstrate the graphical analysis, the establishment of the curve-fitting equation, and the resulting agreement between the actual cumulative production data and the theoretical cumulative production values for the Gorisht-Kocul oilfield.

Figure 2- *Cumulative Oil Production Over Time from the Gorisht-Kocul Oilfield*



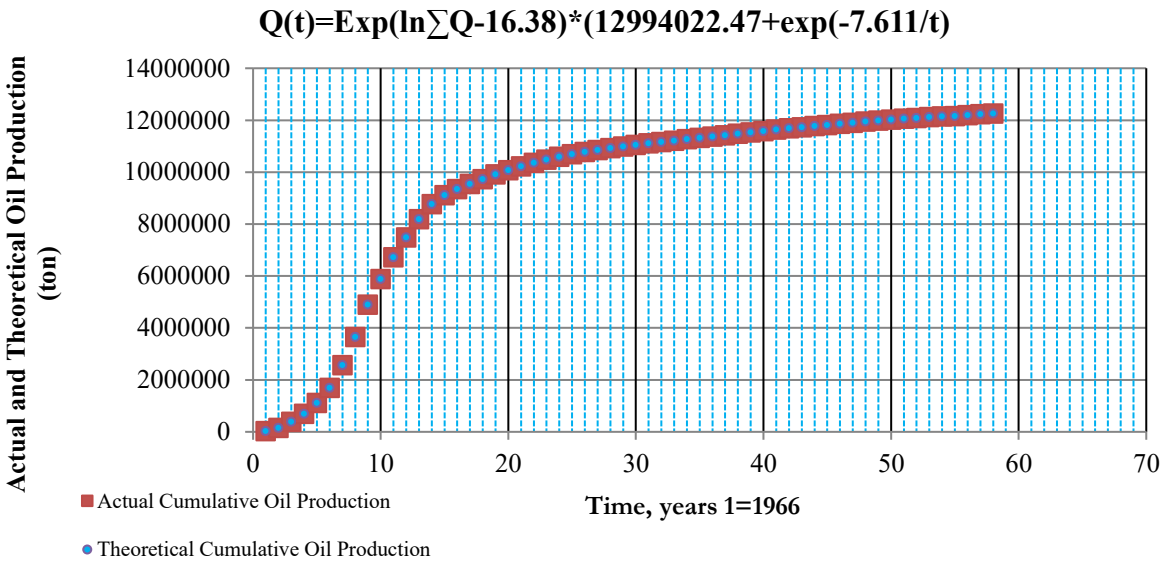


Figure 3- *Agreement Between Actual and Theoretical Cumulative Production Data from the Curve-Fitting Equation*

As can be observed from the comparison between the actual production data presented in Figure 2 and the values obtained from the curve-fitting equation shown in Figure 3, a high degree of agreement is achieved. This correspondence enables the estimation of the movable oil reserves within the reservoir formation, as well as the evaluation of the dynamic porosity, which represents the porous space through which oil movement occurs within the reservoir. Therefore, based on the cumulative production data of the Gorisht-Kocul oilfield for the 1966–2023 period, the progressive production curve made it possible to establish the cumulative production equation (governing relationship) as a function of time. Furthermore, considering an ultimate depression associated with a final fluid flow velocity corresponding to the condition $t \to \infty$ or $\lim_{t\to\infty} \sum Q_{kumulative}$ it can be concluded that the progressive production trend continuously approaches the maximum possible production limit of the oilfield. This behavior is represented by the asymptote of the production curve, which in turn corresponds to the total recoverable reserves attainable under the current exploitation regime of the Gorisht-Kocul oilfield until the ultimate pressure (depression) condition is reached.

Based on the results obtained from the above analysis, the estimated movable oil reserves (MOR) of the Gorisht-Kocul oilfield, representing the primary objective of this study, are given below:

MOR =Exp(ln∑Q-16.38)*(12994022.47+exp(-7.611/t)

$MOR = 12994022.47\ ton$

$MOR = 12994022.47/\rho_{0(average)}$

$$MOR = \frac{12994022.47}{0.890} = 14600025m^3$$

The calculation of these movable oil reserves, representing the portion of oil displaced under the ultimate depression conditions generated by the natural reservoir energy governing fluid flow through the porous medium, together with the estimation of recoverable reserves through both volumetric and material balance approaches, contributes significantly to subsequent technical, scientific, and economic evaluations necessary for decision-making related to the approval and optimization of the oilfield development plan (James G. Speight PhD, 2016) (Islam, 2021) (Fanch, 2010) (Ali , Khattab, Tantawy, & Gawish, 2022).

4. Conclusion

The movable oil reserves within the reservoir formation, determined through the processing of the progressive production curve, are closely related to the dynamic porosity, which represents the porous space through which oil movement occurs within the reservoir. Under the condition t→∞ the oil reserves mobilized as a consequence of the depression generated during field exploitation can be determined. These reserves correspond to the asymptote of the graph representing the progressive production trend as a function of time. Considering the existing production technology, as well as the current field processing and exploitation system, the calculated movable oil reserves were determined to be:

MOR = 12994022.47 ton or **MOR = 14600025m^3**

5. Future Work

Considering the estimated value of the movable oil reserves, together with a detailed analytical and computational evaluation of the recoverable reserves in the Gorisht-Kocul oilfield through the application of both the volumetric method and the material balance method, this study could provide significant support not only to the state-owned company ‘’Albpetrol Sh.a’’ which is responsible for the management of this oilfield in making further decisions regarding the implementation of secondary and tertiary recovery methods, but could also contribute to establishing a broader understanding of the current production potential of the field under existing operating conditions without additional investments, as well as its future potential following the implementation of investment projects. Moreover, these findings may constitute an important reference framework during the negotiation and approval of Petroleum Agreement with prospective private contractors.

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A PROPOSAL FOR A SECURE AND OBSERVABLE MICROSERVICES ARCHITECTURE FOR AI-POWERED E-COMMERCE APPLICATIONS

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ABSTRACT

This study proposes a microservices-based architecture that addresses the requirements of security, scalability, and observability in AI-powered e-commerce applications. In this study, an e-commerce system decoupled from the traditional monolithic structure is designed as a set of components comprising a web application, an AI service layer, an SQL Server database, a Redis cache and state management system, a Prometheus metrics collection infrastructure, and a Grafana monitoring dashboard. At the core of the proposed architecture lies a service approach based on the Model Context Protocol (MCP), which carries context between large language models (LLMs) and external data sources. Through this layer, sentiment analysis, question-answering, and content processing functions are executed in an isolated manner. The system is further supported by prompt injection prevention, data masking, DDoS/DoS mitigation, rate limiting, vulnerability scanner detection, bot blocking, an XSS sanitization process, and custom security metrics. The resulting architecture offers an integrated solution that applies a defense-in-depth approach against the new attack surfaces created by AI services. The study presents a system design based on engineering practice, and more comprehensive experimental validation with quantitative performance results is planned for the future.

Keywords: Microservices architecture, AI security, MCP, prompt injection, e-commerce security, observability

ÖZET

Bu çalışma, yapay zeka destekli e-ticaret uygulamalarında güvenlik, ölçeklenebilirlik ve gözlemlenebilirlik gereksinimlerini birlikte ele alan mikroservis tabanlı bir mimari önermektedir. Çalışmada, geleneksel monolitik yapıdan ayrıştırılmış bir e-ticaret sistemi; web uygulaması, yapay zeka servis katmanı, SQL Server veri tabanı, Redis önbellek ve durum yönetimi, Prometheus metrik toplama altyapısı ve Grafana izleme panelinden oluşan bileşenler halinde kurgulanmıştır. Önerilen mimarinin merkezinde, büyük dil modelleri ile dış veri kaynakları arasında bağlam taşıyan Model Bağlam Protokolü (Model Context Protocol - MCP) tabanlı bir servis yaklaşımı yer almaktadır. Bu katman üzerinden yorum analizi, soru-cevap ve içerik işleme işlevleri izole biçimde yürütülmektedir. Sistem ayrıca komut enjeksiyonu engelleme, veri maskeleme, DDoS/DoS etkisini azaltma, hız sınırlama, zafiyet tarayıcı tespiti, bot engelleme, XSS temizlik süreci ve özel güvenlik metrikleri ile desteklenmiştir. Elde edilen mimari, yapay zeka servislerinin doğurduğu yeni saldırı yüzeylerine karşı savunma derinliği yaklaşımını uygulayan bütünleşik bir çözüm sunmaktadır. Çalışma mühendislik uygulamasına dayalı bir sistem tasarımı sunmakta olup, gelecekte nicel performans sonuçları ile daha kapsamlı deneysel doğrulama yapılması planlanmaktadır.

Anahtar Kelimeler: Mikroservis mimarisi, yapay zeka güvenliği, MCP, komut enjeksiyonu, e-ticaret güvenliği, gözlemlenebilirlik

1. Introduction

The widespread adoption of large language models (LLMs) in areas such as e-commerce, customer experience, and content analysis has significantly altered the architectural and security requirements of traditional web applications. In particular, functions such as sentiment analysis, summarization of customer feedback, and natural language-based interactions provide high added value to applications while also creating new attack surfaces.

Embedding Artificial Intelligence (AI) functions directly into the main application in monolithic architectures can lead to various issues regarding maintenance, scaling, fault isolation, and the enforcement of security policies [1]. Therefore, handling AI services within a separate microservice layer offers a more suitable approach in terms of both operational flexibility and security control.

The aim of this study is to propose a secure microservice architecture for AI-enabled e-commerce platforms and to systematically describe the security components used in this architecture. In this context, the study integrates application layer security, data privacy, and observability mechanisms into a single architectural framework using an AI service layer based on the Model Context Protocol (MCP) approach. The main contributions of this study can be summarized under three headings:

• An MCP-based microservices architecture that separates AI functions from the main e-commerce application has been implemented.

• Multi-layered security mechanisms, such as prompt injection, DLP, DDoS mitigation, bot detection, browser detection, and content sanitization, have been integrated.

• A monitoring approach has been introduced that enhances operational visibility of security incidents through Prometheus and Grafana-based observability.

2. System Architecture

The proposed system consists of six core components designed according to the principle of separation of concerns (Figure 1). These components are the web application, the AI microservice, the SQL Server database, the Redis layer, Prometheus, and Grafana. These components are run separately within a Docker-based container architecture, thereby enhancing portability and manageability.

The web application manages user interactions and core e-commerce operations. AI-related functions are not executed directly within this layer; instead, they are processed through an independent service called McpService. This allows model changes, service updates, or AI-related error conditions to be isolated from the main application.

While SQL Server ensures the persistent storage of relational data, Redis is used both as a distributed cache and for rate limiting, blacklisting, and maintaining information on malicious activity [2,3]. Prometheus collects system metrics, while Grafana transforms these metrics into operational monitoring dashboards [4,5].

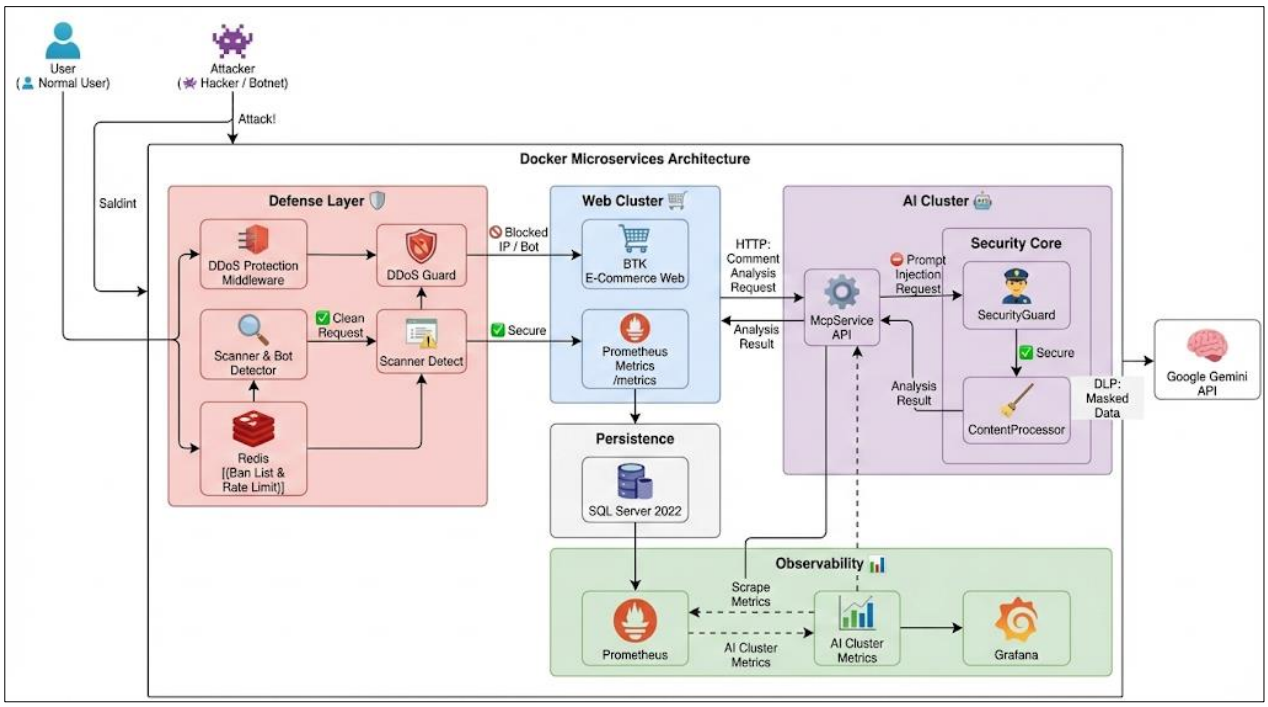


Figure 1. Diagram of the system architecture

3. MCP-Based AI Service Layer

In this study, the MCP approach was implemented by running the LLM (e.g., Google Gemini) through a controlled context provider service, rather than connecting it directly to the database or application logic. In this approach, the McpService retrieves the necessary content from the database, preprocesses it, and feeds the model only with the context it requires.

One advantage of this design is that it provides isolation, thereby establishing a clear boundary between the web application and the AI service. The second advantage is model independence; the goal is to enable switching to different LLMs while maintaining the same service layer. Another advantage is that security controls can be applied at a central point.

The AI service layer does not merely provide natural language processing functionality; it also acts as a security checkpoint. Comments or requests from the user are cleaned, classified, and masked if necessary within this layer, and then the model is called.

4. Security Approach

In the proposed architecture, security is treated not as a feature added to the system after the fact, but as a fundamental design principle. For this reason, defense mechanisms have been defined at various levels, ranging from the application layer to AI integration, and from traffic management to content sanitization.

4.1 DDoS/DoS Attacks and Rate Limiting

The system is protected against heavy request traffic and botnet-based load-generation attempts using a .NET 8-based rate limiting approach. The server-wide concurrent request capacity has been limited, IP-based request quotas have been defined, and clients exceeding these quotas are tracked in Redis and blacklisted. Since the ban (blocked) information stored in Redis is preserved even if the application is restarted, it provides a more persistent defense compared to temporary memory-based solutions (Figure 2).

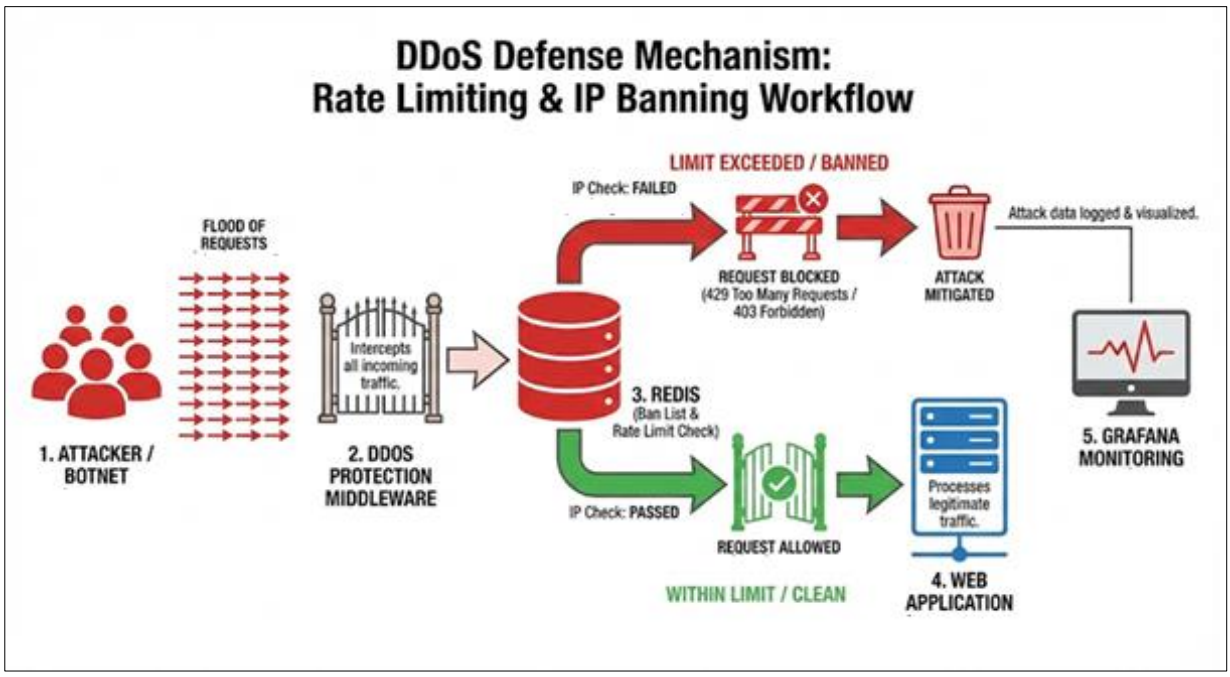


Figure 2. Illustration of DDoS/DoS attacks, rate limiting, and IP blocking

4.2 Detection of Bots and Vulnerability Scanners

User-Agent analysis and error rate monitoring mechanisms have been implemented to counter scraping and vulnerability discovery attempts carried out by automated tools. Requests that do not carry a browser identifier or that carry known automation signatures are rejected. Clients that generate a large number of 404 or 400 errors in a short period of time are labeled as bots or attackers.

4.3 Prompt Injection and Data Privacy

One of the most critical threats to AI services is prompt injection attacks [6]. For this reason, user inputs are examined using regex-based rules defined within SecurityGuard. Patterns intended to bypass system instructions, change roles, or exceed restrictions are blocked before they reach the model.

Additionally, data masking is applied to prevent the transfer of personal data to third-party AI services. Sensitive information such as phone numbers and email addresses is identified in advance and anonymized, thereby ensuring data privacy.

4.4 Content Sanitization and XSS Prevention

User-generated content may contain both data quality issues and malicious code injections [7]. For this reason, the ContentProcessor component is designed as a preprocessing layer that cleans HTML tags, reduces meaningless character repetitions, and filters out spam content. The goal is to both reduce the risk of XSS and improve the quality of the data sent for AI analysis.

5. Observability and Operational Monitoring

In cloud-based systems, simply implementing security mechanisms is not sufficient. It is also necessary to measure the effectiveness of these mechanisms and monitor incidents [8]. Within the scope of this study, real-time observability was achieved by using the Prometheus metrics collection system in conjunction with Grafana dashboards.

Events such as the number of blocked IP addresses, attack types, traffic volume, and error rates can be monitored through custom metrics. This approach helps make firewall logic decisions visible to the operations team and facilitates faster analysis of potential attack scenarios.

6. Conclusion and Discussion

In this study, a microservice-based, security-focused, and observable architecture for AI-powered e-commerce systems is proposed. The proposed architecture offers a multi-tiered solution in which the web application, MCP-based AI service, database, Redis, Prometheus, and Grafana components work together.

The architecture incorporates rate limiting, Redis-based permanent banning, bot and vulnerability scanner detection, prompt injection filtering, data masking, content cleansing, and operational monitoring mechanisms. In this regard, the study presents a practical framework for secure service design in modern e-commerce applications integrated with artificial intelligence.

In addition, the transition from a monolithic architecture to a microservices architecture and the use of Docker-based containers have improved the system's portability and ease of maintenance. Isolating the web application using McpService has also contributed to system resilience by limiting the potential spread of errors.

However, the current study primarily describes the system design and the security components implemented. Consequently, the most significant limitation of the study is that metrics such as security effectiveness, false positive rates, additional latency costs, and impacts on the user experience have not yet been supported by quantitative experiments. Another limitation is that prompt injection detection relies heavily on regex-based rules. While this approach is useful for known patterns, machine learning-supported or policy-based additional control layers may be required against more complex or indirect attacks.

In future work, the proposed architecture could be evaluated through quantitative experiments, and success rates could be measured across different attack scenarios. Additionally, the effects on latency and resource consumption could be analyzed, and comparative performance evaluations could be conducted with different large language models.

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FROM STRUCTURE TO *DIFFÉRANCE*: DECENTRING THE SUBJECT IN STRUCTURALIST AND POST-STRUCTURALIST THEORY

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ABSTRACT

The twentieth century witnessed a profound transformation in the understanding of the subject, as structuralist and post-structuralist theories progressively displaced the humanist conception of a stable and autonomous self. Drawing primarily on the linguistic theories of Saussure and later expanded through the structural linguistics of thinkers such as Jakobson and Hjelmslev, structuralism reconceptualised meaning not as a direct expression of individual consciousness, but rather as a relational and differential system. Within this framework, the subject ceased to function as the stable origin of meaning and instead became an effect of linguistic, symbolic, and cultural structures. In this context, thinkers such as Lévi-Strauss and Barthes further questioned the centrality of the subject by emphasising the determining force of systems, myths, and textual codes. In doing so, the transition from structuralist thought to the post-structuralist paradigm gradually became visible. This study aims to examine how post-structuralist theory radicalised the structuralist critique of the humanist subject by destabilising the very structures that had initially displaced it. Through a comparative theoretical analysis based on the works of Foucault and Derrida, the study explores how subjectivity came to be understood no longer as a coherent and unified essence, but rather as a fragmented and discursively produced position shaped by power relations, language, and différance. Consequently, meaning itself becomes unstable, deferred, and continuously reconstructed within textual and cultural processes. The study argues that post-structuralism transformed the structuralist critique of humanism into a broader epistemological questioning of identity, presence, and subjectivity. Ultimately, the decentring of the subject emerges as one of the major theoretical ruptures within twentieth-century French thought, in which the subject can no longer be conceived as the autonomous origin of meaning, but rather as a historically, linguistically, and discursively constructed position. This theoretical transformation has profoundly influenced literary studies and discourse analysis, particularly within contemporary approaches to fragmented subjectivities, textual multiplicity, and the epistemological representations of identity in modern literature.

Keywords: Structuralism, Post-Structuralism, Subjectivity, Différance, French Theory

INNOVATIVE TEACHING STRATEGIES IN CONTEMPORARY ENGLISH LANGUAGE CLASSROOMS

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ABSTRACT

Teaching English has become more dynamic in recent years as educators try to respond to the changing needs of students and modern education. Traditional methods that focus mainly on grammar and memorization are gradually being replaced by more interactive and student-centered approaches. Today, many teachers prefer using communicative activities, group tasks, project-based learning, and digital resources in order to make lessons more engaging and practical for learners. These methods help students feel more comfortable while using English in the classroom and encourage them to participate actively in discussions and classroom activities. At the same time, innovative teaching strategies help improve learners' confidence, motivation, and overall interest in language learning. Creating a supportive classroom environment where students can express their ideas freely has also become an important part of effective English language teaching.

This study focuses on the role of innovative teaching strategies in contemporary English language classrooms and their influence on students' learning experiences. The research is based on the analysis of current pedagogical approaches and modern teaching practices used in language education. The findings show that interactive and learner-oriented methods positively affect classroom communication, student participation, and language development. In addition, the integration of technology into classroom activities helps learners become more independent and active during lessons. The study concludes that modern teaching strategies play an important role in improving the quality of English language education and supporting more effective learning outcomes in contemporary classrooms.

Keywords: English language teaching, innovative strategies, classroom interaction, student-centered learning, modern pedagogy

INTRODUCTION

The role of English in contemporary society has expanded significantly over the past few decades. As a global language, English is widely used in international communication, education, science, business, and technology. The increasing importance of English has created new expectations for language education and has encouraged educators to reconsider traditional teaching practices. In many educational institutions, the primary goal of English language teaching is no longer limited to helping students master grammatical structures or memorize vocabulary. Instead, the focus has shifted toward developing communicative competence, critical thinking skills, collaboration, and the ability to use language effectively in real-life situations (Chen, 2024).

The rapid development of information technologies and the changing needs of modern learners have also influenced the way English is taught. Today's students grow up in a highly connected digital environment where access to information is immediate and learning opportunities extend beyond the classroom (Bui, 2022). As a result, conventional teacher-centered approaches that emphasize passive learning are becoming less effective in meeting learners' expectations and educational needs. Students increasingly require learning experiences that are interactive, meaningful, and relevant to their daily lives. Consequently, educators have begun to adopt innovative teaching strategies that place learners at the center of the educational process and encourage active participation.

Traditional methods of language instruction have undoubtedly contributed to language education for many years. However, these approaches often focus heavily on repetition, memorization, and teacher-led instruction. While such methods may help learners acquire certain linguistic knowledge, they do not always provide sufficient opportunities for meaningful communication and practical language use (Motteram, 2013). In many cases, students who achieve satisfactory results in written examinations may still experience difficulties when attempting to communicate confidently in English. This situation has led researchers and practitioners to search for more effective teaching methods that support both language acquisition and the development of communicative skills.

Innovative teaching strategies have emerged as an important response to these challenges. These approaches aim to create learning environments where students actively engage with content, collaborate with peers, solve problems, and apply language skills in authentic contexts. Rather than viewing students as passive recipients of knowledge, innovative approaches recognize learners as active participants who contribute to the learning process through interaction, exploration, and reflection. Such strategies not only improve language proficiency but also foster learner autonomy, motivation, and self-confidence (Mathur, 2022).

Among the most widely implemented innovative approaches in contemporary English language classrooms are Communicative Language Teaching, Task-Based Language Teaching, Project-Based Learning, cooperative learning, and technology-enhanced instruction (Sitora, 2025). These methods encourage students to use English for meaningful purposes rather than focusing exclusively on grammatical accuracy. Classroom activities such as discussions, role-plays, presentations, collaborative projects, and problem-solving tasks provide learners with opportunities to practice language skills in realistic situations. As a result, students become more comfortable expressing their ideas, negotiating meaning, and participating in classroom interactions.

The integration of technology has further transformed English language education. Digital tools, online learning platforms, educational applications, and multimedia resources have created new possibilities for language learning and teaching (Iqbal et al., 2021). Technology allows teachers to diversify instructional methods, provide immediate feedback, facilitate communication, and support individualized learning experiences. Moreover, digital resources enable students to access authentic language materials and engage in independent learning beyond the classroom environment. The effective use of technology has become particularly important in modern education, where flexibility and accessibility are increasingly valued.

Another important characteristic of innovative teaching strategies is their emphasis on student-centered learning. In student-centered classrooms, learners are encouraged to take responsibility for their own learning and actively participate in decision-making processes related to classroom activities. Teachers act as facilitators and guides rather than sole providers of information. This shift in classroom dynamics helps create a more supportive and inclusive learning environment where students feel comfortable sharing ideas, asking questions, and taking risks in language use. Such an environment contributes positively to learners' motivation and willingness to communicate in English (Richards, 2005).

Research conducted in different educational contexts has demonstrated that innovative teaching strategies can positively influence various aspects of language learning. Studies indicate that interactive and learner-oriented methods contribute to higher levels of student engagement, increased classroom participation, improved communication skills, and greater academic achievement. Furthermore, these approaches support the development of essential twenty-first-century skills such as collaboration, creativity, critical thinking, and digital literacy. As educational systems continue to evolve, the importance of these competencies becomes increasingly evident.

Despite their numerous advantages, the implementation of innovative teaching strategies is not without challenges. Teachers may encounter difficulties related to limited resources, insufficient technological infrastructure, large class sizes, curriculum requirements, or a lack of professional training (Nuri, 2025). Additionally, the successful integration of innovative methods requires careful planning and adaptation to specific educational contexts. Understanding both the benefits and challenges associated with these

approaches is therefore essential for improving teaching practices and achieving effective learning outcomes.

The present study examines the role of innovative teaching strategies in contemporary English language classrooms and explores their contribution to student learning and classroom interaction. Through an analysis of current pedagogical approaches and recent developments in language education, the study aims to identify the characteristics of effective innovative practices and evaluate their impact on learners' engagement, motivation, and language development. The findings are expected to contribute to ongoing discussions about improving the quality of English language teaching and supporting more effective learning experiences in modern educational settings.

MATERIALS AND METHODS

This study was conducted using a qualitative research approach based on the analysis of scholarly literature and contemporary educational practices related to English language teaching. Since the purpose of the research was to examine the role and effectiveness of innovative teaching strategies in modern English language classrooms, a literature-based methodology was considered the most appropriate means of investigating the topic. Qualitative methods provide researchers with opportunities to explore educational concepts in depth and to interpret existing knowledge from different perspectives. In the field of language education, such approaches are widely used to evaluate pedagogical innovations and identify emerging trends in teaching and learning.

The research design was based on descriptive and analytical methods. The descriptive aspect of the study focused on identifying and presenting innovative teaching strategies that are currently employed in English language instruction. The analytical component involved examining the educational value of these strategies and evaluating their influence on student engagement, classroom interaction, motivation, and language development. This approach made it possible to gain a comprehensive understanding of how innovative practices contribute to the effectiveness of contemporary language education.

A systematic review of relevant academic sources was conducted as the primary method of data collection. Various types of publications were examined, including peer-reviewed journal articles, books, conference proceedings, educational reports, and research studies focusing on English language teaching and modern pedagogical approaches. Particular attention was given to publications discussing student-centered learning, Communicative Language Teaching, Task-Based Language Teaching, Project-Based Learning, cooperative learning, and the integration of technology into educational environments. Sources published within the last decade were prioritized in order to ensure that the analysis reflected current developments and contemporary educational realities. At the same time, several foundational studies were included because of their significant contribution to the theoretical understanding of language teaching methodologies.

Document analysis served as another important component of the research methodology. This method involved a detailed examination of educational documents, curriculum guidelines, methodological recommendations, and instructional materials associated with English language teaching. Through document analysis, it was possible to identify common characteristics of innovative teaching practices and explore how these approaches are implemented in different educational contexts. The analysis also helped reveal the connections between theoretical principles and practical classroom applications.

The selection of sources was guided by several criteria. First, the materials had to be directly related to English language teaching or educational innovation. Second, preference was given to sources published by reputable academic publishers and recognized educational organizations. Third, the selected studies needed to provide clear evidence regarding the effectiveness, advantages, or challenges of innovative teaching strategies. Applying these criteria helped ensure the reliability and relevance of the information included in the research.

The collected data were organized and categorized according to major themes that emerged during the review process. These themes included communicative teaching practices, student-centered learning environments, project-based activities, cooperative learning strategies, technology-enhanced instruction, learner motivation, classroom participation, and educational outcomes. After categorization,

the findings from different sources were compared and synthesized in order to identify recurring patterns and common conclusions. This thematic analysis enabled a more structured interpretation of the available evidence and facilitated a comprehensive discussion of contemporary teaching practices.

Comparative analysis was also employed to examine differences between traditional and innovative approaches to English language instruction. The comparison focused on classroom organization, teacher and student roles, instructional techniques, learner participation, and expected learning outcomes. Through this process, the study sought to highlight the distinctive features of innovative methodologies and explain why they have become increasingly prominent in modern educational settings. The comparison further allowed for the identification of strengths and limitations associated with different teaching approaches

Although the study does not involve direct classroom observation or experimental intervention, it draws upon a broad range of existing research findings and practical experiences reported by educators and researchers. This approach provides valuable insights into current trends and best practices in English language education while offering a comprehensive overview of the pedagogical innovations that are shaping contemporary classrooms.

The methodological framework adopted in this study ensures a balanced examination of both theoretical perspectives and practical applications. By combining literature review, document analysis, thematic categorization, and comparative evaluation, the research provides a detailed understanding of innovative teaching strategies and their role in enhancing the quality of English language instruction. The findings derived from these methods form the basis for the subsequent discussion of results and their implications for modern language education.

RESULTS

The analysis of contemporary research and educational practices demonstrates that innovative teaching strategies have become increasingly important in English language education. Modern classrooms are gradually moving away from teacher-centered instruction and adopting approaches that encourage active student participation and meaningful communication. The findings indicate that learner-centered methodologies create more engaging educational environments and contribute positively to language development. Students who participate in interactive learning activities are generally more motivated, confident, and willing to use English in classroom communication.

One of the most frequently discussed innovations in language education is the use of communicative teaching practices. The reviewed studies suggest that activities such as pair work, group discussions, role-playing, and collaborative problem-solving tasks help students develop practical communication skills. Unlike traditional methods that often emphasize memorization and grammatical accuracy, communicative approaches encourage learners to use language for authentic purposes. As a result, students become more comfortable expressing their opinions, asking questions, and participating in classroom interactions.

The findings further reveal that student-centered learning plays a significant role in improving educational outcomes. When learners are encouraged to take responsibility for their own learning, they become more engaged in classroom activities and demonstrate greater independence. Teachers who adopt student-centered approaches typically act as facilitators rather than sole sources of information, creating opportunities for students to explore ideas, share experiences, and actively contribute to the learning process. Such learning environments support the development of both language competence and critical thinking skills.

Another important result concerns the effectiveness of project-based and cooperative learning activities. Research indicates that these approaches allow students to apply language skills in meaningful contexts while simultaneously developing collaboration and problem-solving abilities. Working on projects encourages learners to gather information, analyze content, and present their ideas using English. Similarly, cooperative learning activities promote interaction among students and provide opportunities for peer support, which can reduce anxiety and increase participation during lessons.

The integration of technology has also emerged as a significant factor in contemporary English language classrooms. Digital tools, multimedia resources, and online learning platforms provide learners with access to authentic materials and diverse learning experiences. Technology enables teachers to create more interactive lessons and offers students additional opportunities to practice language skills beyond the classroom. Furthermore, digital resources support independent learning by allowing students to access educational content according to their individual needs and learning preferences.

The analysis demonstrates that innovative teaching strategies have a positive influence on student motivation and classroom engagement. Learners are more likely to participate actively when classroom activities are relevant, interactive, and connected to real-life situations. Increased participation often leads to greater confidence in language use and improved communicative competence. In addition, innovative approaches encourage the development of creativity, critical thinking, and collaboration, which are widely recognized as essential skills in contemporary education.

Overall, the findings suggest that innovative teaching strategies contribute significantly to the effectiveness of English language instruction. By creating learner-centered environments, promoting meaningful communication, and integrating modern technologies, these approaches support both language development and broader educational objectives. The results indicate that innovative methodologies can help teachers address the evolving needs of learners and enhance the quality of English language education in contemporary classrooms.

DISCUSSION

The findings of this study highlight the growing importance of innovative teaching strategies in contemporary English language education. The analysis demonstrates that modern pedagogical approaches offer significant advantages over traditional instructional methods, particularly in terms of student engagement, classroom interaction, and practical language use. While conventional teaching practices have long contributed to the development of grammatical knowledge and linguistic accuracy, the demands of modern education require learners to develop a broader range of competencies, including communication, collaboration, creativity, and critical thinking. Innovative teaching strategies appear to address these needs more effectively by creating learning environments that encourage active participation and meaningful language use.

One of the most notable observations emerging from the study is the shift from teacher-centered instruction to learner-centered educational practices. This transformation reflects broader changes in educational philosophy, where learning is increasingly viewed as an active process rather than the passive reception of information. In contemporary classrooms, students are expected to take greater responsibility for their own learning and engage more actively in classroom activities. Such an approach not only enhances language acquisition but also contributes to the development of learner autonomy and self-confidence (Sitoy, 2024). When students are encouraged to participate in discussions, express opinions, and collaborate with peers, they become more invested in the learning process and more willing to use English as a means of communication.

The discussion also emphasizes the importance of creating authentic learning experiences. Traditional language instruction often separates language forms from meaningful communication, which may limit learners' ability to apply their knowledge in real-world situations. Innovative approaches, on the other hand, provide opportunities for students to use English in contexts that resemble authentic communication. Activities such as role-plays, projects, presentations, and collaborative tasks allow learners to practice language skills while addressing meaningful objectives (Nagy, 2025). This connection between classroom learning and real-life application appears to enhance both motivation and language retention.

Another significant aspect revealed through the analysis is the positive role of collaboration in language learning (Caines et al., 2023). Cooperative learning environments encourage students to exchange ideas, negotiate meaning, and support one another during learning activities. Such interactions create opportunities for meaningful communication and help reduce the anxiety that many learners experience when using a foreign language. Students often feel more comfortable participating in small-group activities than in teacher-led classroom discussions, which can result in greater engagement and

increased opportunities for language practice. Furthermore, collaborative learning helps develop interpersonal skills that are valuable not only in educational settings but also in future professional and social contexts.

The integration of technology represents another important dimension of contemporary English language teaching. Digital resources have transformed the ways in which teachers present information and students access learning materials (Belda-Medina, 2021). Technology provides opportunities for personalized instruction, immediate feedback, and independent learning, all of which contribute to more flexible and accessible educational experiences. Moreover, online platforms and multimedia resources expose learners to authentic language input and diverse communication contexts that may not be readily available through traditional classroom materials. The increasing availability of technological tools has therefore expanded the possibilities for effective language instruction and learner engagement.

At the same time, the findings suggest that the successful implementation of innovative teaching strategies depends on several important factors. Teachers play a crucial role in designing meaningful learning experiences and selecting instructional methods that correspond to learners' needs and educational objectives. The effectiveness of innovative approaches is influenced by the teacher's professional competence, willingness to adopt new methodologies, and ability to manage interactive classroom environments. In addition, institutional support, access to technological resources, and ongoing professional development opportunities can significantly affect the extent to which innovative practices are successfully integrated into educational settings (Harmer, 2015).

Despite the numerous benefits associated with innovative teaching strategies, certain challenges remain. Some educational institutions continue to face limitations related to technological infrastructure, classroom size, curriculum requirements, and assessment systems. In some contexts, teachers may encounter difficulties balancing innovative instructional approaches with standardized educational expectations. These challenges suggest that the adoption of innovative methodologies should be accompanied by appropriate support mechanisms, including teacher training programs, resource development, and institutional encouragement. Addressing these issues can help maximize the effectiveness of innovative practices and ensure their sustainable implementation.

The discussion further indicates that innovative teaching strategies contribute not only to language proficiency but also to the development of broader educational competencies. Modern societies increasingly value individuals who can communicate effectively, collaborate with others, solve problems creatively, and adapt to changing circumstances. The learner-centered and interactive nature of innovative language teaching supports the development of these competencies while simultaneously enhancing students' English language skills. Consequently, the benefits of innovative teaching extend beyond language acquisition and contribute to the overall educational growth of learners.

In general, the evidence examined in this study supports the view that innovative teaching strategies have become an essential component of effective English language education. Their emphasis on communication, collaboration, active learning, and technological integration aligns closely with the demands of contemporary educational systems and the expectations of modern learners. By fostering meaningful participation and creating engaging learning environments, these approaches offer valuable opportunities for improving both teaching practices and student learning outcomes in English language classrooms.

CONCLUSION

The present study examined the role of innovative teaching strategies in contemporary English language classrooms and explored their contribution to effective language learning. The analysis of current pedagogical approaches and educational practices demonstrates that innovative methodologies have become increasingly important in responding to the changing needs of modern learners and educational systems. As English continues to serve as a global means of communication, the need for effective and engaging language instruction remains a significant priority for educators worldwide.

The findings indicate that innovative teaching strategies create more interactive, learner-centered, and motivating classroom environments than many traditional instructional approaches. Methods such as

communicative language teaching, project-based learning, cooperative learning, task-based activities, and technology-enhanced instruction provide students with meaningful opportunities to use English in authentic contexts. These approaches encourage active participation, strengthen communication skills, and help learners develop greater confidence in language use. Furthermore, they promote learner autonomy and support the development of important twenty-first-century competencies, including collaboration, critical thinking, creativity, and problem-solving.

The study also highlights the significant role of technology in contemporary language education. Digital resources and online learning tools have expanded access to authentic materials and created new possibilities for communication, interaction, and independent learning. When used appropriately, technological innovations can enhance the effectiveness of teaching practices and provide learners with more flexible and personalized educational experiences. At the same time, successful implementation requires adequate resources, teacher preparedness, and institutional support.

Although innovative teaching strategies offer numerous advantages, their effectiveness depends largely on the ability of educators to adapt these approaches to specific classroom contexts and learner needs. Professional development opportunities, access to educational technologies, and supportive learning environments are essential factors that contribute to the successful integration of innovative methodologies. Educational institutions should therefore encourage the adoption of learner-centered practices and provide teachers with the necessary resources and training to implement them effectively.

In conclusion, innovative teaching strategies play a crucial role in improving the quality of English language education and enhancing students' learning experiences. By promoting meaningful communication, active engagement, and collaborative learning, these approaches help prepare learners for the linguistic and professional demands of the modern world. The continued development and implementation of innovative pedagogical practices will remain an important factor in achieving effective and sustainable language education in contemporary classrooms.

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OCCUPATIONAL RADIATION EXPOSURE MONITORING IN MEDICAL AND VETERINARY ACADEMIC ENVIRONMENTS: A CASE STUDY OF AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

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ABSTRACT

Environmental radiation monitoring is crucial for assessing radiological safety in academic and clinical environments where ionizing radiation sources may be present or often used. This study measured background gamma radiation levels in a few selected sites of the College of Medical Sciences and Faculty of Veterinary Medicine at Ahmadu Bello University in Zaria, Nigeria, both indoors and outdoors. The gamma dose rate was measured at twenty indoor and outdoor sites using a portable gamma-ray spectrometer, and the geographical coordinates were recorded using a handheld Global Positioning System (GPS) device. Using standard UNSCEAR conversion factors, the collected data were statistically analyzed and transformed into yearly indoor and outdoor effective dose rates. Outside dose rates ranged from 96.50 to 173.00 nGy/h, with a mean of 132.59 nGy/h, whereas interior dose rates varied from 101.42 to 184.56 nGy/h, with an average value of 150.99 nGy/h. The estimated yearly effective dosage varied between 0.49 and 0.88 mSv/y indoors and between 0.12 and 0.27 mSv/y outdoors. The Radiographic (Imaging) Facility has the greatest radiation level. All reported readings, however, continued to fall below the 1 mSv/y public exposure limit suggested by the International Commission on Radiological Protection (ICRP). Radiation intensity varied moderately over the research area, with relatively high levels found around laboratory and radiography facilities, according to spatial distribution mapping. The results show that there are no appreciable radiological health risks for employees, students, or visitors due to the current radiation levels in the surroundings under investigation. Nonetheless, regular ambient radiation monitoring is advised to guarantee ongoing adherence to global radiation safety and protection regulations.

Keywords: Background radiation, gamma spectrometry, environmental monitoring, annual effective dose

WHY WOULD AN ETHICALLY PROVEN *SHOCKVERTISING* CAMPAIGN BACKFIRE SO AGGRESSIVELY? ETHICS BOUNDARIES IN ADVERTISING AND AUDIENCE'S PERSPECTIVE CASE STUDY: SPINNEYS "MISSING" ADVERTISING CAMPAIGN - LEBANON 2025

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ABSTRACT

In advertising campaigns, particularly billboards, brands resort to using attention-grabbing techniques to capture the audience's focus and manipulate consumer behavior. Multiple categories can also be employed to convey a message within a single campaign. These categories range from shock advertising, engagement advertising, teaser advertising, reveal advertising, and many others. This is precisely what the Spinneys campaign tended to achieve in announcing its new branch, employing these advertising techniques. This campaign initiated a wave of discontent on social media and in society. That wave quickly turned aggressive, bombarding the campaign with criticism. Many argued that, in a country already facing war and uncertainty, a commercial campaign that plays on the theme of "missing people" could feel harmful and trigger deep fear among citizens. However, the ethical boundaries of these advertising categories vary according to several factors, such as the audience's psychology and background, as well as the manner in which the campaign is executed, including its visuals, language, and other elements. The findings of this study highlight the ethical boundaries of these types of advertising, as well as how to maintain responsibility toward society while achieving creativity and leaving an impact.

Keywords: Advertising, Reveal Advertising, Engagement Advertising, Consumers Psychology, Target Audience, Consumer Behavior

WHEN A SIMPLE DISH BECOMES LUXURY: RETHINKING PRICE, VALUE, AND FAIRNESS IN LOCAL FOOD MARKETS

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ABSTRACT

This study explores a simple but surprisingly complex question: why do people sometimes accept high prices for basic food—and other times strongly reject them?

The paper looks at a recent case in Lebanon where a tomato and garlic sandwich, traditionally seen as a simple and affordable food, was sold at a premium price by a well-known brand. The reaction was immediate and divided. Some people defended the price, arguing that it reflects the brand, the experience, and the setting. Others rejected it, insisting that such a product should remain accessible and not be turned into a luxury item.

Based on qualitative analysis of online reactions and public discussion, the study shows that pricing is not only about cost or quality. It is also shaped by culture, familiarity, and what people believe is fair. Interestingly, many consumers who reject high prices for local foods are often willing to pay similar prices for foreign or globally recognized dishes.

The paper argues that when it comes to culturally familiar products, pricing becomes more than a business decision—it becomes a social and cultural issue. It opens a discussion on how far branding can go in transforming the ordinary into something premium, and where consumers draw the line.

SHAPING THE FUTURE OF ORAL HEALTHCARE USING ARTIFICIAL INTELLIGENCE

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ABSTRACT

Artificial Intelligence (AI) is increasingly reshaping contemporary dentistry by enhancing diagnostic precision, optimizing treatment planning, and improving patient-centered care. This presentation critically examines the expanding integration of AI technologies across diverse dental specialties, including oral radiology, oral pathology, periodontology, orthodontics, prosthodontics, and restorative dentistry. Particular emphasis is placed on the application of machine learning and deep learning algorithms in radiographic interpretation, caries detection, early diagnosis of oral diseases, personalized therapeutic decision-making, and predictive analytics for treatment outcomes. Recent advancements demonstrate that AI-driven systems have the potential to improve clinical efficiency, reduce diagnostic variability, and support evidence-based dental practice. Nevertheless, the widespread implementation of AI in dentistry is accompanied by significant ethical, legal, and regulatory challenges, including concerns regarding data privacy, algorithmic bias, transparency, and professional accountability.

Keywords: Artificial Intelligence, Oral Healthcare, Dentistry

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Çelik Elyaf/PA6.10 KOMPOZİTLERİN TERMAL VE ELEKTROMANYETİK KALKANLAMA ÖZELLİKLERİNİN İNCELENMESİ

INVESTIGATION OF THE THERMAL AND EMI SHIELDING PROPERTIES OF STEEL Fiber/PA6.10 COMPOSITES

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ÖZET

Elektrikli ve otonom araç teknolojilerindeki hızlı gelişim, araçlarda kullanılan elektronik kontrol üniteleri, batarya yönetim sistemleri, radar sensörleri, haberleşme modülleri ve güç elektroniği bileşenlerinin sayısını önemli ölçüde artırmıştır. Bu durum, elektromanyetik girişim (EMI) kaynaklı sinyal bozulmaları, veri kayıpları ve sistem performansında kararsızlık gibi problemlerin daha kritik hale gelmesine neden olmuştur. Özellikle otomotiv sektöründe elektromanyetik girişim kalkanlama (EMK) özelliğine sahip, hafif, dayanıklı ve ekonomik malzemelere olan ihtiyaç giderek artmaktadır. Literatürde karbon esaslı iletken dolgu malzemeleri yaygın olarak kullanılmasına rağmen, çelik elyafların yüksek mekanik dayanım, elektromanyetik dalga soğurma kapasitesi, işlenebilirlik ve maliyet avantajı sayesinde otomotiv uygulamaları için önemli bir alternatif oluşturduğu bildirilmektedir. Bu çalışmada, yüksek mekanik performans, kimyasal direnç ve biyobazlı yapıya sahip mühendislik termoplastiği poliamid 6.10 (PA6.10) matrisi içerisine farklı oranlarda çelik elyaf (ÇE) ilave edilerek iletken kompozitler geliştirilmiştir. Kompozitler çift vidalı ekstrüder kullanılarak eriyik harmanlama yöntemiyle üretilmiş, ardından enjeksiyon kalıplama prosesi ile standart test numuneleri hazırlanmıştır. Ağırlıkça %10, %20 ve %30 ÇE içeren kompozitlerin morfolojik, termal ve elektriksel özellikleri incelenmiştir. Elde edilen sonuçlara göre, artan ÇE ile bozunma sıcaklığı düşmüş, yüksek ÇE desteğinde bozunma sıcaklığının azalarak olumsuz etkilenebileceği bildirilmiştir. Morfolojik açıdan incelendiğinde, ÇE ile PA 6.10 arayüzey etkileşimi değerlendirildiğinde ise elyaf ile matris arasında büyük boşluklar olduğu belirlenmiştir. Kalıntı miktarı değerlendirildiğinde saf numuneninkine göre eklenen katkı oranları miktarı ile benzer olarak kalıntı miktarı artmıştır. Bu sonuç, 800 °C'de ÇE'nin varlığını yüksek oranda koruduğunu göstermektedir. ÇE kompozitlerin yarı iletken sınıfında olmasına rağmen elektriksel iletkenlik değerinin oldukça düşük oluşu da göz önüne alındığında EMK değerinin düşük olması da bu durumu desteklemektedir. Yapıya ÇE katkısı eklendiğinde kompozitlerde artan bir EMK verimliliği görülmüştür. ÇE10, ÇE20 ve ÇE30 kompozitleri sırasıyla yaklaşık 11 dB, 12 dB ve18 dB olarak kalkanlama etkinliği sergilemiştir.

Anahtar kelimeler: Batarya paketleri, Poliamid 6.10, Çelik Elyaf, Elektromanyetik Kalkanlama.

ABSTRACT

The rapid development of electric and autonomous vehicle technologies has significantly increased the number of electronic control units, battery management systems, radar sensors, communication modules, and power electronics components used in vehicles. This situation has made problems caused by electromagnetic interference (EMI), such as signal distortion, data loss, and instability in system performance, more critical. Therefore, the demand for lightweight, durable, and cost-effective materials with electromagnetic interference shielding (EMI shielding) properties has been steadily increasing, particularly in the automotive industry. Although carbon-based conductive fillers are widely used in the literature, steel fibers have been reported as an important alternative for automotive applications due to their high mechanical strength, electromagnetic wave absorption capability, processability, and cost advantages. In this study, conductive composites were developed by incorporating different amounts of steel fiber (SF) into a polyamide 6.10 (PA6.10) engineering thermoplastic matrix, which exhibits high mechanical performance, chemical resistance, and a bio-based structure. The composites were produced by melt blending using a twin-screw extruder, followed by injection molding to prepare standard test specimens. The morphological, thermal, and electrical properties of the composites containing 10 wt.% SF, 20 wt.% SF, and 30 wt.% SF were investigated. According to the obtained results, the degradation temperature decreased with increasing SF content, indicating that high SF loading may negatively affect the thermal degradation behavior. Morphological evaluations revealed the presence of large gaps between the SFs and the PA6.10 matrix, indicating limited interfacial adhesion between the fiber and matrix phases. Residue analysis demonstrated that the residual amount increased proportionally with the additive content compared to the neat sample. This result indicates that the SFs largely maintained their structural integrity at 800 °C. Although the SF composites exhibited semiconductive behavior, the relatively low electrical conductivity values also supported the limited EMI shielding performance. However, the addition of SFs into the structure led to an increase in EMI shielding effectiveness. The SF10, SF20, and SF30 composites exhibited shielding effectiveness values of approximately 11 dB, 12 dB, and 18 dB, respectively.

Keywords: Battery Pack, Polyamide 6.10, Steel Fiber, EMI Shielding.

1. GİRİŞ

Elektrikli araçların çevre dostu ve sürdürülebilir olması ve fosil kaynakların azalması gibi etkenlerden dolayı çok yakın gelecekte, içten yanmalı motora sahip araçların yerini alacağı öngörülmektedir. Ancak elektrikli araçlarda bulunan ve içinden yüksek voltaj geçen parçalar ve alternatif akım ile çalışan motordan çalışma sırasında düşük frekanslı elektromanyetik dalgalar yayılmaktadır. Elektromanyetik dalgalar araç içerisinde bulunan diğer elektrikli cihazların çalışmasını olumsuz etkilerken, insanların bu dalgalara uzun süreli maruz kalması sonucu da çeşitli sağlık problemlerine yol açabilmektedir [1-4].

Bu olumsuz etkileri ortadan kaldırmak için çeşitli araştırmalar başlatılmış olup, elektromanyetik kalkanlama (EMK) özelliğine sahip koruyucu malzemeler geliştirmek amaçlanmıştır. Yalnızca elektrikli araçlar değil tüm elektrikli cihazların ihtiyacına bir çözüm olması hedeflenmektedir. [5-8]

Metaller, iletken ve manyetik özelliğe sahip olduğu için EMK uygulamalarında geçmiş yıllardan beri yaygın olarak kullanılmaktadır. Fakat son yıllarda iletken özellikte karbon esaslı katkılar ve iletken polimerler de yayın olarak kullanılmaya başlamıştır. Literatürde, metal plaka, tel, kaplama, boya, yapıştırıcı, elyaf, kumaş elastomer, termoset veya termoplastik kompozitler gibi pek çok alanda EMK çalışmaları yürütülmektedir [9]. Çeşitli araştırmalar, polimerlere grafit, karbon dolgu maddesi veya çelik dolgu maddesi gibi iletken dolgu maddelerinin eklenmesinin, bu polimerlerin ekranlama performansını önemli ölçüde artırabileceğini ortaya koymuştur [10].

Poliamidler, kolay proses edilebilirlik ve yüksek mekanik dayanımı gibi özellikleri nedeniyle otomotiv sektöründe yaygın olarak kullanılan malzemelerdir [11,12]. Biyobazlı poliamidler, sürdürülebilir olması ve yüksek uzama değeri gibi avantajlara sahiptirler. Biyobazlı poliamidlerden PA 6.10 biyobazlılık oranı %60 civarında olan bir malzemedir. [13-14] Literatürdeki çalışmalara bakıldığında, iletken özelliğe sahip çeşitli poliamid esaslı malzemelerin [14-15] özellikle EMK üzerine yapılan çalışmalar oldukça sınırlıdır.

Bu çalışmada, farklı oranlarda çelik elyaf (ÇE) içeren PA6.10 esaslı kompozitler hazırlanmış ve dolgu miktarının çekme ve darbe davranışı, termal bozunma özellikleri ve EMK üzerindeki etkileri bütüncül bir yaklaşımla analiz edilmiştir. Böylece ÇE'nin, PA6.10 matrisli kompozitlerde kullanım potansiyeli ve performans sınırları ortaya konmuştur.

2. MATERYAL ve METOD

Polimer matrisi olarak erime sıcaklığı yaklaşık 220 °C olan poliamid 6.10 (PA6.10), Radici Group (RADIPOL® DC40, İtalya) kullanılmıştır. Dolgu malzemesi olarak Bekaert'ten tedarik edilen Çelik elyaf (GR90/E/5) kullanılmıştır ve ön işleme tabi tutulmadan, tedarik edildiği formda doğrudan kompozit üretim sürecine dahil edilmiştir.

PA6.10 peletleri, eriyik işleme sırasında hidrolitik bozunmayı en aza indirmek amacıyla 80 °C'de 12 saat boyunca kurutulmuştur. Numuneler, 220-260 °C işleme sıcaklığında eriyik işleme yöntemi kullanılarak çift vidalı ekstrüderde hazırlanmıştır. Ekstruderden elde edilen şeritler, enjeksiyon kalıplama işleminden önce su banyosunda soğutulduktan sonra pelet haline getirilip kurutulmuştur. Mekanik, termal, elektriksel, morfolojik ve EMK testleri için standart test numuneleri, bir enjeksiyon kalıplama makinesi kullanılarak üretilmiştir. Tablo 1'de üretilen numunelerin kodları ve bileşimleri verilmiştir.

Tablo 1. ÇE/PA6.10 kompozitlere ait numune kodlamaları ve bileşen miktarları

Numune Kodları	PA6.10 (% ağırlıkça)	ÇE (% ağırlıkça)
PA6.10	100	-
PA6.10ÇE10	90	10
PA6.10ÇE20	80	20
PA6.10ÇE30	60	30

2.1. Karakterizasyon

Malzemelerin mekanik özellikleri, ISO 527-2 standardına göre Tip 1A numuneler (170 mm × 10 mm × 4 mm) kullanılarak çekme testi ile değerlendirilmiştir. Ölçümler, ZwickRoell Z021 üniversal test cihazı ile oda sıcaklığında (23 °C, %50 bağıl nem) ve 50 mm/dk çapraz kafa hızında gerçekleştirilmiştir.

Kompozit malzemelerin morfolojik yapısını ve elyafların dağılımını incelemek için Quanta 400F Field Emission markalı taramalı elektron mikroskobu (SEM) cihazı ile kesit yüzey görüntülemesi yapılmıştır.

Elektriksel iletkenlik testi, IM3536 LCR METER markalı elektriksel özellikler ölçüm cihazında oda sıcaklığında gerçekleştirilmiştir.

Isıl özellikler, termogravimetrik analizi (TGA) ile belirlenmiştir. TGA, 25-800 °C sıcaklık aralığında 10°C/dk ısıtma hızında METTLER Toledo TGA 1 cihazında gerçekleştirilmiştir. Test esnasında ortamın inert hale gelmesi için 30ml/dk akış hızıyla azot gazı beslenmiştir.

EMK verimliliği ölçümü R-bantta (1.7-2.6 GHz) çalışan dikdörtgen dalga kılavuzu Rezonatör ile gerçekleştirilmiştir.

3. BULGULAR

3.1. Kompozitlerin Mekanik Özellikleri

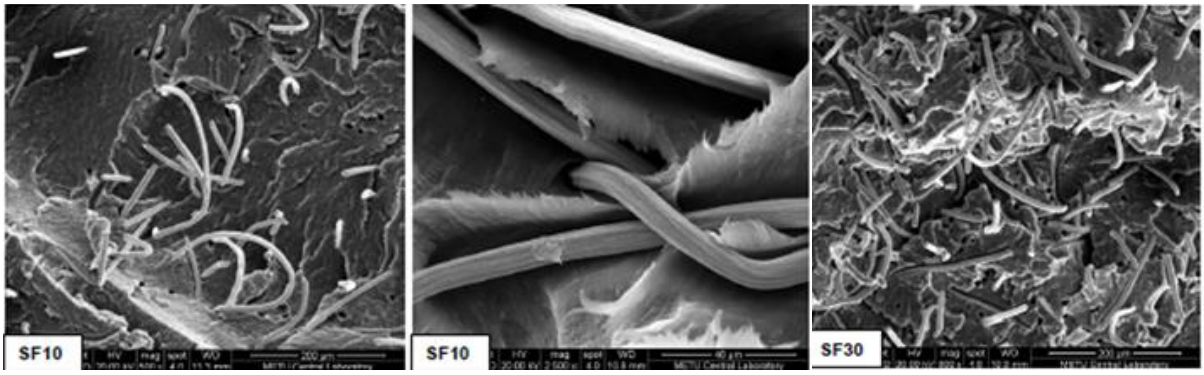
ÇE takviyeli kompozitlerin mekanik özellikleri Tablo 2'de verilmiştir. ÇE eklenmesi PA 6.10 matrisin 60.5 MPa olan çekme dayanımını bir miktar düşürmüştür. Artan oranlarda ÇE kullanıldığında bu azalma eğilimi devam etmiştir. %30 oranında ÇE eklenmesi ile çekme dayanımı değeri 52 MPa olmuştur. Dayanım değerinde %30 ÇE eklenmesi ile yaklaşık %14'lük bir değişim gözlenmiştir.

Tablo 2. Saf PA6.10 ve PA6.10/SF kompozitlerin çekme dayanımı değerleri (MPa)

Numune Kodu	Çekme Dayanımı (MPa)
PA6.10	60.5
PA6.10ÇE10	57
PA6.10ÇE20	55
PA6.10ÇE30	52

3.2. Kompozitlerin Morfolojik Özellikleri

Şekil 1'de ÇE/PA6.10 kompozitlerin SEM kesit görüntüleri (Skala soldan sağa: 200µm – 40µm) verilmiştir. ÇE yüklemesinin artırılmasının PA6.10 matrisinde sürekli bir iletken ağ oluşumuna yol açtığı görülmüştür. Düşük elyaf içeriğinde elyaflar birbirinden izole durumdayken, yüksek elyaf içeriğinde (ÇE30) güçlü ara bağlantılar gözlemlenmektedir; bu durum, elektriksel iletkenlik ile EMI koruma özelliklerinde önemli ölçüde iyileşme olduğunu göstermektedir.



Şekil 1. SF destekli kompozitlerin SEM kesit görüntüleri (Skala soldan sağa: 200µm – 40µm-200µm)

3.3. Kompozitlerin Elektriksel İletkenlik Testi Sonuçları

Saf PA6.10 numunesinin elektriksel iletkenliği $1.4x10^{-9}$ S/cm olarak bulunmuştur ve bu değer Saf PA6.10 numunesinin yalıtkan olduğunu göstermektedir. ÇE takviyeli kompozitlerin elektriksel iletkenlik değerleri katkı miktarları artıkça sırasıyla $8.0x10^{-6}$, $2.7x10^{-5}$ ve $4.7x10^{-3}$ değerlerine artış göstermiştir. ÇE ilavesi ile kompozitlerin yarı iletken sınıfına geçiş yaptığı belirlenmiştir.

3.4. TGA Test Sonuçları

TGA test sonuçlarından elde edilen bozunma sıcaklıkları Tablo 3'te verilmiştir. ÇE10 kompozitin T_{max1} bozunma sıcaklıkları saf PA6.10 numunesininki ile hemen hemen aynı değerde bulunmuştur. Bunun

yanında ÇE10 kompozitinin T_{deg5} bozunma başlangıç sıcaklığı saf PA6.10 numunesininkinden yüksek değerde gözlemlenmiştir. ÇE20 ve ÇE30 kompozitlerinin T_{max1} sıcaklığında düşüş olduğu belirlenmiştir. ÇE20 ve ÇE30 kompozitlerin T_{deg5} değerleri saf PA6.10 numunenin bozunma sıcaklık değerlerinin altında kalmıştır. Özellikle ÇE30 kompozitinin bozunma sıcaklığında 15 °C'lik bir değişim görülmüştür. Elde edilen sonuçlara göre, yüksek çelik elyaf desteğinde bozunma sıcaklığının azalarak olumsuz etkilenebileceği gözlenmiştir. Kalıntı miktarı değerlendirildiğinde saf numuneye göre eklenen katkı oranları miktarı ile doğrusal olarak kalıntı miktarını artmıştır.

Tablo 3. Saf PA6.10 ve SF destekli kompozitlerin TGA sonuçları

Numune Kodu	T_{deg5} (°C)	T_{max1} (°C)	Kalıntı miktarı (%)
PA6.10	423.88	464.22	0.18
PA6.10ÇE10	429.74	464.22	13.61
PA6.10ÇE20	416.17	459.70	18.75
PA6.10ÇE30	408.83	461.40	29.08

3.5. Elektromanyetik Kalkanlama Performansı

ÇE destekli kompozitlerin EMK eğrileri ve farklı ÇE oranlarındaki PA6.10 kompozitlerin orta değer (f=2.15 GHz) frekansa göre EMK değişimi incelenmiştir. PA6.10 numunesinin yalıtkan bir malzeme olarak herhangi bir kalkanlama etkinliği göstermediği gözlemlenmiştir. Yapıya ÇE katkısı eklendiğinde kompozitlerde artan bir EMK verimliliği görülmüştür. ÇE10, ÇE20 ve ÇE30 kompozitleri sırasıyla yaklaşık 11 dB, 12 dB ve18 dB olarak kalkanlama verimliliği sergilemiştir. Malzemenin elektriksel iletkenlik değeri arttıkça EMK değeri de doğrusal artar, elektriksel iletkenlik ne kadar yüksekse o kadar yüksek kalkanlama verimliliği beklenmektedir.

4. SONUÇ

Bu çalışma kapsamında, PA6.10 matrisi içerisine farklı oranlarda ÇE ilave edilerek kompozit malzemeler başarıyla üretilmiş ve mekanik, elektriksel, termal ve elektromanyetik özellikleri sistematik olarak değerlendirilmiştir. Eriyik işleme ile kompozit üretimi ve enjeksiyon kalıplama yöntemleriyle kalıplanan numunelerde, artan çelik elyaf içeriğinin malzeme özellikleri üzerinde belirgin etkiler gösterdiği belirlenmiştir.

Çekme testleri sonuçları, çelik elyaf ilavesinin PA6.10 matrisinin çekme dayanımında genel olarak azalmaya neden olduğunu, ancak düşük oranlı katkıda sınırlı mekanik iyileşmelerin de gözlemlenebildiğini göstermiştir. SEM analizleri, elyaf oranı arttıkça matris içerisinde daha belirgin bir iletken ağ yapısının oluştuğunu ve özellikle yüksek dolgu oranlarında güçlü ara bağlantıların meydana geldiğini ortaya koymuştur.

Elektriksel iletkenlik sonuçları, çelik elyaf katkısının kompozitlerin iletkenliğini önemli ölçüde artırdığını göstermiştir. TGA analizleri, düşük ve orta dolgu oranlarında termal kararlılığın kısmen korunduğunu, ancak yüksek elyaf içeriğinde bozunma sıcaklıklarının düşerek termal kararlılığın olumsuz etkilendiğini ortaya koymuştur. Bununla birlikte, artan elyaf oranı ile kalıntı miktarının yükselmesi, yüksek sıcaklıklarda ÇE'nin yapıda önemli ölçüde korunduğunu doğrulamıştır. EMK testleri ise ÇE katkısının EMI koruma performansını belirgin şekilde artırdığını göstermiştir. En yüksek kalkanlama verimliliği ÇE30 numunesinde elde edilmiştir. Genel olarak sonuçlar, ÇE takviyesinin PA6.10 kompozitlerinde elektriksel iletkenlik ve EMI kalkanlama performansını iyileştirdiğini ortaya koymaktadır.

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LEGITIMACY FOR INSTITUTIONAL CORRUPTION: NORMALIZED CORRUPTION AND INSTRUMENTALISM

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ABSTRACT

This paper explores the factors that lead citizens to adopt an instrumental approach to institutional corruption, meaning that they legitimate it if they believe that it helps achieve desirable outcomes. Most explain the spread of corruption and the public tolerance of it by diffusion and normalization dynamics rooted in collective action problems. We develop a theoretical framework based on this reasoning but add other variables. We then test our research model using survey data collected from citizens of various European countries from the Global Corruption Barometer, which Transparency International manages. The findings indicate that the rationales of diffusion and normalization can explain perceptions of institutional corruption as instrumental only to a limited extent. This conclusion questions the common explanations about the origins and persistence of corruption. At the very least, it suggests that considerations about outcomes and procedural justice exist in parallel, rather than being interchangeable dimensions. Practical implications follow.

Practically we conclude the following:

- The fact that corruption is widespread at many levels and sectors in society might lead people to engage in corrupt practices to achieve immediate outcomes and payoffs, but not to legitimate and justify these actions normatively and morally.
- As long as people believe that corruption is morally wrong, it is possible to mobilize them to fight it. Changing behavior is easier than changing beliefs and moral perceptions.
- Practical strategies to fight corruption should emphasize the moral or ethical dissonance that might arise from a contradiction between their corrupt behavior to achieve short-term results and their moral beliefs, and challenge people with it.

DIFFERENT STORAGE CONDITIONS *LUCILIA SERICATA* COMPARATIVE EVALUATION OF THE REGENERATIVE EFFECTIVENESS OF LARVAL SECRETIONS

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ABSTRACT

This study evaluated the effects of *Lucilia sericata* in different storage temperatures and durations on the bioavailability and in vitro wound healing potential of secretions obtained from first-stage larvae. To overcome the logistical limitations associated with using fresh secretions, the aim was to determine optimal storage conditions suitable for clinical applications. Larval secretions were stored at +4 °C, −20 °C, and room temperature for 24 and 48 hours. In vitro wound healing activity was analyzed using a scratch assay performed with the 3T3 murine fibroblast cell line. Cell migration and wound closure rates were measured using pixel-based numerical analysis methods via ImageJ software. Statistical differences between the negative control, fresh secretion (positive control), and experimental groups were evaluated using the Kruskal-Wallis test at 24, 48, and 72-hour intervals. The results demonstrated that secretions stored at −20 °C for 48 hours showed significantly higher efficacy in wound closure compared to samples kept at +4 °C or room temperature. Specifically, it was determined that storage at -20 °C for 48 hours exhibited higher biological activity compared to a 24-hour period at the same temperature. The findings suggest that *L. sericata* demonstrated that secretions retain their biological efficacy under controlled conditions, and that a 48-hour protocol at -20°C provided the highest functional effect. The study revealed that cold chain optimization can reduce dependence on fresh secretions, potentially enabling the development of more sustainable, standardized, and clinically accessible secretion-based therapeutic strategies in maggot debridement treatment.

Keywords: *Lucilia sericata,* Wound Healing, Scratch Test, Fibroblast Migration, Storage Conditions.

1. INTRODUCTION

The larvae of *Lucilia sericata* facilitate the rapid healing of chronic wounds through their ability to liquefy necrotic tissue, inhibit microbial growth, and stimulate granulation. Although this method, widely known in the literature as 'Maggot Debridement Therapy' (MDT), typically utilizes live larvae, challenges such as patient discomfort, the sensation of larval feeding, or psychological reluctance occasionally limit its clinical application. These factors have prompted interest in using larval secretions (extracts) collected in isotonic solutions as a therapeutic alternative.

However, the bio-stability and efficacy of these secretions under various storage conditions remain insufficiently documented. This lack of standardization complicates the transport of extracts to distant clinical centers and perpetuates a reliance on live larvae. To address this, our study evaluates the biological activity of *Lucilia sericata* secretions stored at different temperatures and durations. The potential of the extract was investigated *in vitro* using fibroblast cells, which are critical mediators in the wound healing process.

2. EXPERIMENTAL STUDIES

2.1. Secretion Collection Studies

Secretion Preparation

Fresh chicken liver was homogenized at room temperature (20-28°C) using a blender. Water distilled from a water distiller (Marienfeld®) was boiled using a heater, and 1300 ml of distilled water was added for every 1000 g of liver. 40 g of agar (Merck®) was weighed using a precision balance (Denver

Instrument® TP-214), and after homogenization, the mixture was divided into equal volumes (not exceeding 700 ml) in 1000 ml autoclave flasks and sterilized by autoclaving at 121°C (Nüve OT 4060) to prevent contamination and spoilage. The sterilized medium was poured evenly into 90x150 mm petri dishes under a fume hood (Airstream ESCO Class II BSC), labeled, and stored at +4°C until use, with each petri dish weighed using a precision balance. The average weight of the culture media in petri dishes was determined to be 25-30 grams.



Figure 1: Culture medium preparation stages

Cage Installation: The culture medium was prepared, and the cages were set up and monitored. The colonies were fed 25–30 grams of chicken liver weekly, supplemented with a continuous supply of sugar and water. The experimental conditions were maintained at a constant temperature of 26–28 °C and a relative humidity of 27–36%. The colonies were kept in a room with a 3-hour light cycle, and the cages were constructed using stainless steel and fine mesh (30×30×30 cm). The cages were established using sterile eggs obtained from the laboratory. These eggs were counted under a microscope (Olympus SZX2-ZB10) and inoculated onto the chicken liver-based culture medium. Approximately 3 hours after introducing the liver into the cages, the collected eggs were transferred to the culture media and incubated at 25 °C for 72 hours (Nüve EN 400). Water and sugar were provided to the colony using cotton-plugged flasks. Each cage was maintained with an average population of 1500 flies. To meet the protein requirements of adult flies and stimulate oviposition, approximately 25 grams of chicken liver was provided to each cage weekly on a fixed day and time.

Egg Inoculation: Under a microscope, the eggs were inoculated into a culture medium prepared with chicken liver (1 kilogram), agar-agar (40 grams), and 1300 ml of distilled water.

Obtaining the Secretion: On Monday (day 3), 3000 larvae were individually separated from the culture medium. For every 500 larvae, 1 ml of physiological saline was added dropwise every hour using a syringe. The container was then placed inside another vessel covered with fine gauze, with the center of the lid removed to allow oxygen flow. After a 6-hour waiting period, the sample was collected.

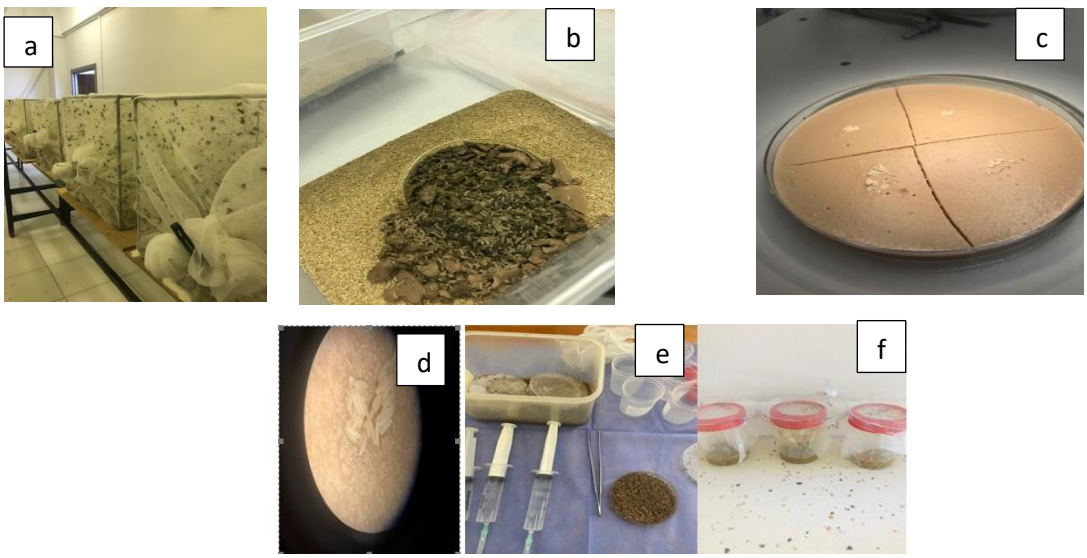
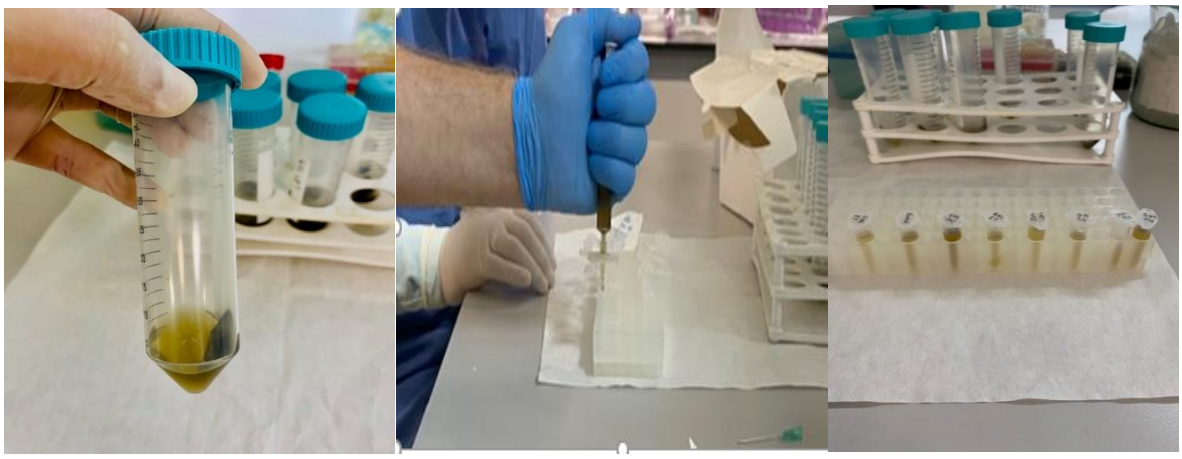


Figure 2: a) After the pupae hatch and adult fly formation*Lucilia sericata*the appearance of their cages **b)** It has progressed from egg to first stage larva. *Lucia sericata* changes in the culture medium as a result of the larvae consuming the culture medium. **c)**Inoculated onto a culture medium prepared with liver .*Lucia sericata* eggs **d)** Inoculated onto a culture medium prepared with chicken liver.*Lucilia sericata*microscopic image of the eggs **e)**Phase 1: Preparing for an outbreak. *Lucilia sericata* The stage of separating the larvae from the culture medium. **f)**Extracted Phase 1*Lucilia sericata* left in distilled water for 6 hours to allow the larvae to release their secretions

2.2 Cell Culture

According to the study protocol, the desired number of cells were seeded onto plates and cultured until the cells had sufficient proliferation potential. The cells included in the study...*Lucilia sericata*The cytotoxicity of secretions was evaluated using the "wound (scratch) test". In addition, all working equipment was sterilized with UV before the experiment to eliminate the risk of contamination. Cell culture experiments were performed in the cell culture laboratory of the Bezmialem Vakıf University Experimental Application and Research Center. The stages of cell culturing were: 3T3 mouse fibroblast cells used in the study were obtained frozen in cryo tubes with DMSO at -80 °C. The culture medium to be used for the cells was prepared by adding 10% FBS (Fetal Bovine Serum), 1% Penicillin/Streptomycin (100 U/ml penicillin and 100 µg/ml streptomycin) and primocin at a ratio of 1/1000 to DMEM (Dulbecco's modified Eagle) containing 1.0 g/L glucose (5.5 mM) and HEPES (25 mM). This culture medium was stored at +4°C. For cell culturing, the culture medium was kept in a water bath at 37°C. The cell mixture in the cryo tube (containing culture medium and DMSO) taken from -80°C was prepared for culturing by keeping it in a water bath. After thawing the 1 mL frozen cells, the cells were transferred to a 15 mL falcon and 2 mL of fresh culture medium was added. This process was done to remove the DMSO present in the cells during the freezing process. The 3 mL culture medium containing the cells was centrifuged at 300 RCF for 4 minutes. Thus, a cell pellet free of DMSO was formed at the bottom of the falcon. The culture medium on top of the cell pellet was poured into a liquid waste container, and only the cell pellet was obtained. For the cell suspension process, 2 mL of fresh culture medium was added to the sterile cell culture flask using an automated pipette tip, ensuring homogeneous distribution of the cells. To ensure confluent cell distribution during the initial culture phase, 4 mL of fresh culture medium was added to the T-25 cell culture flask. The 2 mL of suspended cells were slowly added to this medium using an automated pipette tip. Homogeneous distribution of cells was ensured in the flask and checked under a microscope. Incubation was performed at 37 °C and 5% CO2.$_2$The procedure was performed in a T-25 cell culture flask. 3T3 mouse fibroblast cells were observed for 48 hours to ensure adhesion and confluentness (in 2D) to the flask. When the cells reached a sufficient number for passage (between 48-72 hours), the medium in the flask was gently poured off the liquid waste, 2 mL of Trypsin EDTA was added directly, and the cells were allowed to remain at the bottom of the flask by incubating for 5 minutes. To remove the Trypsin EDTA medium, the cells were centrifuged, the liquid was discarded, and the cells were suspended in fresh medium. After cell counting, the cells were placed in 24-well plates at appropriate cell sizes (3 x 10^6).[5]The cell) plating process was started. After the 24-well cells became confluent (after 48 hours), a scratch was made by passing a 100-200 microliter pipette tip over the adherent cells at the bottom of each well. Thus, the first technical step for the wound (scratch) experiment was performed. For each well with a scratch at the bottom and containing culture medium, the process of adding the secretions to be investigated was started. 5 microliters of secretion active substance were added to the culture medium in each well [63-65]. At 37 °C, %5 CO_2.The samples were incubated for 24, 48, and 72 hours. The wound opening was measured and microscopically imaged using an inverted microscope. To ensure consistent field of view during image acquisition, markers were created near the scratching point to serve as reference points.

The image of the incision at hour 0 was recorded as the first image, and incubation continued. At the end of 72 hours, the imaging and cell migration status in all groups were finalized both statistically and visually.



a) **b)** **c)**

Figure 3: a) Pellet and liquid phase formed in the secretion after centrifugation. **b)**Passing the secretions through a 0.02 nanometer filter. **c)**Filtered *Lucilia sericata* secretions

Groups studied in cell culture medium:

1. **C (+):**This is a positive control group. It contains secretion collected after 6 hours and delivered to the cell culture laboratory.

2. **C (-):**This is a negative control group. It contains no active ingredients.

3. Secretions were stored at +4^{0}C, -20^{0}C and room temperature for 24 hours.

4. Secretions were stored at +4^{0}C, -20^{0}C and room temperature for 48 hours.

3. Bradford Experiment

The Bradford assay was performed to equalize the protein concentrations of the secretions collected fresh (after 6 hours) and those stored at +4 °C, -20 °C, and room temperature for 24 and 48 hours. Measurements were conducted in 96-well plates using a Thermo Multiskan GO instrument at a wavelength of 595 nm, with a total volume of 200 µl per well. A bovine serum albumin (BSA) stock solution (2 mg/mL) was used to generate a standard curve. Based on the absorbance values, the volume required from each sample to obtain 10 µg of protein in a final volume of 50 µl was calculated. To prepare the working solution containing 10 µg of protein, specific volumes of each larval secretion extract were diluted in DMEM medium. The measured protein concentrations and the calculated volumes required to standardize the samples to 10 µg of protein are presented below:

Protein Konsantrasyonları	Eşit (10 mikrogram) Konsantrasyon İçin Çekilen Protein
Pozitif Kontrol: 9 µg	22 µg
24 saat oda sıcaklığı: 4 µg	50 µg
24 saat +4 ^{0}C: 13 µg	17 µg
24 saat -20^{0}C: 5 µg	40 µg
48 saat oda sıcaklığı: 6 µg	33 µg
48 saat +4 ^{0}C: 9 µg	22 µg
48 saat -20^{0}C: 9 µg	22 µg

Figure 4: Measurement results show protein concentrations and the amount of secretion drawn from the samples to ensure that each mixture prepared for the Bradford assay contains an equal amount of 10 micrograms of protein.

2.4. Cell Scratch Assay

The *in vitro* scratch assay is a simple and cost-effective method for studying cell migration.[2]. The migration path of individual cells at the leading edge of the scratch was tracked with the help of time-lapse microscopy and image analysis software.A cell scratch assay was performed to determine under which storage conditions Lucilia sericata secretion was most effective in the migration of 3T3 mouse fibroblast cells to the wound site. The cells were placed in 10^5Tissue samples were seeded into 96-well tissue culture dishes containing 500 µl of DMEM medium supplemented with 10% FBS, 1% penicillin-streptomycin, and 4 mM L-glutamine at a concentration of $2x10^5$ cells/ml, and incubated until a single layer covered the substrate. Then, a representative wound was created by making a linear incision from top to bottom using a sterile 200 µl pipette tip. After the incision, the dish was washed with PBS to prevent any residue from forming or remaining, and then 500 µl of DMEM medium was added to each well, followed by inoculation in 5% CO_2.The samples were incubated in a 37°C incubator for 24 hours. Secretion was added to the positive control wells, while no secretion was added to the negative control wells. Then, photographs of the cells were taken at the zero hour using a ZEIZZ Primo Vert WF10X\20 inverted microscope and a Moticam 1SP MP1.3 camera, and this photograph was designated as the zero (starting) photograph.

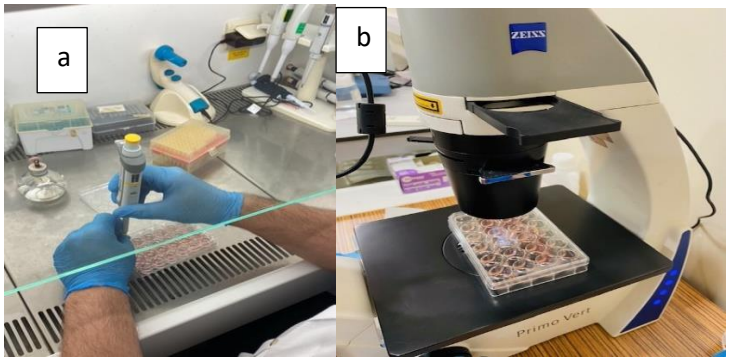


Figure 5: a) Performing the cell scratch test **b)** Microscopic examination of cells that underwent the cell scratch test.

2.5. Statistical Analyses

In our thesis study, we used the Kruskal-Wallis test to numerically evaluate the cell culture results of the scratch assay experiment. To create the graph, we used a negative control without secretion application at 24, 48, and 72 hours, a positive control with fresh secretion taken after 6 hours, and +4°C at 24 and 48 hours. -20^{0}C, The average of the 3-day changes in cells treated with secretions stored at room temperature and at 24°C was calculated. The averages were calculated as follows: for each sample, three lines were drawn on the cell culture images from the scratch assay experiment using ImageJ software, representing the top, middle, and bottom of the cell migration zone. The average of these three lines, drawn from negative and positive controls, was taken, and the result was accepted as 100%. Then, to calculate the percentage average for each condition (since at least three lines are required to perform the test), three different lines were drawn, and the difference between this line value and the 100% line value in the controls was calculated as a percentage. This calculation determined which condition resulted in more complete closure of the representative wound opening after secretion application, using the pixel unit of distance measurement accepted by ImageJ software.

-Cell Count: At 72 hours of cell culture, the number of migrating cells was counted within a representative area created by a scratch assay. Comparisons were performed based on the percentage of cells that migrated into the intercellular (scratch) space in both positive and negative control groups. To evaluate the effect of the test samples, the difference between the migration levels of the controls and the samples treated with secretions was calculated. Finally, the percentage increase in cell migration relative to the baseline was determined following the application of the secretions.

3. RESULTS AND EVALUATION

3.1. Statistical Findings Related to Cell Culture

Called the scratch test.*in vitro*In the model, firstly, after creating a wound scratch pattern in confluent 3T3 fibroblast cells, wound closure percentages were determined by comparing the migratory movements of the cells at 24, 48, and 72 hours of culture with the migratory movements of negative controls without larval fluid at the same hours. The closure percentages were statistically compared with the closure rates obtained by comparing the migration rates of larval secretions kept under different temperature conditions with the closure rates of negative controls. In this case, when the wound closure percentages of larval secretions stored at room temperature for 24 hours were compared with those of freshly collected larval secretions at 24, 48, and 72 hours according to the Kruskal-Wallis test, no statistically significant difference was observed in the first 24 hours (day 1), 48 hours (day 2), and 72 hours (day 3) compared to the positive control group and under different storage conditions, while the group that best closed the wound gap in the cells where the secretion kept for 24 hours was applied according to the Kruskal-Wallis test was +4.^{0}The cells to which the secretions stored in cell C were applied showed a 124.92% higher rate of closure.

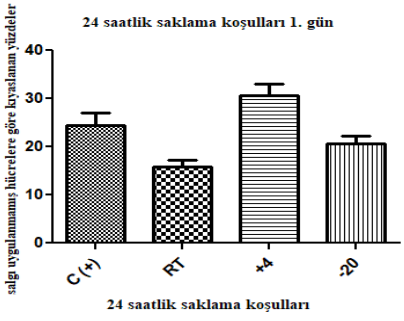
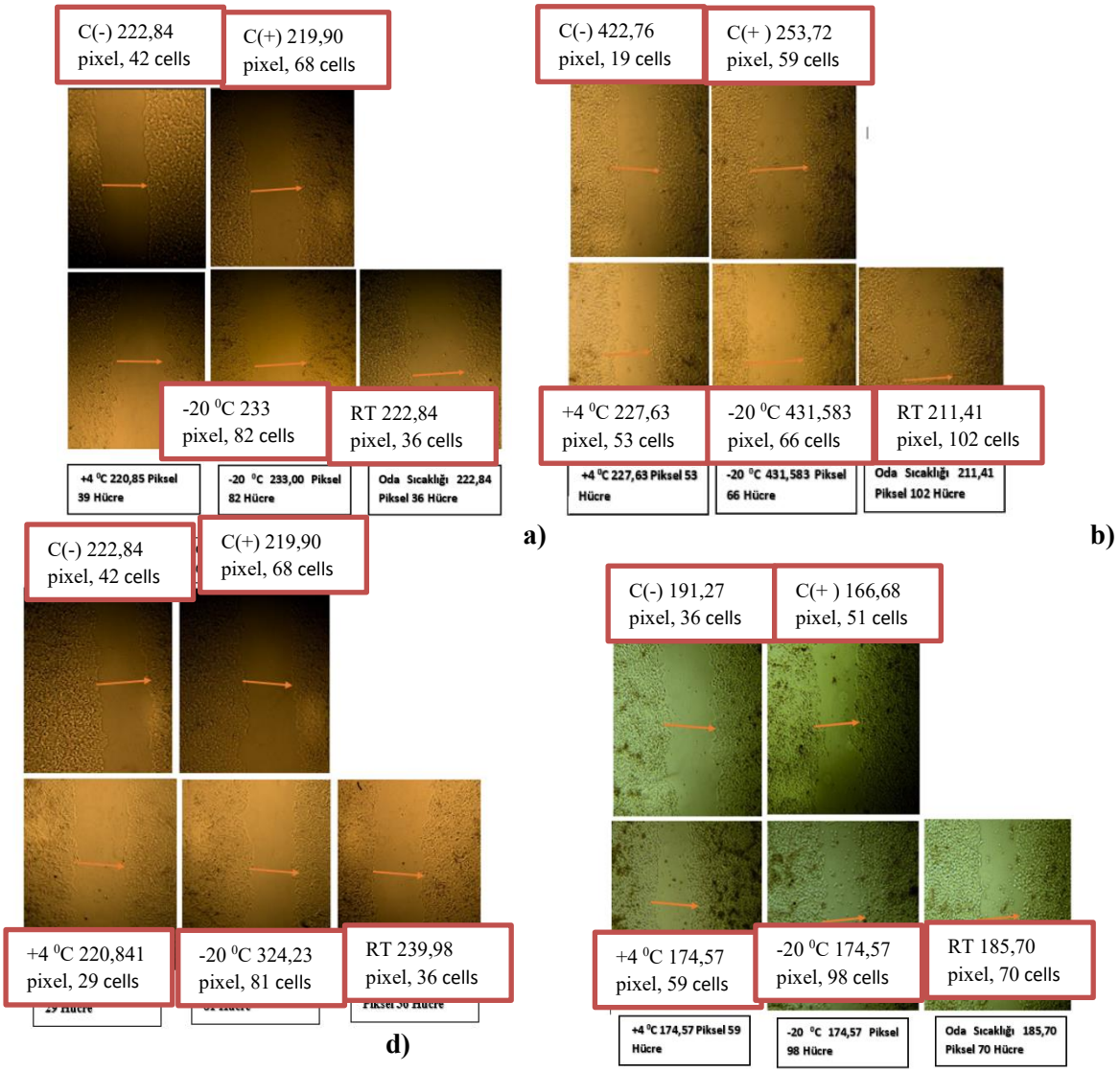


Figure 6: Comparison of secretions stored at different temperatures for 24 hours, over the first 24 hours.

3.2. Visual Findings Related to Cell Culture

To determine the efficacy of *Lucilia sericata* secretions on 3T3 mouse fibroblast migration, a scratch assay was conducted, monitoring cells over a 72-hour period. Secretions stored at +4 °C, -20 °C, and room temperature for 24 and 48 hours were compared against negative (C(-)) and positive (C(+))

controls. Cell migration was analyzed by capturing photographs at 24, 48, and 72 hours under identical conditions. Simultaneously, wound closure percentages were calculated for each storage condition to quantify the regenerative effect. Comparative visual data illustrating the cell migration patterns ranging from non-treated cells to those treated with secretions stored under the aforementioned temperature and duration protocols are presented. Specifically, the migration profiles of cells treated with secretions stored at -20 °C (for both 24 and 48-hour protocols) were analyzed at the 72-hour mark to determine the optimal storage strategy for maintaining the biological activity of the larval extract.



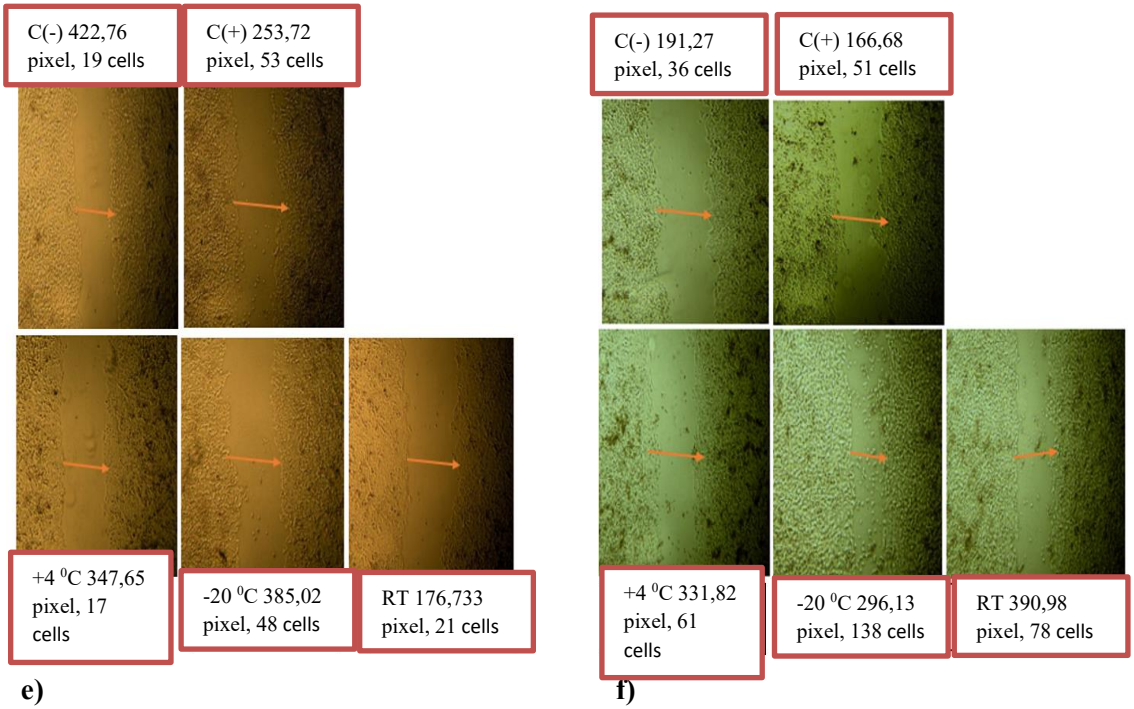


Figure 7: Comparison of *Lucilia sericata* secretions stored under different conditions. (a–c) Secretions stored for 24 hours at +4 °C, -20 °C, and room temperature, compared to negative (C(-)) and positive (C(+)) controls at 24, 48, and 72 hours, respectively. **(d–f)** Secretions stored for 48 hours at +4 °C, -20 °C, and room temperature, compared to negative (C(-)) and positive (C(+)) controls at 24, 48, and 72 hours, respectively. The square markers in the images indicate the specific experimental condition, the width of the wound gap (in pixels), and the number of fibroblasts migrated into the wound area

4. GENERAL ASSESSMENT AND CONCLUSIONS

To determine the efficacy of *Lucilia sericata* secretions on 3T3 mouse fibroblast migration, a scratch assay was conducted, monitoring cells over a 72-hour period. Secretions stored at +4 °C, -20 °C, and room temperature for 24 and 48 hours were compared against negative (C(-)) and positive (C(+)) controls. Cell migration was analyzed by capturing photographs at 24, 48, and 72 hours under identical conditions. Simultaneously, wound closure percentages were calculated for each storage condition to quantify the regenerative effect. Comparative visual data illustrating the cell migration patterns—ranging from non-treated cells to those treated with secretions stored under the aforementioned temperature and duration protocols—are presented. Specifically, the migration profiles of cells treated with secretions stored at -20 °C (for both 24 and 48-hour protocols) were analyzed at the 72-hour mark to determine the optimal storage strategy for maintaining the biological activity of the larval extract.

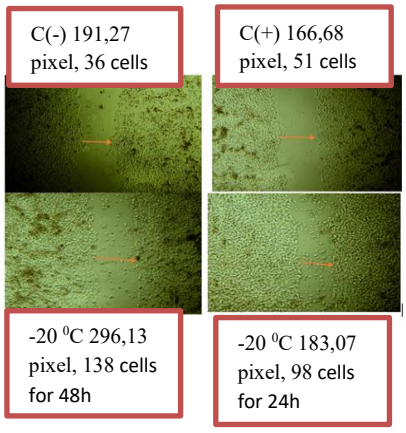


Figure 8: Comparison of fibroblast migration at 72 hours for secretions stored at -20 °C for 24 hours vs. 48 hours, including secretion-treated and untreated control groups.



Figure 9: Comparison of fibroblast migration at 72 hours between cells treated with secretions (stored at -20 °C for 48 hours) and untreated control cells.

Since the group stored at -20 °C demonstrated superior efficacy compared to all other storage conditions, we further investigated whether a 24-hour or 48-hour storage duration at this temperature was more effective (see Figure 9). Our evaluation confirmed that secretions stored at -20 °C for 48 hours provided the most significant enhancement in wound closure and fibroblast migration.

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MEASURING FINANCIAL EFFICIENCY IN THE TURKISH AUTOMOTIVE SECTOR USING DATA ENVELOPMENT ANALYSIS: 2020–2025 PERIOD

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ABSTRACT

The aim of this study is to evaluate the financial efficiency levels of Doğuş Otomotiv, Ford Otosan, Karsan, Otokar, and Tofaş, companies operating in the Turkish automotive sector, using Data Envelopment Analysis (DEA). In the automotive sector, where global competition is intensifying, cost pressures are increasing, and technological transformation processes are accelerating, it is crucial for companies to utilize their resources effectively and efficiently. In this context, the research comparatively examines the relative efficiency performance of firms based on financial data from the 2020–2025 period.

In the study, total assets, operating expenses, and net financial debt were included as inputs; net sales and net profit were included as outputs. The extent to which companies, considered as decision-making units, effectively utilize their existing resources and the level of output they can produce with similar inputs were analyzed using DEA. The analysis identified efficient and inefficient companies, and potential areas for improvement were revealed for companies falling below the efficiency frontier. Furthermore, by evaluating efficient companies as reference units, performance benchmarks for the sector were determined.

The findings of this research are expected to contribute to the evaluation of the financial performance of businesses in the automotive sector, the improvement of resource utilization efficiency, and strategic decision-making processes. In addition, it is believed that the study will provide an academic contribution to current Data Envelopment Analysis (DEA) applications in the Turkish automotive sector.

Keywords: Data Envelopment Analysis, Automotive Industry, Financial Performance, Resource Utilization Efficiency, Turkish Automotive Companies

CHAPTER 1

INTRODUCTION

1.1. Background and Motivation

The automotive sector is one of the strategically important industries in terms of economic growth, industrial production, employment capacity, and export performance of countries. Dynamics such as technological advances, global competitive conditions, sustainable production approaches, and the electric vehicle transition directly affect the operational processes of automotive companies. In this context, the effective and efficient use of available resources by companies is of great importance for ensuring sustainable financial performance.

The Turkish automotive sector holds a significant place in the national economy in terms of production volume, export capacity, and supply chain networks. In recent years, global economic fluctuations, cost pressures, supply chain disruptions, and exchange rate volatility have made the financial structures of companies increasingly important. Therefore, measuring the financial efficiency levels of companies operating in the sector is crucial both for managerial decision-making processes and for resource utilization efficiency.

While various methods are used to evaluate the financial performance of companies, Data Envelopment Analysis (DEA), which allows simultaneous evaluation of multiple inputs and outputs, is one of the most widely preferred methods for efficiency measurement. DEA enables the measurement of the relative efficiency levels of decision-making units operating in similar fields.

The aim of this study is to evaluate the financial efficiency levels of Doğuş Otomotiv, Ford Otosan, Karsan, Otokar, and Tofaş for the 2020–2025 period using Data Envelopment Analysis. The study analyzes the extent to which companies effectively use their financial resources and identifies potential improvement areas for inefficient companies.

1.2. Literature Review

Table 1: Literature Review

AUTHOR	SECTOR	INPUT VARIABLES	OUTPUT VARIABLES	METHOD	EFFICIENT UNITS
Asst. Prof. Dr. İsmail ÇELİK Semra AYAN (2017)	BIST (Stock Exchange)	Asset Turnover Ratio Equity Turnover Ratio Fixed Asset Turnover Ratio Receivables Turnover Ratio Inventory Turnover Ratio Total Assets	Return on Assets Return on Equity Operating Profit Margin Net Sales	Input-oriented CCR Model	119 Companies
Emre Bilgin Sarı (2018)	INDUSTRY	Incentives and Supports Import Ratios	Export Ratio Number of R&D Firms	Data Envelopment Analysis	12 Organized Industrial Zones
M. Emin Baysal Mehmet Uygur Bilal Toklu (2004)	TCDD PORTS	Number of Staff Cargo Handling Capacity	Cargo Handled Annual Revenue	Input & Output-oriented CCR Model	7 Ports
Abdullah Yalama Mustafa Sayım (2008)	MANUFACTURING SECTOR	Current Ratio Financial Leverage Ratio Equity/Total Assets Equity/Total External Resources ST Liabilities/Total Liabilities Fixed Assets/Equity Net Sales/Assets Net Sales/Equity	Return on Equity Return on Assets	Input-oriented Data Envelopment Analysis	15 Companies Listed on IMKB
Ünal H. Özden (2008)	FOUNDATION UNIVERSITIES	Total Expenses Number of Faculty Members Number of Other Academic Staff	Undergraduate & Graduate Student Count Postgraduate Student Count Number of Publications Education & Training Revenues Other Revenues	CCR & BCC Models	25 Foundation Universities in Turkey
Hüseyin Budak (2011)	BANKING SECTOR	Number of Branches Number of Staff Total Interest + Non-interest Expenses	Total Deposits Total Loans Total Interest + Non-interest Income Net Profit	CCR Model	22 Banks in Turkey
Mitra Salimi Altan (2010)	INSURANCE SECTOR	Cash & Cash Equivalents	Receivables from Core Operations	CCR Model	25 Insurance Companies

AUTHOR	SECTOR	INPUT VARIABLES	OUTPUT VARIABLES	METHOD	EFFICIENT UNITS
		Tangible Assets Financial Assets incl. Risk-related Investments Liabilities from Core Operations Insurance Technical Reserves Paid-in Capital	Net Period Profit/Loss		in Turkey
Joaniciusz Nazarko Ewa Chodakowska (2015)	CONSTRUCTION SECTOR	Number of Employed Persons	Turnover Gross Operating Surplus	Data Envelopment Analysis	25 Countries in Europe
Jian Liu Hongfu Liu Xi-Long Yao Yang Liu (2015)	COAL MINING	Number of Employees Capital Stock Energy	Coal Output Wastewater Waste Gas Solid Waste	Data Envelopment Analysis	Shanxi & Inner Mongolia Coal Mines in China
Ke Wang Yi-Ming Wei Zhimin Huang (2017)	ENERGY	Energy Consumption Installed Capacity Employees	Electricity Production	Data Envelopment Analysis	Thermal Power Plants in China
Thakur Prasad Upadhyay Chander Shahi Mathew Leitch Reino Pulkki (2011)	LUMBER INDUSTRY	Materials Labor Energy	Lumber Volume	Data Envelopment Analysis	24 Lumber Mills in Canada
Weidong Chen (1999)	STEEL SECTOR	Number of Employees Fixed Assets Current Resources Cost of Sales Energy Consumption	Crude Steel Output Gross Output Value Revenue Profit	CSR Model	35 Steel Firms in China

CHAPTER 2

MATERIAL AND METHODS

The material of this study consists of financial data belonging to companies operating in the Turkish automotive sector. The decision-making units (DMUs) considered in the research are Doğuş Otomotiv, Ford Otosan, Karsan, Otokar, and Tofaş. Financial statements from the 2020–2025 period were examined and the financial efficiency levels of the companies were comparatively evaluated.

The data used in the research were obtained from independently audited financial statements published by the companies, annual reports, and publicly available financial data sources. Financial indicators commonly used in the literature were taken into account in constructing the dataset.

The input and output variables used in the study were determined as follows:

Input Variables

- Total Assets
- Operating Expenses
- Net Financial Debt

Output Variables

- Net Sales

- Net Period Profit

The selected variables were determined to measure the financial resource utilization efficiency of the companies. Total assets, operating expenses, and net financial debt are considered as inputs representing the resource utilization capacity of companies, while net sales and net period profit are treated as financial performance outputs.

Data Envelopment Analysis (DEA), a non-parametric linear programming-based method, was used to measure financial efficiency. The DEA method measures the relative efficiencies of decision-making units with similar inputs and determines which companies are on the efficiency frontier. The input-oriented CCR model was preferred in this study. With the help of this model, the extent to which input levels can be reduced while maintaining the same level of outputs was evaluated.

2.1 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a linear programming-based method used to measure the relative efficiency of decision-making units when there are multiple input and output variables. The CCR model, first developed by Charnes, Cooper, and Rhodes, performs efficiency measurement under the assumption of constant returns to scale.

The fundamental purpose of DEA is to compare the efficiency levels of decision-making units operating in similar fields and to identify reference units for inefficient entities. In this context, the method contributes to managerial decision-making processes regarding more effective use of resources.

The stages of applying Data Envelopment Analysis are as follows:

- Identification of decision-making units
- Selection of input and output variables
- Ensuring data reliability
- Application of the model
- Evaluation of efficiency results

Table 2: Years

YEARS	CODE
2020	YR
2021	YS
2022	YK
2023	YU
2024	YD
2025	YB

Table 3: Inputs

INPUTS	CODE
TOTAL ASSETS	SN1

INPUTS	CODE
OPERATING EXPENSES	SN2
NET FINANCIAL DEBT	SN3

Table 4: Outputs

OUTPUTS	CODE
NET SALES	SA
NET PERIOD PROFIT	SB

Data Envelopment Analysis (DEA) was used to examine the productivity levels of selected automotive companies in Turkey on a yearly basis. The input variables for the 2020–2025 period include total assets, operating expenses, and net financial debt. The output variables include net sales and net period profit. The LINDO 6.1 software was used for solving the DEA model in this research.

Strengths:

1. DEA creates different pathways to bring the performance of an inefficient decision-making unit to the level of relatively efficient units in its group. Selecting the most appropriate improvement path for the decision-making unit creates alternatives for future options.

2. Applying DEA allows decision-making units to better understand their production processes by identifying all relevant inputs and outputs.

3. A detailed database containing the data required for the DEA study and the analysis results can be created.

4. DEA assumes that input and output data are not produced by a random mechanism—that is, they are deterministic. For this reason, it is used as a non-parametric method that does not assume data follow a specific functional distribution, making it a more advantageous efficiency analysis method for deterministic situations.

5. Since efficiency analysis is performed according to the frontier function formed by the best observations rather than the average function produced by statistical boundary estimation methods, the targets set are based on the best-performing units as benchmarks. This strengthens the meaning and validity of the efficiency analysis performed with DEA.

Weaknesses:

1. Since DEA is generally tested with physical input and output measures, it is limited to technical input–output efficiency. The capabilities of the method can be strengthened by assigning relative prices or priority weights to outputs and inputs (where possible).

2. Qualitative input and output measures can weaken the results. It is vital that the relevant inputs and outputs accurately reflect the production process for the method to yield reliable results. If a critical input or output is excluded from the analysis, the results of the method may be misleading and biased.

3. In DEA, the difference between observed performance and best performance is attributed solely to inefficiency, and measurement errors for extreme observation points are considered insignificant.

4. DEA models are static and evaluated at a single point in time. In practice, since converting some inputs into outputs by decision-making units may take more than one period, the production process has a dynamic character. Therefore, appropriate discount rates must be used for data from different periods.

5. The fact that the superiority of the decision-making units included in the reference group is relative makes it difficult to interpret whether these units are truly efficient when evaluated independently. Therefore, DEA efficiency results should be evaluated within the framework of relativity.

Stages of Applying Data Envelopment Analysis:

- Identification of decision-making units
- Identification of inputs and outputs
- Accessibility and reliability of data
- Evaluation of efficiency results

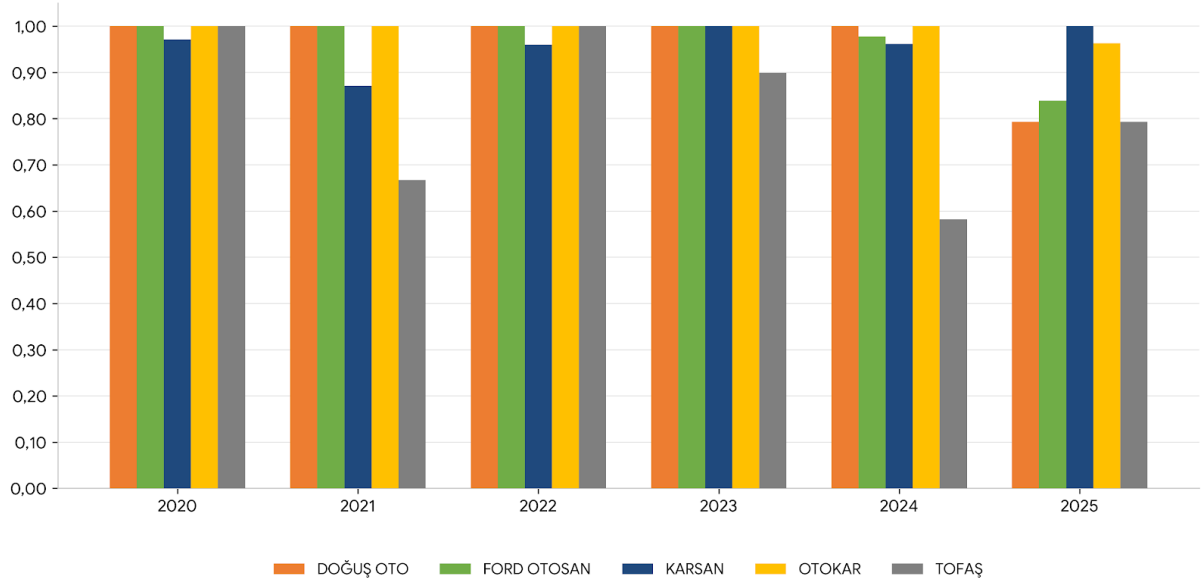
CONCLUSION

In this study, a comparison of the efficiency of automotive companies in Turkey was carried out using DEA and efficiency scores were determined. If input and output criteria are increased, a more reliable DEA study can be conducted. Detailed investigations for improvement efforts in future years can be carried out in line with the determined criteria.

Table 5: Results Table

	DOĞUŞ OTO	FORD OTOSAN	KARSAN	OTOKAR	TOFAŞ
2020	1.000	1.000	0.971	1.000	1.000
2021	1.000	1.000	0.871	1.000	0.667
2022	1.000	1.000	0.960	1.000	1.000
2023	1.000	1.000	1.000	1.000	0.899
2024	1.000	0.978	0.962	1.000	0.582
2025	0.793	0.839	1.000	0.963	0.793

Figure 1: Column Chart of Results



Based on the findings obtained, Otokar and Ford Otosan were observed to be the companies with the most stable efficiency performance throughout the analysis period. In particular, Otokar's maintenance of full efficiency from 2020–2024 and its only limited decline in 2025 demonstrates that the company

uses its resources effectively. Similarly, Ford Otosan achieved full efficiency in most years and experienced only limited efficiency losses in the last two years.

Although Karsan's efficiency performance showed a fluctuating pattern throughout the period, its achievement of full efficiency in 2023 and 2025 is noteworthy. This indicates that the company has shown improvement in resource utilization over time. Doğuş Otomotiv, despite maintaining an efficient performance for many years, experienced a significant decline in its efficiency score in 2025, resulting in a relative productivity loss.

Tofaş was identified as the company with the most variable efficiency performance during the analysis period. Despite reaching full efficiency in some years, the low efficiency scores obtained particularly in 2021 and 2024 indicate that there are areas for improvement in the company's process of converting its existing inputs into outputs.

In general, the decline in efficiency scores observed in most companies in 2025 suggests that cost pressures, economic fluctuations, increased investment expenditures, and operational efficiency factors in the automotive sector may have had an impact on efficiency levels. Accordingly, it is important for companies to optimize their financial resource use, strengthen cost management, and focus on productivity-enhancing strategies.

In 2020, most companies within the scope of the analysis operated at full efficiency. The fact that only Karsan's efficiency score fell below 1 in this year indicates that the company used its existing inputs in output production with lower efficiency compared to other firms. The other companies achieving full efficiency points to a strong performance across the sector.

In 2021, certain differentiations occurred in efficiency performances. Tofaş's efficiency score falling to 0.667 reveals significant relative inefficiency in resource use. The efficiency losses observed in Karsan during the same period also indicate operational and financial efficiency problems for some companies within the sector.

In 2022, most companies returning to or approaching full efficiency levels again indicates that the sector entered a recovery trend. However, Karsan's efficiency score still remained below the full efficiency frontier, showing that the company had not yet fully reached the level of reference companies.

The year 2023 can be considered one of the most successful years in the analysis period. Four of the five companies under review reaching full efficiency demonstrates an increase in resource utilization efficiency across the sector. Tofaş's performance with an efficiency score of 0.899, very close to the full efficiency frontier, also supports the general rise in efficiency this year.

In 2024, efficiency declines in some companies are noteworthy. Tofaş's achievement of 0.582—the lowest efficiency score in the analysis period—shows that the company experienced significant productivity problems in its input-to-output conversion process. The limited declines in Ford Otosan and Karsan also indicate a partial weakening of efficiency levels across the sector.

The year 2025 was a period characterized by a general decline in efficiency levels. Only Karsan achieving full efficiency shows that the other companies experienced relative productivity losses. This suggests that increasing cost pressures, changes in economic conditions, investment expenditures, or differences in operational processes may have had an impact on the efficiency levels of the companies.

The study contributes to the comparative evaluation of the financial efficiency levels of companies operating in the Turkish automotive sector. In future research, incorporating different input and output variables, using different DEA models, and making inter-sector comparisons may provide more comprehensive contributions to the literature.

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EXTRACTIVE POLITICS, INCLUSIVE ECONOMICS: REASSESSING INSTITUTIONAL THEORY THROUGH CHINA

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ABSTRACT

The Institutional theory, particularly the framework of Acemoglu and Robinson, states that long-term economic prosperity could fail to be achieved under extractive institutions, because the prevention of creative destruction and lack of pluralism in the political system would hinder overall innovation. China, however, presents a difficult case for this framework. After the catastrophic outcomes of the Maoist era, including the Great Chinese Famine, Deng Xiaoping's reforms after 1978 introduced the Household Responsibility System and Special Economic Zones, moving China's economic institutions in a more inclusive direction without any major shift in its political structure. Despite keeping extractive political institutions, China sustained an average GDP growth rate of 9 to 10 percent over three decades, thus contradicting the idea that inclusive economic institutions are essential for long-term economic sustainability. While the inclusive/extractive binary offers valuable analytical insights, it cannot fully explain the complexity of China's institutional arrangements. The purpose of this paper is to examine the sustainability of China's economic growth under extractive political institutions by examining the role and effectiveness of its hybrid governance model. By using qualitative methods and economic indicators, this paper aims to support the debate on whether China's long-term success can be achieved via a hybrid governance model. This study concludes that China has not disproven the institutional theory but has shown that binary logic has limits of its own, and much more flexible frameworks should be developed to fully understand hybrid systems and different developmental pathways.

Keywords: Institutional theory, Extractive and Inclusive institutions, Hybrid Governance Model, Chinese Economic Development, Political Economy, Authoritarian Growth.

INTERACTIVE TEACHING AS A TOOL FOR FOSTERING CREATIVE THINKING IN PRIMARY CLASSROOMS

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ABSTRACT

The development of creative thinking is considered one of the main goals of modern primary education. In recent years, interactive teaching methods have become widely used because they encourage students to participate actively in the learning process and express their ideas more freely. This study examines the role of interactive teaching in fostering creative thinking among primary school learners. Special attention is given to methods such as brainstorming, group discussions, role-play activities, educational games, and collaborative learning tasks. Unlike traditional teaching approaches, these methods help students think independently, solve problems creatively, and communicate more effectively with their classmates. Interactive activities also create a more engaging classroom atmosphere that increases students' interest and motivation during lessons.

The findings of the study show that interactive teaching methods positively influence students' imagination, self-confidence, and willingness to learn. Classroom experiences indicate that pupils become more active and productive when they are directly involved in discussions and practical activities. In addition to supporting creative thinking, interactive learning also contributes to the development of communication and teamwork skills. The study concludes that the effective use of interactive teaching methods in primary classrooms can improve both students' creative abilities and the overall quality of the educational process.

Keywords: interactive teaching, creative thinking, primary education, active learning, student-centered learning

INTRODUCTION

The rapid transformation of contemporary society has significantly influenced educational priorities around the world. Schools are no longer expected to focus solely on the transmission of factual knowledge. So, they are also responsible for developing the skills that enable learners to adapt to changing circumstances, solve problems effectively, and think independently. Among these skills, creative thinking has become one of the most important competencies for students in the twenty-first century (Mangion and Vella, 2023). Creativity supports innovation, encourages flexibility in thinking, and helps individuals generate original ideas when faced with new situations. For this reason, fostering creative thinking has become an essential objective of modern educational practice, particularly during the primary school years when the foundations of cognitive development are being established.

Primary school students possess a natural curiosity about the world around them. They are eager to ask questions, explore unfamiliar concepts, and express their thoughts in unique ways. However, the extent to which these abilities develop depends largely on the learning environment created by teachers (Hopfenbeck et al., 2022). Traditional forms of instruction, which often rely heavily on explanation, memorization, and repetition, may not always provide sufficient opportunities for students to think creatively or participate actively in classroom activities. As educational approaches continue to evolve, increasing attention has been given to teaching methods that encourage students to become active participants in their own learning.

Interactive teaching has emerged as one of the most effective approaches for achieving this goal. Unlike teacher-centred instruction, interactive teaching places students at the centre of the learning process and encourages them to engage directly with educational content, their classmates, and their teachers. Learning becomes a dynamic process in which students are encouraged to discuss ideas, share experiences, ask questions, and work collaboratively to solve problems. Such interactions create opportunities for learners to develop independent opinions and construct knowledge through meaningful participation rather than passive observation (Schiccatano, 2025).

The relationship between interactive teaching and creative thinking is particularly important in primary education. Creative thinking develops most effectively when students are given opportunities to experiment with ideas, explore alternative solutions, and express themselves freely. Interactive classroom activities provide precisely these opportunities by encouraging participation, communication, and reflection. Methods such as brainstorming, educational games, role-playing activities, group discussions, and collaborative projects allow children to approach learning tasks from different perspectives while simultaneously strengthening their imagination and problem-solving abilities (OECD, 2023).

Brainstorming activities, for example, encourage students to generate multiple ideas without fear of making mistakes. This process helps children develop fluency and flexibility in thinking while increasing their confidence in expressing original opinions. Group discussions provide opportunities for learners to listen to different viewpoints, justify their own ideas, and engage in constructive dialogue (Maor et al., 2025). Through these interactions, students learn to evaluate information critically and develop a deeper understanding of the topics being studied.

Similarly, role-play activities allow learners to explore real-life situations through imagination and creative expression. By assuming different roles and perspectives, students develop empathy, communication skills, and the ability to think beyond conventional solutions. Educational games contribute to creativity by combining learning with enjoyment and active participation. When students are engaged in game-based learning environments, they often demonstrate greater motivation and a stronger willingness to experiment with new ideas. Collaborative learning tasks further support creative development by encouraging cooperation, teamwork, and the exchange of diverse perspectives among classmates.

Numerous educational studies have highlighted the positive effects of interactive teaching methods on student achievement and engagement. Researchers have found that students who participate actively in classroom activities are more likely to demonstrate higher levels of motivation, self-confidence, and creative performance (Smare and Elfatihi, 2023). Interactive learning environments not only increase academic involvement but also create conditions in which students feel comfortable sharing ideas and taking intellectual risks. Such experiences are particularly valuable in primary classrooms, where positive learning habits and attitudes toward education begin to develop.

Despite the growing recognition of interactive teaching, its implementation remains inconsistent across different educational settings. Some classrooms continue to rely primarily on traditional instructional approaches, limiting opportunities for students to engage actively in the learning process. In addition, factors such as limited classroom resources, large class sizes, and insufficient teacher training may affect the effective use of interactive methods (Craft, 2003). Therefore, examining the educational value of interactive teaching remains an important area of research.

The purpose of this study is to explore how interactive teaching contributes to the development of creative thinking among primary school students. Particular attention is given to the role of brainstorming, discussions, educational games, role-play activities, and collaborative learning tasks in promoting creativity within the classroom. By analysing the educational benefits of these methods, the study aims to demonstrate how interactive teaching can create more engaging learning environments and support the intellectual and personal development of young learners.

MATERIALS AND METHODS

This study was conducted as a theoretical and descriptive research focusing on the relationship between interactive teaching methods and the development of creative thinking in primary education. Rather than collecting empirical data from a particular group of students, the study draws upon existing educational literature, contemporary pedagogical theories, and research findings related to creativity and interactive learning. The purpose of this approach was to examine how interactive teaching practices contribute to the formation of creative thinking skills among young learners and to identify the educational conditions that support this process.

The research is based on a review and analysis of academic publications addressing creativity in education, student-centred learning, active learning strategies, and classroom interaction. Books, peer-reviewed journal articles, conference papers, and educational reports published in recent years were examined in order to obtain a comprehensive understanding of the topic. Particular attention was given to studies investigating the use of brainstorming, group discussions, educational games, role-play activities, and collaborative learning tasks in primary school settings. These methods were selected because they are among the most frequently used interactive teaching practices and are commonly associated with the development of higher-order thinking skills.

A qualitative analytical approach was employed throughout the study. The collected literature was reviewed systematically to identify recurring themes, common findings, and theoretical perspectives concerning the role of interactive learning in fostering creativity. Similarities and differences among various educational approaches were examined, allowing for a broader understanding of how interactive teaching influences students' cognitive development. The analysis also considered the characteristics of primary school learners, including their developmental needs, learning preferences, and natural inclination toward exploration and imaginative activity.

In addition to reviewing existing research, the study incorporates conceptual analysis of key educational notions related to creativity and interaction. The concept of creative thinking was explored from both psychological and pedagogical perspectives, while interactive teaching was examined as a learner-centred approach that promotes active participation and knowledge construction. This conceptual framework made it possible to analyse the educational value of interactive methods beyond their immediate classroom applications and to consider their broader contribution to children's intellectual growth.

The interpretation of the findings was guided by contemporary educational theories that emphasize active learning, social interaction, and learner engagement. Constructivist perspectives were particularly relevant, as they view learning as a process in which knowledge is built through experience, communication, and reflection. Such theoretical foundations provide a useful framework for understanding why interactive teaching methods often create favourable conditions for the development of creative thinking.

Through the synthesis of theoretical knowledge and research evidence, the study seeks to provide a comprehensive overview of the educational potential of interactive teaching in primary classrooms. The selected methodology allows for an in-depth examination of the topic and supports the formulation of conclusions regarding the role of interactive learning environments in fostering creativity among young learners.

RESULTS

The analysis of the reviewed literature demonstrates that interactive teaching methods play a significant role in supporting the development of creative thinking among primary school students (Veliu and Hoxha, 2023). Across different educational contexts, researchers consistently emphasize that creativity develops more effectively in learning environments where students are encouraged to participate actively, share ideas, and engage in meaningful interaction. Unlike traditional instructional approaches that often prioritize the reproduction of information, interactive teaching creates opportunities for learners to explore concepts independently and construct their own understanding through experience (OECD, 2024).

One of the most frequently highlighted findings in the literature concerns the positive relationship between classroom participation and creative expression. Studies indicate that students who are actively involved in discussions, collaborative activities, and problem-solving tasks tend to demonstrate greater flexibility in their thinking and a stronger willingness to express original ideas (Egan, 2005). Interactive classroom environments encourage learners to contribute without excessive concern about making mistakes, which helps create a sense of psychological safety that is essential for creativity. When students feel that their opinions are valued and respected, they become more confident in presenting unique perspectives and experimenting with new solutions.

The analysis also reveals that brainstorming activities contribute significantly to the development of creative thinking skills. Educational researchers frequently describe brainstorming as an effective strategy for generating multiple ideas within a short period of time. In primary classrooms, this method encourages students to move beyond conventional responses and consider alternative possibilities (Rosen and Tager, 2020). By focusing on idea generation rather than immediate evaluation, brainstorming allows children to use their imagination more freely and develop greater cognitive flexibility. The reviewed studies suggest that regular participation in such activities can gradually strengthen students' ability to approach problems creatively and think from different perspectives.

Another important finding relates to the educational value of role-play activities. The literature indicates that role-playing provides opportunities for students to engage with learning content in a more personal and imaginative manner. Through assuming different characters and situations, children are encouraged to explore various viewpoints, make decisions, and respond to challenges in creative ways. Researchers note that these experiences often promote both creativity and empathy, as students learn to understand situations from perspectives other than their own. In primary education, role-play activities appear particularly effective because they correspond closely with children's natural inclination toward imaginative play (Munro, 2020).

The reviewed sources further demonstrate that educational games can make a meaningful contribution to creative development. Learning activities that incorporate elements of play tend to increase student motivation and engagement while creating opportunities for experimentation and exploration. Educational games often require learners to make decisions, develop strategies, and adapt their thinking in response to changing situations. Such experiences stimulate curiosity and encourage students to search for original solutions. The literature suggests that when games are carefully integrated into instructional practice, they can support both academic learning and the development of creative thinking skills (OECD, 2023).

Collaborative learning emerges as another significant factor influencing creativity in primary classrooms. The analysis indicates that group-based activities provide learners with opportunities to exchange ideas, negotiate meanings, and build upon the contributions of their peers. Through interaction with classmates, students become exposed to different perspectives and alternative approaches to solving problems. This process broadens their thinking and encourages intellectual flexibility. Researchers frequently emphasize that creativity is not solely an individual characteristic but can also develop through social interaction and collective learning experiences.

The findings additionally suggest that interactive teaching methods contribute to the development of several complementary skills that support creative thinking. Communication, self-confidence, cooperation, and independent learning are among the competencies most frequently associated with interactive classroom practices (Veliu and Hoxha, 2023). Students who regularly participate in discussions, collaborative tasks, and practical activities often demonstrate greater confidence in expressing their thoughts and defending their ideas. These qualities create favourable conditions for creativity because they encourage learners to take intellectual risks and engage more actively with learning challenges.

The literature also highlights the role of teachers in creating environments that nurture creativity through interaction. Effective implementation of interactive teaching methods depends not only on the activities themselves but also on the teacher's ability to facilitate discussion, encourage participation, and provide constructive feedback. Studies indicate that teachers who adopt supportive and flexible instructional

approaches are more likely to create classroom climates in which creativity can flourish. Such environments encourage students to view learning as a process of exploration rather than simply the acquisition of correct answers (Smare and Elfatihi, 2023).

Overall, the reviewed research provides substantial evidence that interactive teaching methods have a positive influence on the development of creative thinking in primary education. Although different methods contribute in different ways, they share a common characteristic: they actively involve students in the learning process and encourage them to think, communicate, and explore beyond the boundaries of traditional instruction. The findings suggest that classrooms characterized by interaction, collaboration, and active participation offer particularly favourable conditions for fostering creativity among young learners.

DISCUSSION

The findings of this study support the widely accepted view that interactive teaching methods can make a meaningful contribution to the development of creative thinking in primary education. The reviewed literature suggests that creativity is more likely to flourish in classrooms where students are encouraged to participate actively, exchange ideas, and engage in collaborative learning experiences. Although creativity is often associated with individual talent or personal characteristics, the findings indicate that the classroom environment also plays a crucial role in shaping students' creative potential. When children are given opportunities to express their thoughts freely and explore different perspectives, they become more willing to experiment with ideas and develop original responses to learning tasks.

One of the most significant observations emerging from the analysis is the importance of active participation in the learning process. Traditional teaching approaches often position students as recipients of information, while interactive methods encourage them to become active contributors to classroom learning. This shift appears particularly important for the development of creative thinking because creativity requires learners to engage with knowledge rather than simply reproduce it (Craft, 2003). Students who participate in discussions, collaborative activities, and problem-solving tasks are more likely to analyse information, question assumptions, and generate alternative viewpoints. These experiences help create learning habits that extend beyond academic achievement and contribute to lifelong intellectual development.

The findings also highlight the educational value of learning environments in which mistakes are viewed as a natural part of the learning process. Creativity often involves experimentation and the exploration of unfamiliar ideas. If students are afraid of giving incorrect answers, they may become reluctant to share their thoughts or propose unconventional solutions. Interactive teaching methods can help reduce this concern by creating a classroom culture that values participation and exploration. In such environments, students are encouraged to express themselves without excessive fear of criticism, which contributes to greater confidence and intellectual independence (Hopfenbeck et al., 2022).

Another noteworthy aspect concerns the social dimension of creativity. The reviewed studies demonstrate that creative thinking does not develop exclusively through individual work. Interaction with peers provides learners with opportunities to encounter different perspectives and reconsider their own ideas. Collaborative learning activities encourage students to listen, negotiate, and build upon the contributions of others. As a result, creativity emerges not only from personal reflection but also from meaningful social engagement. This observation is particularly relevant in primary education, where communication and cooperation are essential components of children's overall development.

The analysis further suggests that interactive teaching methods contribute to a broader range of educational outcomes beyond creativity itself. Skills such as communication, teamwork, self-confidence, and independent learning frequently appear alongside creative development in the literature (Munro, 2020). This relationship is not surprising, as many interactive activities require students to articulate their ideas, defend their opinions, and work together toward common goals. Such experiences help learners become more active participants in their own education while simultaneously strengthening their creative capacities.

It is also important to recognize that the effectiveness of interactive teaching depends largely on the teacher's role in the classroom. Simply introducing group work or classroom discussions does not automatically result in meaningful learning experiences. Teachers must carefully plan activities, provide appropriate guidance, and create conditions that encourage equal participation. The literature consistently emphasizes that successful interactive learning requires thoughtful facilitation and a supportive classroom atmosphere. When these conditions are present, interactive methods can become powerful tools for fostering creativity and student engagement.

Despite the positive findings identified in the literature, several challenges remain. In some educational settings, teachers may face limitations related to curriculum requirements, classroom size, or the availability of instructional resources. Time constraints can also make it difficult to organize interactive activities on a regular basis. Furthermore, some educators may feel more comfortable using traditional instructional approaches, particularly if they have received limited training in interactive teaching methods. These factors suggest that the successful implementation of interactive learning requires not only teacher commitment but also institutional support and professional development opportunities.

Overall, the findings reinforce the idea that creativity should be viewed as an educational objective that can be actively supported through appropriate teaching practices. Interactive teaching methods provide valuable opportunities for students to participate, communicate, imagine, and explore. By creating learning environments that encourage curiosity and independent thought, teachers can help primary school students develop the creative skills needed to respond effectively to future academic and social challenges. In this sense, interactive teaching represents not merely a collection of classroom techniques but a broader educational approach that places students' active involvement and creative growth at the centre of the learning process.

CONCLUSION

The development of creative thinking has become one of the key priorities of contemporary primary education. In an era characterized by rapid social and technological change, students need not only academic knowledge but also the ability to think independently, solve problems creatively, and adapt to new situations. For this reason, educational approaches that actively involve learners in the learning process have gained increasing importance. The findings of this study indicate that interactive teaching methods can play a significant role in supporting these objectives and creating conditions that encourage the development of creativity in primary classrooms.

The analysis of the literature demonstrates that interactive teaching provides students with opportunities to participate actively in classroom activities, express their ideas openly, and engage in meaningful communication with their peers and teachers. Methods such as brainstorming, group discussions, role-play activities, educational games, and collaborative learning tasks create learning environments in which students are encouraged to explore different perspectives and generate original ideas. These experiences contribute not only to the development of creative thinking but also to the improvement of communication skills, self-confidence, cooperation, and learner motivation.

The study also highlights the importance of the teacher's role in fostering creativity through interactive learning. The effectiveness of interactive teaching depends largely on the ability of teachers to create supportive classroom environments where students feel comfortable expressing their opinions and experimenting with new ideas. When learning activities are carefully planned and adapted to students' developmental needs, interactive methods can transform the classroom into a space that promotes curiosity, imagination, and active engagement.

Based on the findings, it can be concluded that interactive teaching should be considered an essential component of effective primary education rather than an occasional instructional strategy. Schools and educators should be encouraged to integrate interactive methods more systematically into everyday classroom practice. Providing teachers with professional development opportunities and access to appropriate educational resources may further enhance the successful implementation of these approaches.

In conclusion, interactive teaching offers valuable opportunities for fostering creative thinking among primary school students. By creating learning experiences that encourage participation, exploration, and collaboration, teachers can help young learners develop the creative competencies required for both academic success and lifelong learning. Future research may further examine the practical implementation of interactive teaching methods in different educational contexts and explore their long-term impact on students' creative development.

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BARRIERS TO DENTAL CARE ACCESS IN PRESCHOOL CHILDREN WITH AUTISM SPECTRUM DISORDER

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ABSTRACT

Children with autism spectrum disorder (ASD) often face difficulties in accessing dental care due to behavioral and sensory challenges. Evidence from Southeast Europe remains limited, particularly regarding dental service utilization in early childhood.

A cross-sectional study included preschool children aged 4–6 years with ASD and typically developing children. Data were collected using structured caregiver-reported questionnaires on dental attendance and access-related challenges. Group differences were analyzed using appropriate statistical tests, with significance set at $p < 0.05$.

Children with ASD showed significantly reduced dental service utilization compared to controls. Dental visits within the previous 12 months differed significantly between groups ($p = 0.003$), with more children with ASD having never visited a dentist (37.8% vs. 8.9%). Reasons for the last dental visit also differed significantly ($p < 0.001$), with children with ASD more often attending due to pain or not attending at all, while routine check-ups were more common among controls.

Caregivers reported substantial barriers, particularly behavioral and sensory difficulties during dental visits ($p < 0.001$). Children with ASD also showed lower daily oral hygiene frequency ($p = 0.035$).

Preschool children with ASD face significant barriers to dental care, resulting in fewer preventive visits and greater reliance on symptom-driven treatment. These findings highlight the need for adapted, child-centered dental services and targeted caregiver support.

Keywords: Autism spectrum disorder; dental visits; pediatric dentistry.

THE IMPORTANCE OF PHYSICS PROBLEMS SOLVED USING MATHEMATICAL METHODS IN SECONDARY EDUCATION

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ABSTRACT

This study examines the importance of integrating mathematical methods into physics problem-solving in secondary education and their impact on students' academic development. The research is based on a questionnaire conducted with students enrolled in various university study programs that include physics-related courses. The study aims to investigate students' perceptions regarding the role of mathematics in understanding physics concepts, developing analytical thinking, and improving problem-solving abilities. The questionnaire includes ten structured questions focusing on the frequency and effectiveness of mathematical approaches in physics instruction, students' confidence in applying mathematical tools, the challenges encountered during problem-solving, and possible improvements in teaching practices. The collected data provide insights into how secondary education prepares students for university-level physics studies and how mathematical reasoning contributes to conceptual understanding in physics.

The findings are expected to highlight the strong relationship between mathematics and physics education and to emphasize the need for greater integration of mathematical methods in secondary school physics instruction. The study may contribute to improving educational practices by encouraging teaching strategies that strengthen students' analytical and logical thinking skills while enhancing their ability to apply physical laws through mathematical reasoning.

Keywords: Physics education, mathematical methods, physics problem-solving, secondary education, mathematics in physics, teaching practices.

1. INTRODUCTION

The transition from secondary education to university-level STEM programs is often associated with significant challenges, particularly in mathematics and physics courses. Many first-year students experience difficulties in understanding physical concepts and applying mathematical reasoning to solve scientific problems. These challenges are closely connected to the level of preparation acquired during upper secondary education, where mathematics and physics form the foundation of scientific learning.

Physics is inherently linked to mathematics, since mathematical methods provide the language and tools necessary for describing, analyzing, and interpreting physical phenomena. In secondary education, the use of mathematical methods in physics problem-solving helps students develop analytical thinking, logical reasoning, and quantitative skills. Moreover, integrating mathematics into physics instruction enables students to connect abstract mathematical concepts with real-world applications, thereby improving conceptual understanding and problem-solving abilities.

In recent years, rapid technological development and the increasing complexity of STEM disciplines have intensified the demands of university curricula. As a result, students are expected to possess stronger mathematical competencies and greater ability to apply mathematical techniques in physics-related contexts. Insufficient preparation in these areas often becomes a major obstacle for students pursuing higher education in STEM fields.

Within this context, this study examines the importance of mathematical methods in solving physics problems during secondary education and their contribution to students' preparation for university-level STEM studies. The research focuses on students' perceptions and experiences regarding the role of mathematics in physics learning and its impact on their academic readiness and conceptual understanding.

Previous research has examined how students employ mathematical tools in advanced physics problem-solving and the obstacles they encounter when linking formal mathematical procedures with physical interpretation. These investigations underline the importance of analyzing both students' reasoning patterns and the barriers that limit the effective application of mathematics in physics contexts (Caballero et al., 2014).

Several studies have highlighted the close connection between mathematical competence and students' achievement as well as conceptual development in physics courses. Findings indicate that proficiency in mathematics can strongly affect learning outcomes and support the formation of physics concepts through instruction (Meltzer, 2002).

Within this context, mathematics in physics has been described as a particular mode of thinking in which symbolic representations and conceptual meaning are deeply intertwined. Difficulties in solving physics problems frequently emerge from discrepancies between students' interpretation of mathematical expressions and their intended use in instructional settings (Redish, 2005).

A related perspective emphasizes that interpreting physics equations extends beyond the mechanical application of formulas and requires meaningful conceptual analysis of mathematical representations. Effective learning in physics therefore depends on students' capacity to relate symbolic structures to the corresponding physical principles and interpretations (Sherin, 2001).

In addition, differences in students' success in physics problem-solving have been associated with the ways knowledge is structured and utilized during learning activities. The findings indicate that learners often depend on particular reasoning approaches, which shape their ability to integrate mathematical operations with conceptual understanding in physics (Tuminaro and Redish, 2007).

Building on these studies, the present research examines the role of mathematical methods in physics problem-solving within secondary education and their influence on students' later academic development. By analyzing students' perceptions through a structured questionnaire, this study aims to explore how mathematical reasoning supports conceptual understanding, analytical thinking, and problem-solving abilities in physics. The study is also motivated by previous findings emphasizing the close connection between mathematics and physics learning, the importance of conceptual interpretation of equations, and the challenges students face when applying mathematical knowledge in physics contexts.

The findings are expected to provide insights into students' confidence, difficulties, and experiences related to the use of mathematics in physics courses, while also contributing to discussions on improving teaching practices and strengthening interdisciplinary learning approaches in physics education.

2. MATERIALS AND METHODS

This study adopts a quantitative research approach to investigate students' perceptions regarding the importance of mathematical methods in solving physics problems during secondary education. The research is based on a survey methodology, which enables the systematic collection and statistical analysis of data from a relatively large sample of respondents. The quantitative design was chosen as it allows for the identification of trends, patterns, and relationships in students' perceptions concerning the integration of mathematics in physics education.

Data were collected through a structured questionnaire administered to 300 university students enrolled in STEM-related study programs. The participants were drawn from both Albanian and international universities. Although the respondents are currently studying in different higher education institutions, all of them share a common academic background, as they completed their secondary education within the Albanian education system. This criterion ensures comparability in terms of prior exposure to mathematics and physics instruction at the secondary level.

The target population consisted of students from disciplines such as Physics, Mathematics, Mathematics–Physics, Engineering, Informatics, Computer Science, Information Technology, Data Science, and other STEM-related fields. These students were considered particularly suitable for the study, as they are able to critically reflect on the effectiveness of mathematical preparation received during secondary education and evaluate its relevance to university-level physics courses.

The questionnaire was designed to explore students' experiences and perceptions regarding the role of mathematical problem-solving in physics learning during secondary education. It specifically investigates how mathematical methods contribute to conceptual understanding, analytical thinking, problem-solving skills, and the ability to apply physical laws through mathematical reasoning. The instrument also examines the perceived adequacy of teaching practices and the challenges students encountered when using mathematical approaches in physics.

The questionnaire is structured into two main sections. The first section gathers basic demographic and academic information, including the university affiliation and the study program of the respondents, allowing for classification and comparison across different academic backgrounds.

The second section consists of ten items focusing on students' perceptions of mathematical methods in physics education. The questions address key dimensions such as the perceived importance and frequency of mathematical integration in physics instruction, the contribution of mathematical problem-solving to conceptual understanding, students' confidence in applying mathematical tools, the development of specific skills, the adequacy of difficulty level, and the main challenges encountered. Additionally, the questionnaire explores students' views on the relationship between theoretical physics and real-world phenomena, the need for increased emphasis on mathematical approaches, and suggestions for improving teaching practices.

The questionnaire includes a combination of five-point Likert scale items, multiple-choice questions, and one open-ended question. The Likert-scale items allow respondents to express degrees of agreement, importance, frequency, or confidence, providing structured data suitable for quantitative analysis. The multiple-choice questions are used to identify dominant skills developed and main challenges faced, while the open-ended question enables participants to provide qualitative insights and recommendations for improving the teaching of physics through mathematical methods.

Data analysis was conducted using descriptive statistical techniques. Frequencies and percentages were calculated for each response category, and results were presented in tables and graphical representations to facilitate interpretation. The analysis focused on identifying overall trends in students' perceptions and evaluating the extent to which secondary education prepared them for the mathematical demands of university-level physics. The findings of this study are expected to provide valuable evidence on the effectiveness of integrating mathematical methods in physics instruction at the secondary level. Moreover, the results may contribute to improving teaching practices by strengthening the relationship between mathematics and physics in secondary education, thereby enhancing students' readiness for STEM studies at the tertiary level.

3. RESULTS AND CONCLUSION

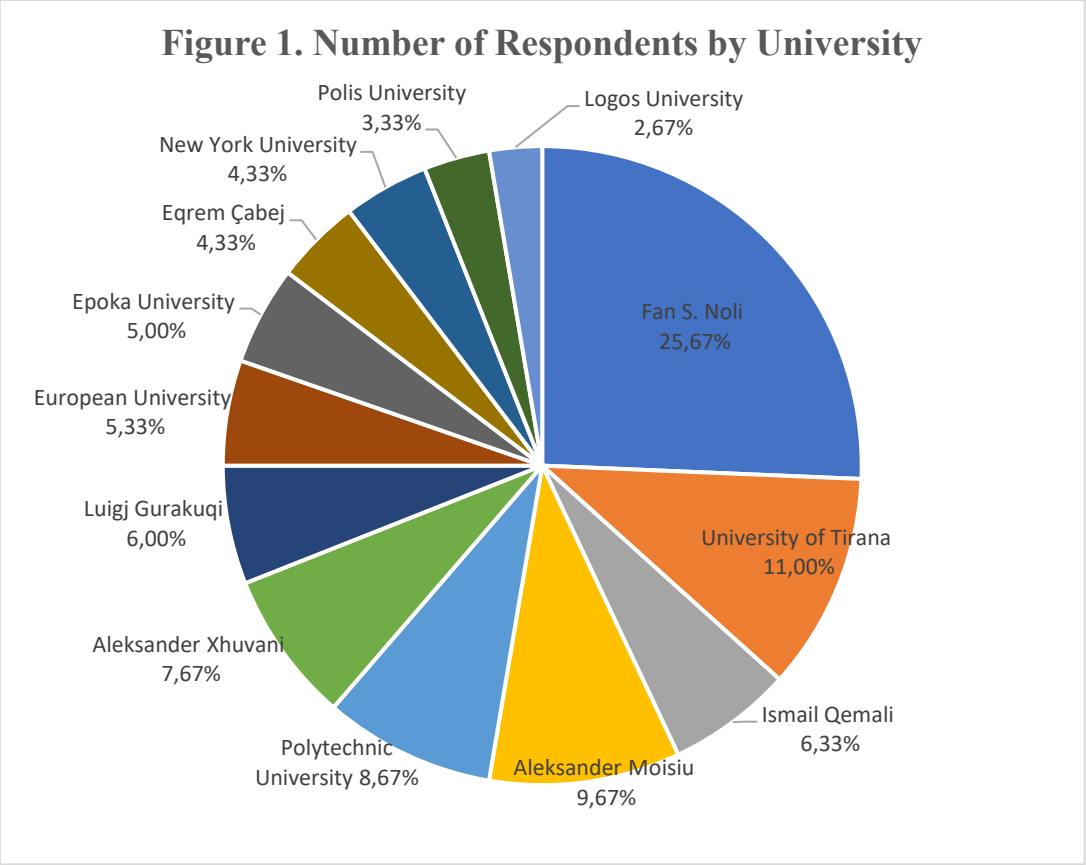
Table 1 and Figure 1 present the distribution of the 300 respondents according to their university affiliation. The largest proportion of respondents comes from Fan S. Noli University with 77 students (25.67%), followed by the University of Tirana with 33 students (11.00%), Aleksander Moisiu University with 29 students (9.67%), and the Polytechnic University with 26 students (8.67%). A notable proportion of participants also come from Aleksander Xhuvani University (7.67%) and Ismail Qemali University (6.33%).

The remaining respondents are distributed among several other universities, including Luigj Gurakuqi University, European University, Epoka University, Eqrem Çabej University, New York University, Polis University, and Logos University College, each contributing between 2.67% and 6.00% of the total sample. The lowest representation is observed for Logos University College with 8 respondents (2.67%).

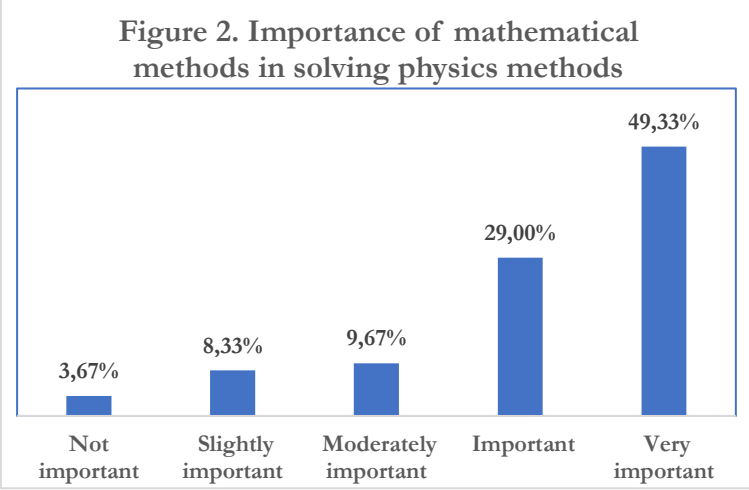
Overall, the data show that the sample includes students from a wide range of universities and academic environments, providing a diverse basis for examining perceptions regarding the role of mathematical methods in physics problem-solving during secondary education.

Table 1. Distribution of respondents by university

University	Number of respondents	Percentage (%)
Fan S. Noli University	77	25.67
University of Tirana	33	11.00
Ismail Qemali University	19	6.33
Aleksander Moisiu University	29	9.67
Polytechnic University	26	8.67
Aleksander Xhuvani University	23	7.67
Luigj Gurakuqi University	18	6.00
European University	16	5.33
Epoka University	15	5.00
Eqrem Çabej University	13	4.33
New York University	13	4.33
Polis University	10	3.33
Logos University College	8	2.67
Total	**300**	**100**



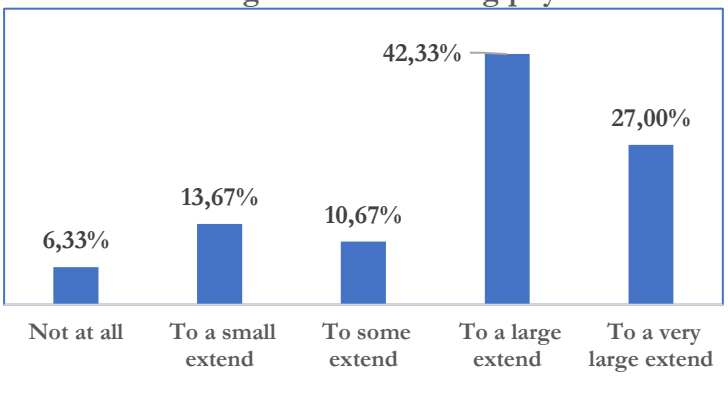
● For the first questionnaire item, students were asked to evaluate the importance of integrating mathematical methods in solving physics problems at the secondary education level. The responses were distributed as follows: Not important (11 students, 3.67%), Slightly important (25 students, 8.33%), Moderately important (29 students, 9.67%), Important (87 students, 29.00%), and Very important (148 students, 49.33%). The distribution of responses is presented in Figure 2.



The results indicate that students largely recognize the importance of mathematical methods in physics problem-solving. More than three-quarters of the respondents (78.33%) considered their integration to be either important or very important, while only 12.00% viewed them as not important or slightly important. A further 9.67% expressed a moderate evaluation. These findings suggest that students perceive mathematical reasoning as a fundamental component of physics learning and acknowledge its contribution to understanding physical concepts and solving physics-related problems.

● For the second questionnaire item, students were asked to evaluate the extent to which mathematical problem-solving in secondary school contributed to their understanding of physics concepts. The responses were distributed as follows: Not at all (19 students, 6.33%), To a small extent (41 students, 13.67%), To some extent (32 students, 10.67%), To a large extent (127 students, 42.33%), and To a very large extent (81 students, 27.00%). The distribution of responses is presented in Figure 3.

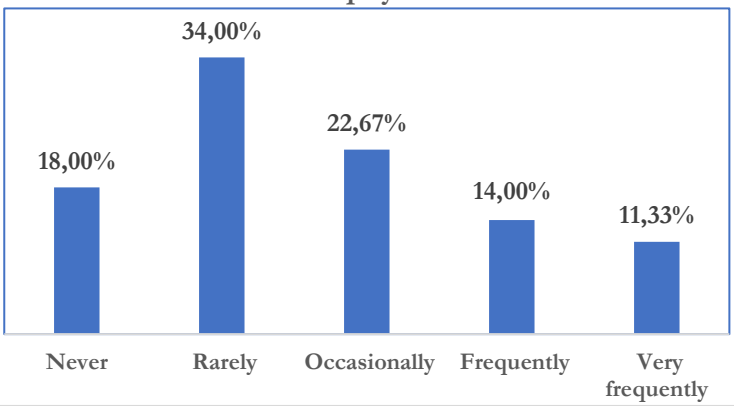
Figure 3. Contribution of math. problem-solving to understanding physics



The results indicate that mathematical problem-solving played a significant role in enhancing students' understanding of physics concepts. A total of 69.33% of respondents reported that it contributed to a large extent or to a very large extent, while only 20.00% perceived its contribution as not at all or to a small extent. Additionally, 10.67% of the students considered its contribution to be moderate. These findings suggest that mathematical methods are widely perceived as an important tool for improving conceptual understanding in physics and for supporting students' ability to interpret and apply physical principles effectively.

● For the third questionnaire item, students were asked to indicate how frequently mathematical methods were emphasized in physics instruction during their secondary education. The responses were distributed as follows: Never (18.00%), Rarely (34.00%), Occasionally (22.67%), Frequently (14.00%), and Very frequently (11.33%). The distribution of responses is presented in Figure 4.

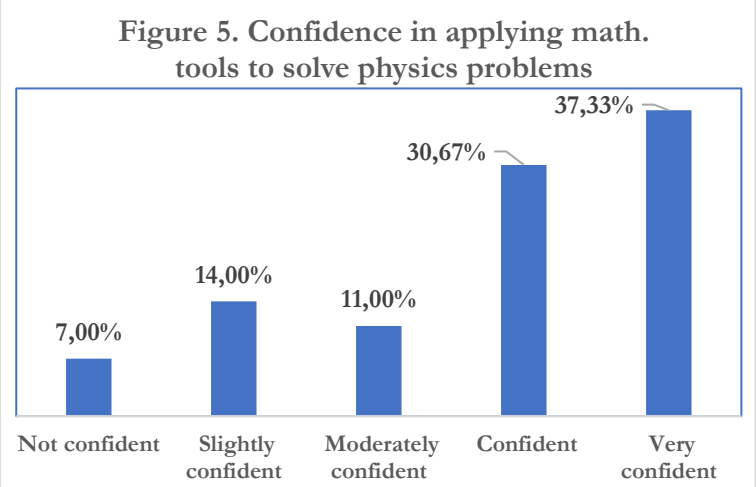
Figure 4. Frequency of emphasis on math. methods in physics instruction



The results indicate that mathematical methods were not consistently emphasized in physics instruction at the secondary education level. The largest proportion of respondents (34.00%) reported that such methods were used rarely, followed by 22.67% who indicated that they were used occasionally. Meanwhile, 25.33% of students stated that mathematical methods were emphasized frequently or very frequently, whereas a relatively large share of respondents (18.00%) reported that they were never emphasized.

These findings suggest that, although mathematical approaches are recognized as important in physics learning, their implementation in secondary education is perceived as uneven and often limited. This points to a need for more systematic and consistent integration of mathematical methods in physics instruction to better support students' conceptual understanding and problem-solving development.

● For the fourth questionnaire item, students were asked to assess their confidence in applying mathematical tools to solve physics problems acquired from secondary education. The responses were distributed as follows: Not confident (7.00%), Slightly confident (14.00%), Moderately confident (11.00%), Confident (30.67%), and Very confident (37.33%). The distribution of responses is presented in Figure 5.



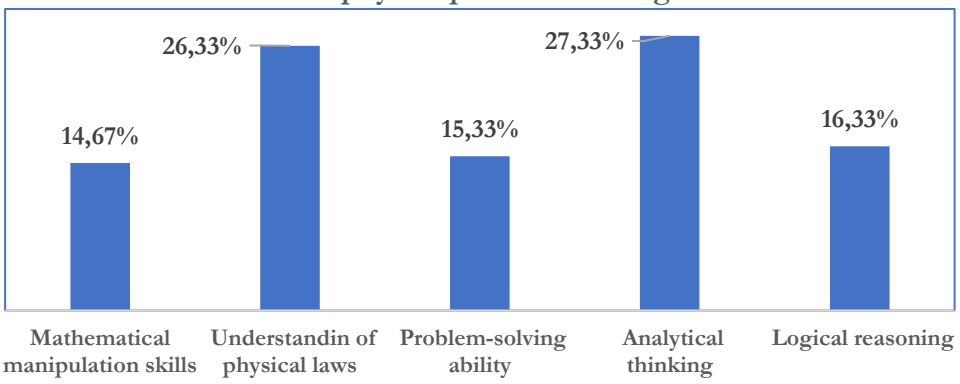
The results indicate that the majority of students report a high level of confidence in applying mathematical tools to physics problem-solving. In total, 68.00% of respondents stated that they are confident or very confident in using these methods, while only 7.00% reported that they are not confident. A smaller proportion of students indicated slight or moderate confidence, accounting for 25.00% of the responses.

These findings suggest that secondary education has generally contributed to developing students' confidence in applying mathematical approaches to physics problems, although a minority of students may still require additional support to strengthen their competence and self-assurance in this area.

● For the fifth questionnaire item, students were asked to identify the skill most developed through mathematical physics problem-solving during secondary education. The responses were distributed as follows: Mathematical manipulation skills (14.67%), Understanding physical laws (26.33%), Problem-solving ability (15.33%), Analytical thinking (27.33%), and Logical reasoning (16.33%). The distribution of responses is presented in Figure 6.

The results indicate that analytical thinking was reported as the most developed skill, with 27.33% of respondents selecting it, closely followed by understanding physical laws at 26.33%. Logical reasoning accounted for 16.33% of responses, while problem-solving ability and mathematical manipulation skills were selected by 15.33% and 14.67% of respondents, respectively.

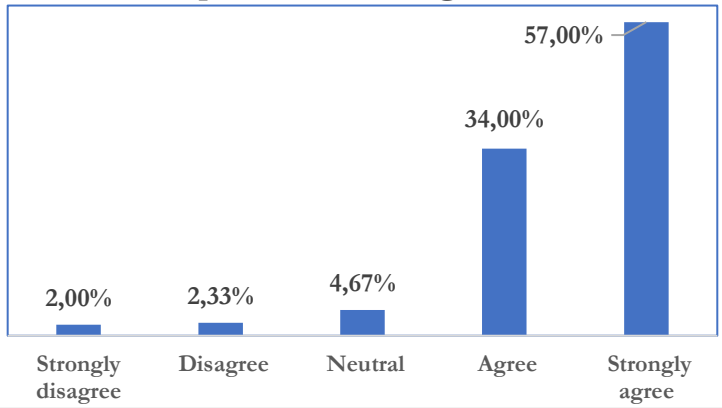
Figure 6. Skills most developed through mathematical physics problem-solving



These findings suggest that mathematical physics problem-solving in secondary education contributes primarily to the development of higher-order cognitive skills, particularly analytical thinking and conceptual understanding of physical laws, while also supporting the development of other complementary skills such as logical reasoning and mathematical manipulation.

● For the sixth questionnaire item, students were asked whether mathematical approaches in physics improved their ability to connect theory with real-world phenomena. The responses were distributed as follows: Strongly disagree (2.00%), Disagree (2.33%), Neutral (4.67%), Agree (34.00%), and Strongly agree (57.00%). The distribution of responses is presented in Figure 7.

Figure 7. Linking physics theory to real-world phenomena through mathematics

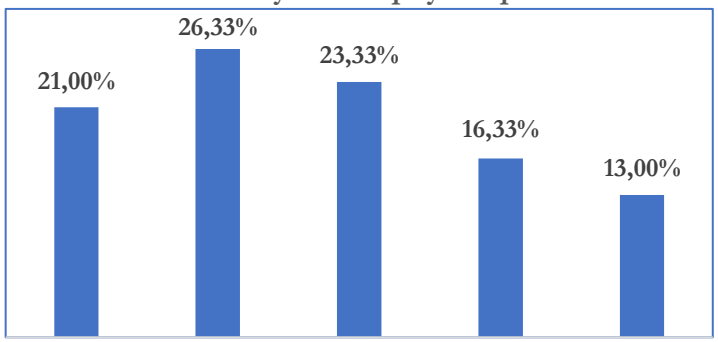


The results indicate a strong positive perception among students regarding the role of mathematical methods in linking theoretical physics with real-world applications. In total, 91.00% of respondents selected either agree or strongly agree, while only a very small proportion (4.33%) expressed disagreement. A further 4.67% of students remained neutral.

These findings suggest that mathematical approaches are widely perceived as highly effective in bridging the gap between abstract physical concepts and practical, real-world phenomena, thereby enhancing students' conceptual understanding and application of physics knowledge.

● For the seventh questionnaire item, students were asked to evaluate the adequacy of the level of mathematical difficulty in secondary school physics problems. The responses were distributed as follows: Very inadequate (21.00%), Inadequate (26.33%), Moderately adequate (23.33%), Adequate (16.33%), and Very adequate (13.00%). The distribution of responses is presented in Figure 8.

Figure 8. Adequacy of math. difficulty in secondary school physics problems

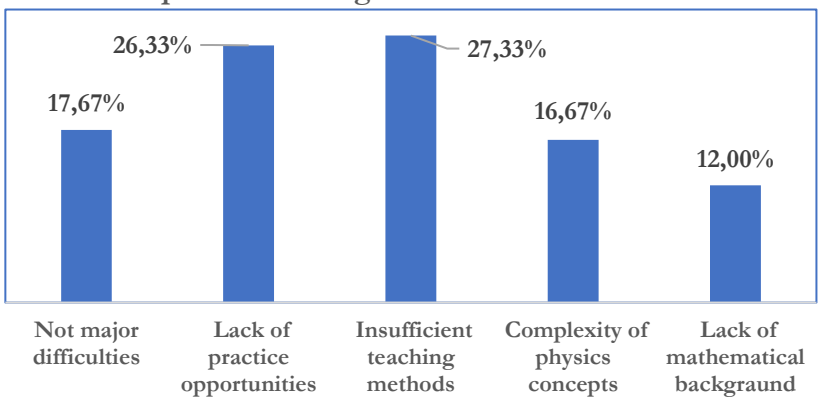


The results indicate that a relatively large proportion of students perceived the level of mathematical difficulty in secondary physics problems as insufficient. In total, 47.33% of respondents considered it either very inadequate or inadequate, while 23.33% rated it as moderately adequate. On the other hand, 29.33% of students viewed the level of difficulty as adequate or very adequate.

These findings suggest that the perceived mathematical challenge in secondary school physics is often considered unbalanced, with a tendency toward insufficient rigor for a significant portion of students. This may indicate the need to better calibrate the level of mathematical complexity in physics instruction to ensure both accessibility and appropriate cognitive challenge.

● For the eighth questionnaire item, students were asked to identify the main challenges they faced in solving physics problems using mathematical methods during secondary education. The responses were distributed as follows: No major difficulties (17.67%), Lack of practice opportunities (26.33%), Insufficient teaching methods (27.33%), Complexity of physics concepts (16.67%), and Lack of mathematical background (12.00%). The distribution of responses is presented in Figure 9.

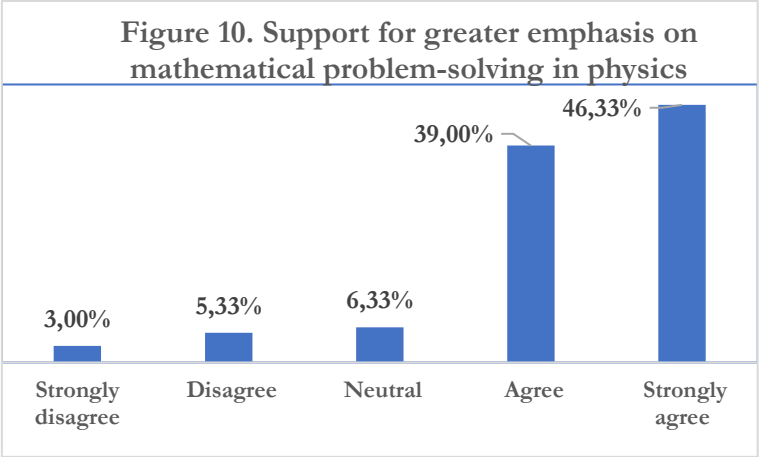
Figure 9. Main challenges in solving physics problems using mathematical methods



The results indicate that the most frequently reported challenge was insufficient teaching methods, selected by 27.33% of respondents, closely followed by a lack of practice opportunities at 26.33%. A smaller proportion of students reported experiencing complexity of physics concepts (16.67%) and lack of mathematical background (12.00%), while 17.67% stated that they did not encounter major difficulties.

These findings suggest that the primary obstacles in applying mathematical methods to physics problem-solving are related more to instructional practices and learning opportunities than to students' inherent mathematical preparation. This highlights the importance of improving teaching strategies and increasing practice-based learning in secondary physics education.

● For the ninth questionnaire item, students were asked whether secondary education should place greater emphasis on mathematical problem-solving in physics. The responses were distributed as follows: Strongly disagree (3.00%), Disagree (5.33%), Neutral (6.33%), Agree (39.00%), and Strongly agree (46.33%). The distribution of responses is presented in Figure 10.



The results indicate a strong overall agreement among students regarding the need for increased emphasis on mathematical problem-solving in physics instruction. In total, 85.33% of respondents selected either agree or strongly agree, while only a small proportion (8.33%) expressed disagreement. A further 6.33% of students remained neutral.

These findings suggest that students widely support strengthening the integration of mathematical methods in secondary school physics, highlighting a perceived need for more structured, consistent, and rigorous application of mathematical approaches in physics education.

The results of this study provide strong evidence that mathematical methods play a fundamental role in physics education and are widely valued by students who have continued their studies in STEM-related fields. The majority of respondents recognized the importance of integrating mathematics into physics problem-solving and reported that mathematical reasoning significantly contributed to their understanding of physics concepts. These findings confirm the close relationship between mathematics and physics and highlight the importance of mathematical competence as a foundation for scientific learning.

The study also demonstrates that mathematical problem-solving contributes to the development of several important cognitive skills. Students identified analytical thinking, understanding of physical laws, logical reasoning, and problem-solving ability as the main skills strengthened through the use of mathematical methods in physics. Furthermore, a large proportion of respondents expressed confidence in applying mathematical tools to solve physics problems, suggesting that mathematical approaches can support both conceptual understanding and academic self-efficacy. Another important finding is that students overwhelmingly agreed that mathematical methods help connect theoretical physics with real-world phenomena. This result indicates that mathematics is not perceived merely as a computational tool but also as a means of interpreting and explaining physical processes. Such a connection is essential for meaningful learning, as it enables students to understand how abstract concepts and equations relate to practical situations and observable phenomena.

Despite these positive perceptions, the findings reveal several challenges in the implementation of mathematical methods within secondary school physics instruction. Many respondents reported that mathematical approaches were only rarely or occasionally emphasized during their secondary education. In addition, a considerable proportion of students considered the level of mathematical difficulty in physics problems to be inadequate. These results suggest that there is still room for improvement in the extent and quality of mathematical integration within physics teaching.

The analysis of students' responses regarding challenges further supports this conclusion. The most frequently reported difficulties were insufficient teaching methods and a lack of opportunities for

practice, while fewer students identified a weak mathematical background as the primary obstacle. This suggests that instructional factors may have a greater influence on students' experiences than their existing mathematical knowledge. Consequently, improvements in teaching strategies, classroom activities, and problem-solving practice may significantly enhance students' learning outcomes.

A particularly noteworthy finding is the strong support for increasing the emphasis on mathematical problem-solving in secondary school physics. More than four-fifths of respondents agreed that greater attention should be devoted to mathematical approaches in physics instruction. This reflects students' recognition of the value of mathematical reasoning not only for success in physics courses but also for their preparation for university-level STEM studies.

In conclusion, the study highlights the necessity of strengthening the integration of mathematics and physics in secondary education. More systematic use of mathematical methods, increased opportunities for problem-based learning, and instructional approaches that encourage analytical reasoning may improve students' conceptual understanding and better prepare them for the academic demands of higher education. By promoting stronger connections between mathematical reasoning and physical interpretation, secondary education can contribute more effectively to the development of scientifically literate and analytically skilled students.

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APENDIX

QUESTIONNAIRE

This questionnaire is designed for students enrolled in study programs that include physics courses as part of their curriculum. It aims to investigate the perceived importance of mathematical methods in solving physics problems during secondary education and how these methods support the development of physics understanding at higher education level.

The main purpose of this study is to explore students' experiences and perspectives regarding the role of mathematical problem-solving in physics learning at the secondary school level. In particular, it seeks to examine how such approaches contribute to conceptual understanding, analytical thinking, and the ability to apply physical laws through mathematical reasoning.

The results of this questionnaire are intended to provide useful insights into the effectiveness of secondary education in preparing students for university-level physics courses. Furthermore, the study may contribute to improving teaching practices by strengthening the connection between mathematics and physics instruction in secondary education.

1. Basic Information about the Student

1.1. University you are affiliated with:

Fan S. Noli University of Korça, Polytechnic University of Tirana, University of Tirana, Ismail Qemali University of Vlora, Aleksander Moisiu University of Durres, New York University of Tirana, Luigj

Gurakuqi University of Shkodra, Eqrem Çabej University of Gjirokastra, Aleksander Xhuvani University of Elbasan, European University of Tirana, Epoka University, Polis University, Logos University College.

1.2. Which study program are you currently enrolled in or have completed:

Physics, Mathematics, Informatics, Mathematics-Physics, Engineering, Data Science, Computer Science, Information Technology, other (STEMprogram).

2. Questionnaire Items

This questionnaire includes 10 questions that explore students' perceptions of the role of mathematical methods in solving physics problems in secondary education. It covers the importance and frequency of using mathematics in physics, its impact on understanding and problem-solving skills, students' confidence, main challenges faced, and suggestions for improving teaching practices.

2.1. How important do you consider the integration of mathematical methods in solving physics problems at the secondary education level?

□ Not important

□ Slightly important

□ Moderately important

□ Important

□ Very important

2.2. To what extent did mathematical problem-solving in secondary school contribute to your understanding of physics concepts?

□ Not at all

□ To a small extent

□ To some extent

□ To a large extent

□ To a very large extent

2.3. How frequently were mathematical methods emphasized in physics instruction during your secondary education?

□ Never

□ Rarely

□ Occasionally

□ Frequently

□ Very frequently

2.4. How confident do you feel in applying mathematical tools to solve physics problems acquired from secondary education?

□ Not confident

□ Slightly confident

□ Moderately confident

□ Confident

□ Very confident

2.5. Which skill was most developed through mathematical physics problem-solving in secondary education?

□ Mathematical manipulation skills

□ Understanding of physical laws

□ Problem-solving ability

□ Analytical thinking

□ Logical reasoning

2.6. Do you believe that mathematical approaches in physics improved your ability to connect theory with real-world phenomena?

□ Strongly disagree

□ Disagree

□ Neutral

□ Agree

□ Strongly agree

2.7. How adequate was the level of mathematical difficulty in secondary school physics problems?

□ Very inadequate

□ Inadequate

□ Moderately adequate

□ Adequate

□ Very adequate

2.8. In your opinion, what was the main challenge in solving physics problems using mathematical methods?

□ No major difficulties

□ Lack of practice opportunities

□ Insufficient teaching methods

□ Complexity of physics concepts

□ Lack of mathematical background

2.9. Should secondary education place greater emphasis on mathematical problem-solving in physics?

□ Strongly disagree

□ Disagree

□ Neutral

□ Agree

□ Strongly agree

2.10. What improvements would you suggest for teaching physics through mathematical methods in secondary education?

_ _ _ _

CYTOGENETIC ANALYSIS OF CYTOTOXIC AND GENOTOXIC EFFECT OF *ROSA GALLICA* L. HYDROSOL OBTAINED BY WATER-STEAM DISTILLATION ON *IN VIVO* TEST-SYSTEM

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ABSTRACT

Rosa gallica L. hydrosol is increasingly incorporated in cosmetics and traditional healthcare, yet data on its cytotoxic and genotoxic safety remain limited. This study aimed to evaluate the cytotoxic and genotoxic risk of *Rosa gallica* L. hydrosol in a mammalian model using classical cytogenetic endpoints. Laboratory strain ICR mice received hydrosol at 11% and 20% (v/v); bone marrow samples were collected at 24 and 48 h after the first administration, while peripheral blood for micronucleus analysis in polychromatic erythrocytes was collected 48 h after the initial hydrosol treatment. Cytotoxicity was assessed through the mitotic index in bone marrow metaphases and the PCE/(PCE+NCE) ratio in peripheral blood, whereas genotoxicity was evaluated by the frequency of structural chromosomal aberrations and micronucleated polychromatic erythrocytes, in line with OECD Test Guideline 474. A direct-acting alkylating mutagen was used as a positive control, and 0.9% NaCl as a negative control.

None of the hydrosol doses substantially reduced mitotic activity or the proportion of polychromatic erythrocytes, indicating the absence of pronounced cytotoxic effects in hematopoietic cells under the experimental conditions. The frequencies of chromosomal aberrations and micronuclei in the hydrosol-treated groups remained low, only slightly above the negative control values, whereas the reference mutagen induced a clear increase in all cytogenetic parameters. These findings suggest that *Rosa gallica* L. hydrosol at 11% and 20% (v/v) exerts a low genotoxic risk *in vivo* and can be regarded as relatively safe with respect to chromosomal integrity in bone marrow and peripheral blood cells.

The obtained results support the safety of this rose product and indicate that, at appropriate concentrations, it is a promising candidate for use in relevant areas of human life.

Keywords: *Rosa gallica* L. hydrosol; mitotic index; genotoxicity; chromosomal aberrations; micronucleus test.

Acknowledgements: The research was supported by the Bulgarian National Science Fund, project KP-06-H36/17, December 2019, granted to Prof. M. Mileva, PhD.

DESIGN AND IMPLEMENTATION OF A CULTURALLY GROUNDED, COGNITIVELY AWARE, AND CAUSALLY HONEST HYBRID RETAIL RECOMMENDATION SYSTEM: SEYR-I ONERI

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ABSTRACT

This paper presents Seyr-i Oneri, an ethics-first hybrid retail recommendation system designed for culturally grounded, cognitively aware, temporally sensitive, causally honest, and explainable product recommendation. The study addresses four limitations of contemporary retail recommenders: the treatment of country as a flat categorical variable, fixed-length recommendation lists that ignore the user's attention budget, correlational scores that are confused with causal effect, and explanations that remain outside the user's moment of decision. The proposed architecture integrates five layers: Cultural Context Embedding (CCE), Cognitive Load Aware Recommender (CLAR), Time-Decay Behavioural Memory (TDM), Causal Uplift Re-ranker (CUR), and Just-in-Time Explainability (JIT-XAI). The system was implemented with FastAPI, Jinja2, SQLite, scikit-learn, LightGBM, SHAP, and vanilla JavaScript. It includes a three-dimensional Hofstede cultural globe, an ethics and fairness dashboard, a live recommendation stream, and user-facing explanation modals. Experiments on a documented synthetic retail corpus show that LightGBM reaches 0.4510 NDCG@10 in the ranking setting and 0.9004 accuracy with 0.957 AUC in the binary engagement setting. The ablation lattice shows that CLAR reduces average top-N from 8.00 to 5.47, TDM produces measurable recency decay, CUR captures uplift heterogeneity, and JIT-XAI adds only 4.56 ms p99 latency overhead. The study demonstrates that recommender-system quality should be defended through accuracy, cognitive burden, temporal memory, causal effect, explainability, fairness, and reproducibility together.

Keywords: recommender systems, hybrid recommendation, cultural context embedding, cognitive load, causal uplift, explainable artificial intelligence, ethical AI, SHAP, LightGBM.

INTRODUCTION

Online retail recommendation systems determine which products users encounter, which alternatives remain visible, and which options are silently pushed out of attention. This decision mechanism is not only a technical ranking problem. It affects information load, privacy, cultural context, user agency, and trust. A recommender that only increases the probability of a click is therefore insufficient for a defensible international research artefact. A scientifically grounded recommender should also explain why an item is shown, keep sensitive attributes outside model inference, forget historical behaviour in a reasonable temporal manner, and ask whether the recommendation itself actually changes behaviour.

Seyr-i Oneri was developed with this motivation. The system begins from a classical hybrid recommender and extends it through five coordinated layers: cultural context, cognitive load, temporal memory, causal uplift, and just-in-time explanation. The project is not presented as a single isolated prediction model. It is a complete research prototype containing a data-generation chain, training scripts, service modules, interface evidence, automated tests, and an ethical feature contract. This makes the contribution both academic and engineering-oriented: the reader can inspect the model assumptions, implementation boundaries, visual interface, and experimental evidence together.

Research gap and contributions

The literature contains separate work on hybrid recommendation, culture-aware modelling, choice overload, temporal recommendation, causal uplift, and explainable artificial intelligence. The gap

addressed in this study is the absence of a compact, end-to-end, inspectable retail recommender that places these concerns inside the same recommendation flow. The contribution is therefore an integrated system design, not a claim that one module universally improves all metrics.

Table 1. Research problems and contribution layers

Problem	Contribution	Evidence in this study
Cultural blindness	CCE maps country into Hofstede-based continuous cultural context.	Cultural vectors, distance formula, country-neighbour visualisation.
Attention-budget blindness	CLAR adapts recommendation-list length by cognitive load.	Average top-N decreases from 8.00 to 5.47 in ablation.
Correlation/causality confusion	CUR estimates heterogeneous uplift through T-learner logic.	Uplift standard deviation becomes 0.047 instead of 0.000.
Late or hidden explanations	JIT-XAI exposes SHAP-like contributions at product-card level.	Only +4.56 ms p99 latency overhead.
Ethical fragility	Sensitive fields are excluded through a fixed model feature contract.	Automated tests and ethics guard verify the invariant.

The research questions follow directly from this mapping: whether cultural context provides interpretable transfer beyond flat country coding; whether recommendation-list length can be adapted to cognitive load; whether temporal decay and causal uplift make ranking more defensible; and whether user-facing explanation can be generated without unacceptable latency. These questions are evaluated through model metrics, ablation evidence, interface behaviour, and testing artefacts.

RELATED WORK

Hybrid recommendation systems combine collaborative, content-based, and rule-based signals to reduce cold start, data sparsity, and overdependence on a single feature family (Ricci et al., 2022; Koren et al., 2022). Deep recommendation models can be effective at large scale, but reproducibility and strong baselines remain central concerns (Covington et al., 2016; Dacrema et al., 2019). For this reason, the evaluation in this study includes random and popularity sanity checks as well as classical, neural, and tree-based models.

Cultural context has been studied in human-computer interaction and user modelling, but many approaches remain disconnected from a working retail architecture. Hofstede's six-dimensional model is not treated here as a deterministic individual-level truth; it is used as an interpretable country-level prior (Hofstede et al., 2010; McSweeney, 2002). The cultural layer therefore supports explanation and transfer rather than stereotyping.

Cognitive-load and choice-overload studies show that more options can reduce decision quality (Sweller, 1988; Iyengar & Lepper, 2000; Bollen et al., 2010). Temporal recommendation research shows that the meaning of past interactions decays over time (Ding & Li, 2005; Vinagre et al., 2015). Uplift modelling provides a way to distinguish high probability from high incremental effect (Kunzel et al., 2019; Diemert et al., 2018). Finally, SHAP-based explainability provides feature-level attribution, but the contribution of this study is to move explanation into the user-facing product experience rather than leaving it in offline analysis (Lundberg & Lee, 2017; Zhang & Chen, 2020).

SYSTEM DESIGN AND METHOD

Architecture and data layers

The system follows a layered architecture: browser interface, FastAPI controller, repository layer, service layer, and storage/model artefact layer. The interface is built with Jinja2 templates and vanilla JavaScript. The repository layer communicates with SQLite tables for users, products, and interaction events. The service layer contains recommendation orchestration, cultural embedding, cognitive-load estimation, temporal memory, causal uplift, explainability, and the page-aware assistant. This separation keeps each scientific module testable and makes the user-facing evidence observable.

Table 2. Data layers and purposes

Layer	Size	Purpose
Legacy synthetic corpus	100,000 rows	Initial training and classical baseline comparison.
Natural synthetic corpus	60,000 rows	Scientific ranking, engagement, and ablation experiments.
Demo database	119 products, 56 users, 1002 events	Live interface demonstration and recommendation flow.
MovieLens-100k	Public external dataset	External validity for TDM, CUR, and JIT-XAI.

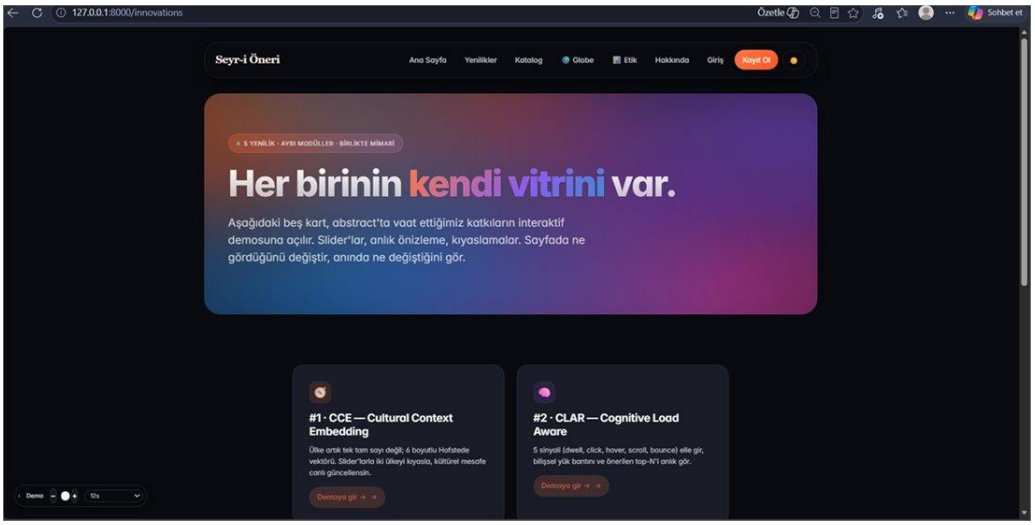


Figure 1. Innovation showcase connecting CCE, CLAR, TDM, CUR, and JIT-XAI to separate demonstration pages.

Ethical feature contract

A central design decision is that the production model uses a fixed and ethically constrained ten-feature contract. Religious and political orientation fields may exist as optional interface/database fields, but they are not allowed to enter model training or runtime inference. This boundary is implemented as a code-level invariant rather than a textual promise. The model feature list, automated tests, and CI-level ethics guard jointly protect the invariant.

Table 3. Production feature contract

Feature group	Included fields	Ethical role
Location and demographic encoding	enc_country, enc_city, enc_county, enc_gender, z_age	Used as ordinary profile context; sensitive orientation fields are excluded.
Behaviour and preference	z_spent_on_product_page, preferred category, preferred colour, price segment, shopping frequency	Represents observed or declared retail preference without religious or political inference.
CCE extension	cce_pdi, cce_idv, cce_mas, cce_uai, cce_lto, cce_ivr	Country-level cultural context, not individual sensitive data.

Mathematical formulation of the five layers

The baseline hybrid score combines store prediction, product prediction, and rule-based compatibility bonuses:

$$s_{base}(u,i) = 0.55p_s(u,i) + 0.35p_p(u,i) + b_{cat} + b_{country} + b_{price} + b_{color}. \quad (1)$$

CCE uses Hofstede dimensions as a country-level contextual prior, not as an individual-level personality label. Each country is represented by a six-dimensional vector, normalised to the unit scale, and compared through Euclidean cultural distance. The cultural bonus is deliberately bounded so that cultural context can support, but not dominate, behavioural evidence.

$$h_c = [PDI_c, IDV_c, MAS_c, UAI_c, LTO_c, IVR_c] \quad (2)$$

$$v_c = \frac{h_c}{100}, \quad d_H(c_a, c_b) = ||v_{ca} - v_{cb}||_2 \quad (3)$$

$$b_{culture}(u,i) = 0.02\, I[d_H(c_u, c_i) < 0.30] \quad (4)$$

CLAR estimates cognitive load from dwell-time variance, click velocity, hover count, scroll thrash, and short-bounce signals. The score is then mapped to a top-N policy so that the interface adapts to the user's observable attention state.

$$L = 0.25s_{dwell} + 0.25s_{click} + 0.15s_{hover} + 0.20s_{scroll} + 0.15s_{bounce} \quad (5)$$

Table 4. CLAR adaptation policy

Load band	L interval	Top-N	Diversity	Min. confidence
Low	[0, 0.25)	12	1.0	0.10
Moderate	[0.25, 0.50)	8	1.1	0.15
High	[0.50, 0.75)	5	1.3	0.25
Overload	[0.75, 1]	3	1.5	0.35

TDM applies Ebbinghaus-style exponential decay to historical interactions:

$$w(\Delta t) = exp(-\frac{ln\,2}{h_{1/2}}\Delta t) \quad (6)$$

$$fam_i = \frac{\Sigma_{e \in E_i} w(\Delta t_e)}{\Sigma_{e \in E} w(\Delta t_e)} \quad (7)$$

$$s_{TDM}(u,i) = s_{base}(u,i) - 0.05 fam_i \quad (8)$$

CUR estimates treatment and control outcome models, derives heterogeneous uplift, and uses the uplift term as a conservative re-ranking signal. JIT-XAI then computes Shapley-style feature contributions and exposes the strongest positive and negative drivers next to recommendation cards.

$$\mu_1(X) = E[Y|T=1,X], \ \ \mu_0(X) = E[Y|T=0,X] \quad (9)$$

$$\tau_i = \mu_1(X_i) - \mu_0(X_i) \quad (10)$$

$$\hat{s}_i = s_i + \lambda \tau_i, \ \ \lambda = 0.15 \quad (11)$$

$$\varphi_j = \Sigma_{S \subseteq N - \{j\}} \frac{|S|!(|N|-|S|-1)!}{|N|!} [v(S \cup \{j\}) - v(S)] \quad (12)$$

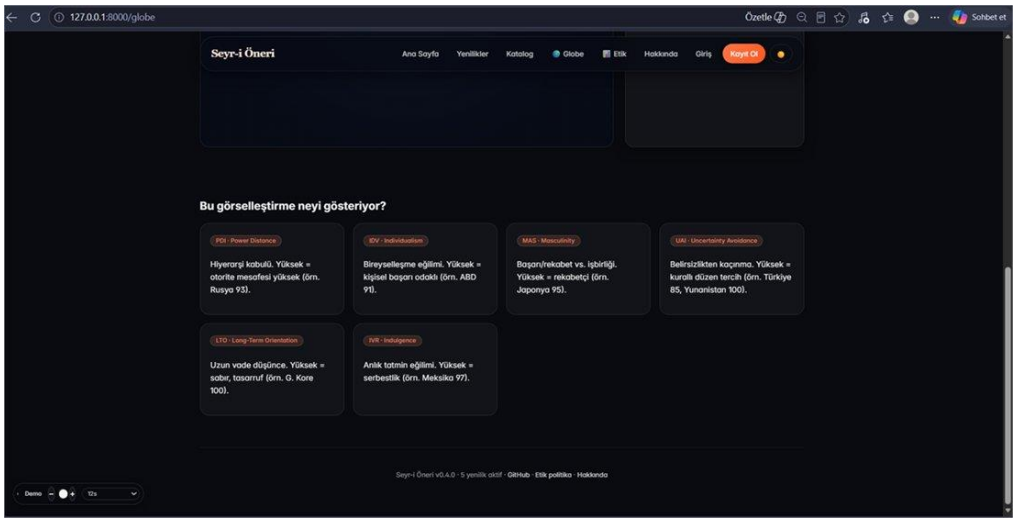


Figure 2. Three-dimensional Hofstede cultural globe showing country density, cultural vectors, and neighbourhood information.

IMPLEMENTATION

The implementation uses FastAPI for routing, Jinja2 for server-rendered pages, SQLite for local persistence, scikit-learn and LightGBM for modelling, SHAP for explanation, and vanilla JavaScript for the interactive interface. At startup, the database schema is initialised and the product catalogue is seeded if empty. The recommendation service collects user statistics, estimates cognitive load, aggregates recent events, builds the feature frame, performs model inference or fallback ranking, applies cultural and temporal adjustments, optionally re-ranks by uplift, and returns recommendations with explanation context.

The interface was designed as evidence rather than decoration. The innovation showcase explains the five scientific layers; the globe page visualises cultural vectors and neighbours; the dashboard displays ethics and fairness indicators; and the recommendation page shows product cards with score, reason labels, CLAR band, and a "Why this?" explanation button. This makes the system easier to defend in a congress setting because the theoretical contributions are visible in a working prototype.

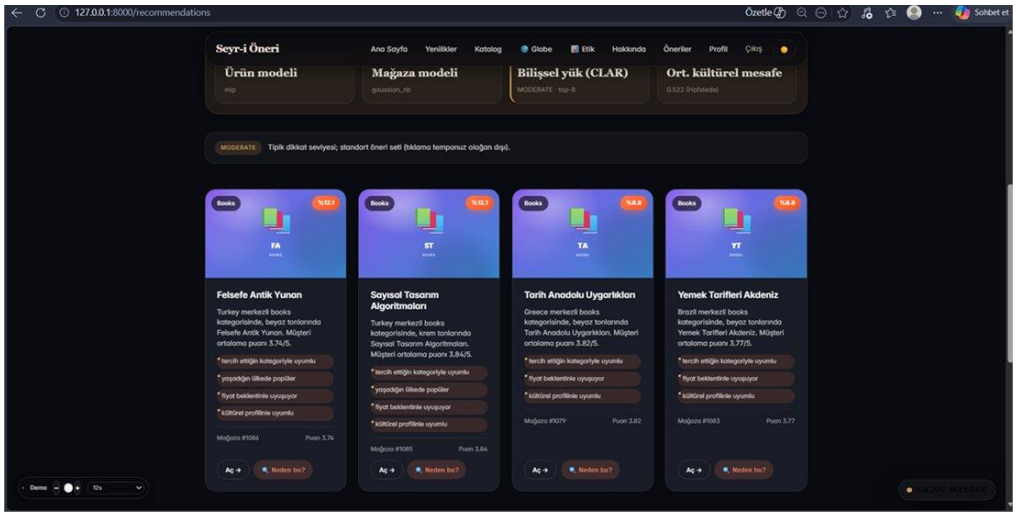


Figure 3. Personal recommendation page showing hybrid score, reason labels, CLAR band, and JIT-XAI access.

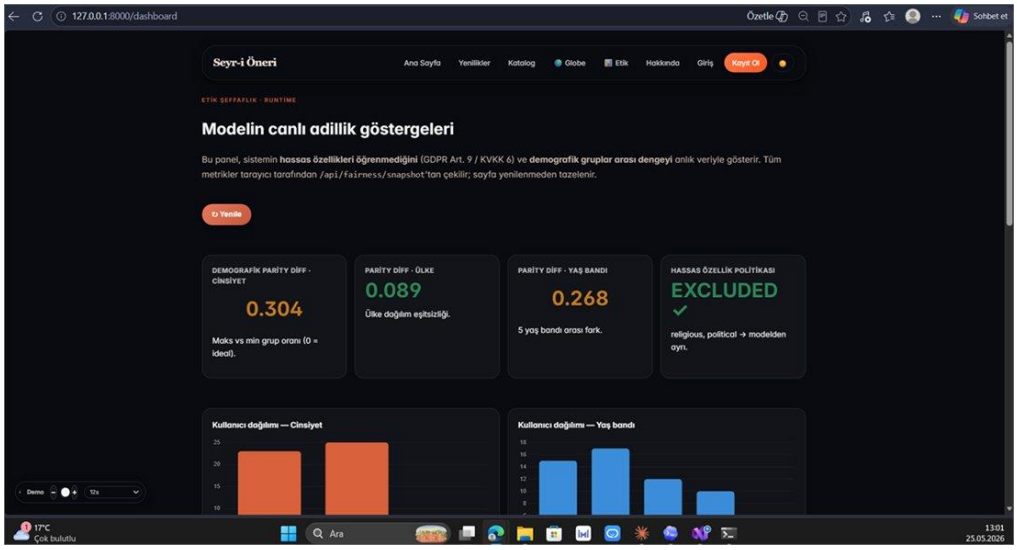


Figure 4. Ethics and fairness dashboard showing demographic distributions, parity difference, and cognitive-load indicators.

EXPERIMENTAL RESULTS

Baseline ranking and binary engagement

The first experiment compares classical and learning-based baselines on the natural synthetic dataset. Random and popularity sanity baselines remain clearly behind learning-based models, showing that the pipeline captures meaningful signal. LightGBM provides the strongest ranking result with 0.4510 NDCG@10 and 0.917 HR@10. In the reframed binary engagement/satisfaction task, the ten-feature baseline reaches 0.9004 accuracy and 0.957 AUC.

Table 5. Main model results

Task / Model	Features	Key result	Interpretation
Random sanity	10	NDCG@10 = 0.0415	Confirms the lower bound.
Popularity	10	NDCG@10 = 0.0727	Popularity alone is insufficient.
Random Forest	10	NDCG@10 = 0.4487	Strong tree-based baseline.
LightGBM	10	NDCG@10 = 0.4510; HR@10 = 0.917	Best ranking baseline.
Binary engagement BASE	10	Accuracy = 0.9004; AUC = 0.957	Strong engagement/satisfaction discrimination.
BASE+CCE	16	Accuracy = 0.8999; AUC = 0.957	CCE is neutral for this target; not harmful.

Ablation and external validity

Each innovation layer serves a different purpose and is therefore evaluated with an operationally appropriate metric. The ablation lattice is more informative than forcing all modules into a single accuracy number. It shows whether each layer changes the behaviour it was designed to affect.

Table 6. Ablation lattice for the five innovation layers

Layer	Metric	Baseline	With layer	Interpretation
CCE	Engagement accuracy	0.8916	0.8914	Neutral; p = 0.875.
CLAR	Average top-N	8.00	5.47	Shorter list under cognitive load.
TDM	Recency strength	1.000	0.958	Exponential decay is active.
CUR	Uplift std	0.000	0.047	Heterogeneous treatment effect is captured.
JIT-XAI	SHAP p99 overhead	2.12 ms	6.68 ms	+4.56 ms; below 50 ms.

MovieLens-100k was used as an external validity check. Because MovieLens does not contain country information or in-session cognitive-load signals, CCE and CLAR cannot be directly transferred to that dataset. TDM, CUR, and JIT-XAI, however, transfer through timestamps, treatment proxies, and model explanations.

Table 7. External validity and testing summary

Evidence	Value	Meaning
MovieLens BASE LightGBM	Accuracy = 0.6879; AUC = 0.7456	Reasonable implicit-feedback baseline.
MovieLens CUR	Uplift mean = +0.175; std = 0.104	Treatment heterogeneity is observable.
MovieLens JIT-XAI	p99 overhead = +8.87 ms	Below practical 50 ms threshold.
Automated tests	80 tests; about 75% line coverage	Covers authentication, repositories, metrics, services, and ethics guard.

Fairness and reproducibility

Fairness outputs summarise accuracy, HR@10, and F1 across country, gender, and age-band groups. In product prediction, HR@10 disparity is 0.0 across all monitored groups. This does not prove that fairness is solved; rather, it shows that fairness indicators are part of the runtime dashboard and can be monitored instead of remaining outside the system. Reproducibility is supported through fixed seeds, documented data layers, saved artefacts, and automated tests.

DISCUSSION

The most important finding is that recommendation-system quality should not be reduced to a single accuracy metric. CCE does not automatically improve every prediction target; it is most valuable when cultural transfer, explanation, or cold-start reasoning matters. Reporting this neutral result is scientifically important because it prevents the cultural layer from being presented as a universal performance booster.

CLAR changes the question from "how many recommendations can the model produce?" to "how many recommendations can the user reasonably evaluate now?" The reduction of average top-N from 8.00 to 5.47 is therefore not a loss of information but an intentional cognitive adaptation. TDM prevents stale interactions from dominating the present list. CUR introduces the causal distinction between products that the user would probably choose anyway and products for which exposure may create incremental effect. JIT-XAI moves explanation from engineering reports to the user decision moment with an acceptable latency cost.

The limitations are also clear. The data are synthetic and cannot represent all complexity of real user behaviour. Hofstede dimensions operate at country level and cannot explain within-country diversity. CUR currently relies on a proxy treatment signal because real randomised exposure logs are unavailable. CLAR thresholds require user-study calibration. SQLite is suitable for a research prototype but not for high-traffic production. These limitations define the next scientific and engineering steps rather than weakening the architectural contribution.

CONCLUSION

This study presented Seyr-i Oneri, an ethics-first hybrid retail recommendation system that integrates cultural context, cognitive-load adaptation, time-decayed behavioural memory, causal uplift re-ranking, and just-in-time explainability. The system is implemented as a working web application and evaluated with baseline comparisons, ablation analysis, external validation, fairness monitoring, and automated tests. The findings show that the project is not simply an accuracy-oriented recommender; it is a defensible reference implementation for recommendation systems that are culturally aware, cognitively gentle, temporally sensitive, causally honest, and explainable to users.

Future work should focus on real A/B exposure logging for CUR, user studies with SUS and NASA-TLX for CLAR and JIT-XAI, external validation on public e-commerce datasets such as RetailRocket and Amazon Reviews, and production-level architecture using PostgreSQL, Redis, observability, rate

limiting, and stronger security controls. In its current form, Seyr-i Oneri provides a compact but comprehensive foundation for internationally presentable research on ethical and explainable retail recommendation systems.

EXTENDED METHODOLOGICAL DETAIL

The compressed congress version still needs to preserve the logic of the larger technical report. For this reason, the method is expanded here around three principles: traceable data generation, ethically bounded feature engineering, and modular service design. The data are synthetic by design; no real personal records are used. However, the synthetic process is not arbitrary. It is shaped to reflect retail long-tail behaviour, dwell-time variability, preference signals, product popularity, category affinity, price segment, and satisfaction. This design makes the corpus suitable for controlled experimentation while avoiding privacy exposure.

The natural synthetic corpus contains 60,000 rows and is used for the main scientific experiments. The legacy 100,000-row corpus is retained for backward comparison and CCE A/B checks. The demo database contains 119 products, 56 users, and 1002 interaction events, which makes it small enough for a local congress demonstration but rich enough to exercise the full recommendation pipeline. Separating these layers avoids a common methodological problem: using the same data both for live demonstration and for all scientific claims.

Table 8. Data-generation and evaluation artefacts

Artefact	Role	Scientific reason
Legacy corpus	Initial baseline and CCE A/B comparison	Shows continuity with earlier project experiments.
Natural corpus	Main ranking and engagement experiments	Provides more realistic conditional relationships.
Demo DB	Live web demonstration	Makes the model behaviour observable in the interface.
Ablation report	Layer-by-layer innovation test	Prevents all claims from being reduced to accuracy.
MovieLens check	External validity	Tests transferable parts of TDM, CUR, and JIT-XAI.

Feature engineering is deliberately conservative. The ten-feature production contract includes location encodings, age normalisation, page-duration normalisation, preferred category, preferred colour, price-segment preference, and shopping frequency. Religious and political orientation fields are excluded from the model even if they exist as optional profile fields. This distinction is important: a database can contain an optional field for expression or profile completeness, but the model must not convert it into a predictive signal.

The CCE extension is handled differently from sensitive individual attributes. Hofstede scores are country-level contextual variables and are not treated as individual traits. They are used to compute a transparent cultural vector and cultural distance. The model therefore does not infer a user's religion, ideology, or protected identity; it uses a country-level cultural prior only as a weak and interpretable contextual signal.

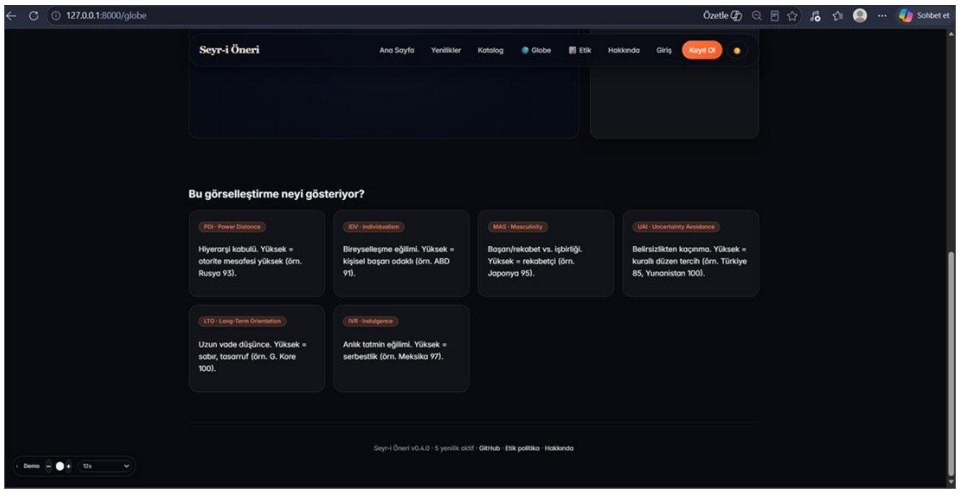


Figure 5. Three-dimensional cultural globe used to inspect Hofstede vectors and cultural neighbourhoods.

SERVICE ORCHESTRATION AND USER-FACING EVIDENCE

The recommendation service orchestrates profile retrieval, interaction aggregation, cognitive-load estimation, temporal memory, model inference, fallback ranking, cultural bonus calculation, causal re-ranking, and explanation generation. This order is important because it allows the system to remain usable even when a model artefact is absent. If trained models are not available, the fallback ranker still produces recommendations from popularity and declared preference signals. This makes the prototype reliable during local demonstration and protects the user experience from model-loading failures.

The interface was designed to make scientific claims visible. A purely backend recommendation model is difficult to defend in a congress presentation because many claims remain hidden in code. Seyr-i Oneri therefore maps every innovation layer to an inspectable interface: CCE to the cultural-distance page and globe, CLAR to signal sliders and load bands, TDM to half-life decay, CUR to uplift categories, and JIT-XAI to explanation cards.

Table 9. Interface evidence for the scientific layers

Interface surface	Observed behaviour	Linked contribution
Innovation showcase	Five modules are presented as separate demonstration pages.	System-level contribution visibility.
CCE page	Country vectors and distances are shown to the evaluator.	Cultural context embedding.
CLAR page	Behavioural signals are converted into load bands.	Cognitive-load adaptation.
TDM page	Half-life parameter changes the decay curve.	Temporal memory.
CUR page	Persuadable and sleeping-dog cases are simulated.	Causal uplift reasoning.
Recommendation page	Reason labels and explanation modal appear near product cards.	JIT-XAI and user-facing transparency.
Dashboard	Parity difference and demographic distributions are monitored.	Ethics and fairness observability.

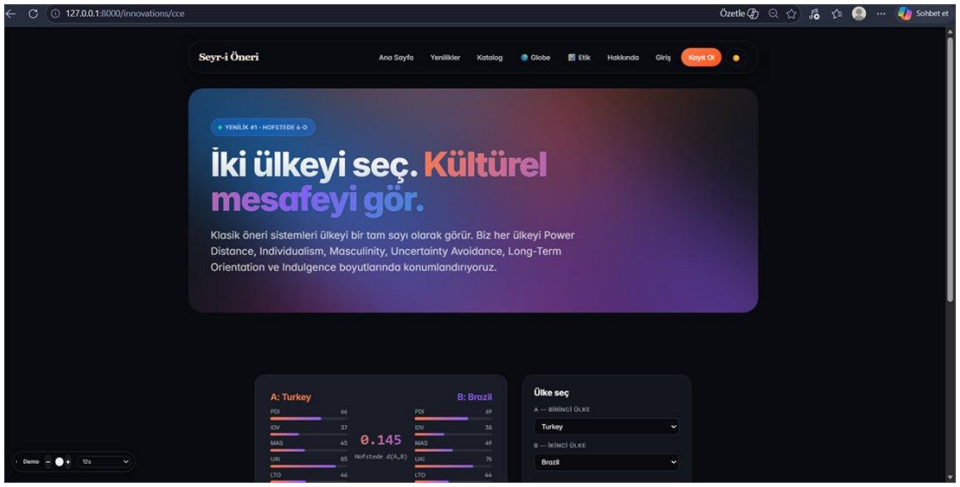


Figure 6. CCE page showing Hofstede dimensions and distance between selected countries.

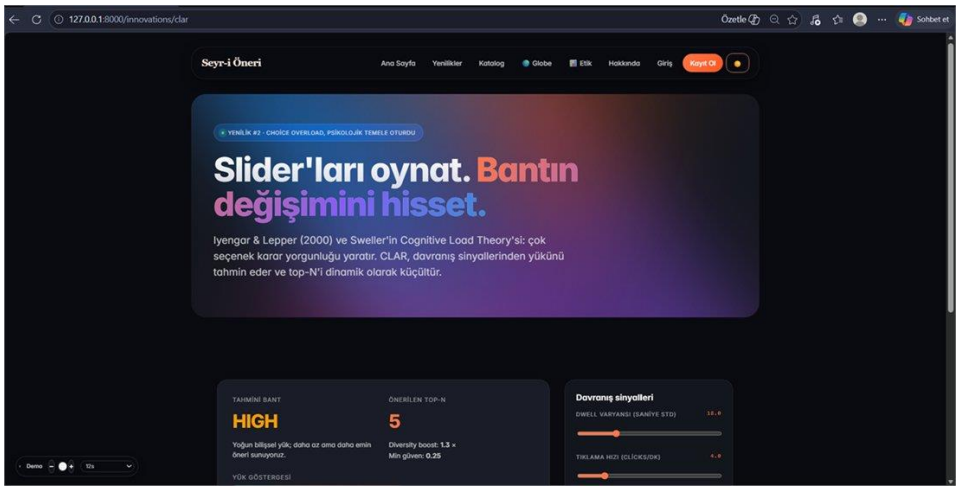


Figure 7. CLAR page converting behavioural signals into cognitive-load bands.

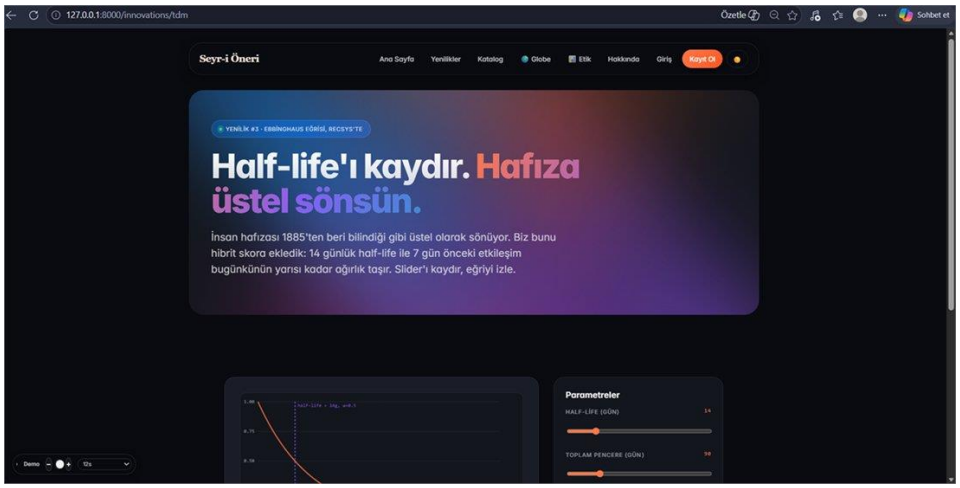


Figure 8. TDM page showing exponential decay under the half-life parameter.

PROCEEDINGS BOOK

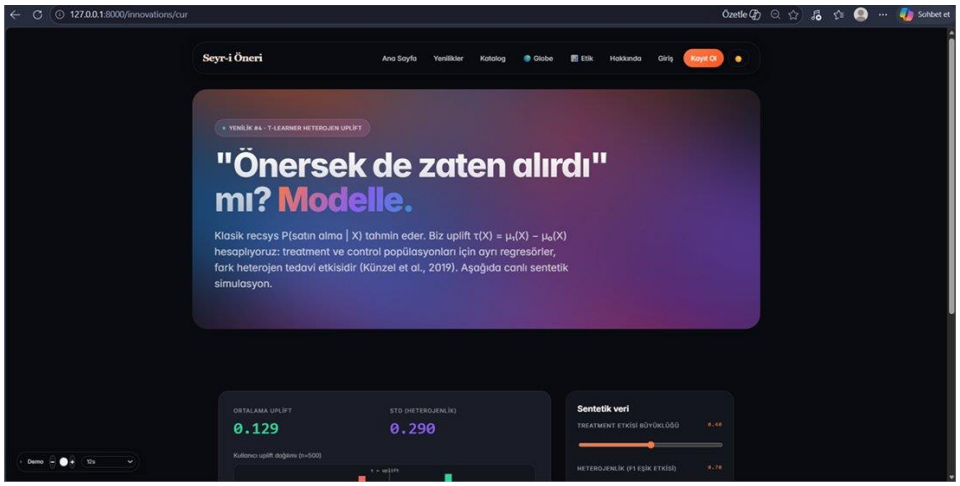


Figure 9. CUR page showing uplift distribution and causal user segments.

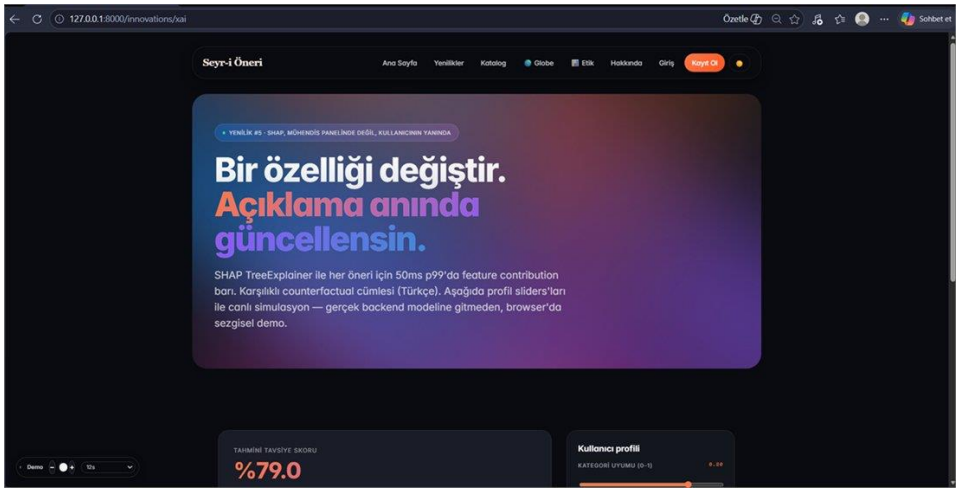


Figure 10. JIT-XAI page presenting feature contributions through SHAP-like bars.

DETAILED FINDINGS

The baseline ranking results show that the model pipeline is not merely reproducing random or popularity-driven order. Random sanity and popularity baselines are weak, while tree-based models and LightGBM capture stronger ranking signal. LightGBM reaches 0.4510 NDCG@10 and 0.917 HR@10 on the natural synthetic dataset. This makes it a strong baseline for the rest of the paper.

Table 10. Main ranking comparison

Model	Features	NDCG@10	MRR@10	HR@10	Fit time
Random sanity	10	0.0415	0.027	0.090	0.0 s
Popularity	10	0.0727	0.048	0.156	0.0 s
KNN	10	0.2181	0.157	0.420	0.3 s
Logistic Regression	10	0.3424	0.235	0.699	25.0 s
Random Forest	10	0.4487	0.309	0.909	86.9 s
MLP	10	0.4503	0.311	0.909	32.1 s
Gaussian NB	10	0.4505	0.310	0.913	0.2 s

LightGBM	10	0.4510	0.310	0.917	276.0 s

The CCE A/B findings are scientifically useful precisely because they are not uniformly positive. Product prediction benefits slightly from CCE in the legacy comparison, whereas store prediction decreases. This suggests that store choice is likely influenced by local coverage, delivery distance, campaign availability, and logistics rather than country-level cultural similarity. Therefore, the correct conclusion is not that CCE should always be activated; it should be used when the task can plausibly benefit from cultural context.

Table 11. CCE A/B comparison

Task	Configuration	Features	Accuracy	NDCG@10	MRR@10	HR@10
Product	BASE	10	0.1873	0.5815	0.4459	1.0000
Product	BASE+CCE	16	0.1920	0.5842	0.4499	0.9990
Store	BASE	10	0.1110	0.4582	0.3005	0.9903
Store	BASE+CCE	16	0.1033	0.4422	0.2918	0.9465

The binary engagement task reframes success as a combined high-dwell and high-satisfaction target. In this setting, the BASE LightGBM model reaches 0.9004 accuracy and 0.957 AUC. Adding CCE remains neutral, which supports a careful interpretation: the cultural layer should be defended through interpretability, transfer, cold-start reasoning, and diversity, not only through direct accuracy gain.

Table 12. Binary engagement / satisfaction results

Configuration	Features	Accuracy	AUC	F1
BASE	10	0.9004	0.957	0.770
BASE+CCE	16	0.8999	0.957	0.769
BASE+CCE+Interaction	24	0.8996	0.957	0.769

The ablation lattice is the strongest compact evidence table because it evaluates each contribution with the metric appropriate to its purpose. CLAR is judged by top-N adaptation, TDM by recency strength, CUR by uplift dispersion, and JIT-XAI by latency overhead. This avoids the misleading practice of forcing all components into a single accuracy metric.

Table 13. Ablation lattice for the five innovation layers

Layer	Metric	Baseline	With layer	Interpretation
CCE	Engagement accuracy	0.8916	0.8914	Neutral; p = 0.875.
CLAR	Average top-N	8.00	5.47	Shorter list under cognitive load.
TDM	Recency strength	1.000	0.958	Exponential decay is active.
CUR	Uplift std	0.000	0.047	Heterogeneous treatment effect is captured.
JIT-XAI	SHAP p99 overhead	2.12 ms	6.68 ms	+4.56 ms; below 50 ms.

MovieLens-100k provides an external validity check. Because the dataset lacks country and in-session behavioural signals, CCE and CLAR cannot be directly tested there. TDM, CUR, and JIT-XAI,

however, can be transferred through timestamps, treatment proxies, and model explanations. BASE LightGBM reaches 0.6879 accuracy and 0.7456 AUC, CUR produces an uplift mean of +0.175 with standard deviation 0.104, and JIT-XAI remains below the 50 ms threshold with +8.87 ms p99 overhead.

VALIDITY, LIMITATIONS, AND ETHICS

The most important interpretation is that the study changes the evaluation surface of a recommender. A single accuracy value cannot explain whether the list is cognitively appropriate, whether older behaviour is overused, whether recommendation exposure creates incremental effect, or whether the user can understand the model's reasoning. The proposed system demonstrates how these concerns can be engineered together without hiding negative or neutral findings.

Table 14. Limitations and mitigation strategies

Limitation	Effect	Mitigation / future work
Synthetic data	May not represent the full complexity of real retail behaviour.	Validate on RetailRocket, Amazon Reviews, or a controlled pilot.
Country-level culture	Within-country and individual diversity may be missed.	Add individual preference surveys and regional cultural signals.
Proxy treatment for CUR	Causal claims remain limited without randomised exposure logs.	Use production A/B exposure logging and randomised holdout.
CLAR calibration	Thresholds are literature- and simulation-based.	Run user studies with SUS, NASA-TLX, and qualitative interviews.
SQLite prototype	Not suitable for heavy production traffic.	Move to PostgreSQL, async access, Redis, observability, and stronger security.

Internal validity is limited by the synthetic data-generation assumptions, because the generated relationships partly determine what the model can learn. External validity is supported by the MovieLens test for transferable components, but CCE and CLAR require data fields that many public datasets do not contain. Construct validity is limited by the engagement definition, which uses dwell time and satisfaction rather than real purchase, return, or repeat-purchase signals. Conclusion validity is protected by reporting neutral findings and by separating each innovation's operational metric.

The ethical contribution is not limited to removing sensitive fields. The key point is that this removal is reproducible and auditable at code level. The model feature list excludes religious and political orientation fields, automated tests verify the invariant, and the ethics guard can stop a build if the invariant is violated. The fairness dashboard and JIT-XAI explanation modal then make the system more accountable to users and evaluators.

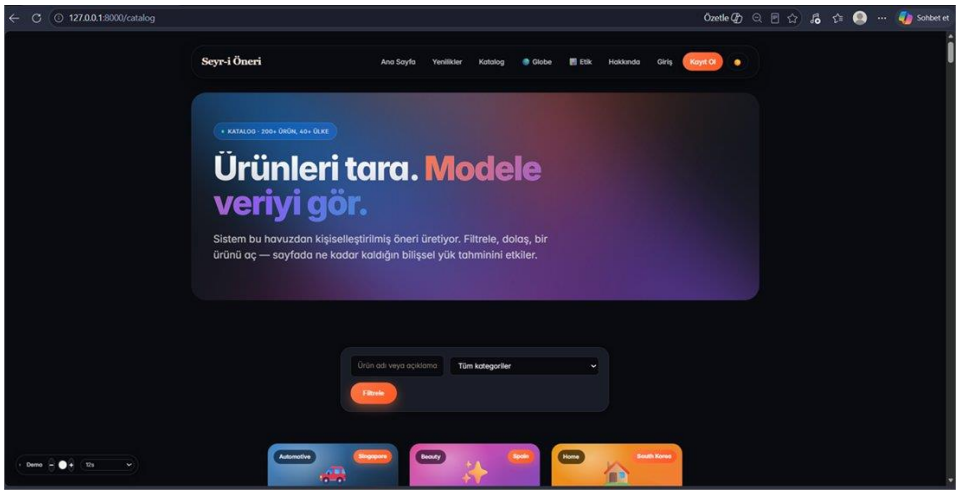


Figure 11. Catalogue page with category filtering and deterministic product visuals used in the live demo.

CONCLUSION AND FUTURE WORK

Seyr-i Oneri is an ethics-first hybrid retail recommendation system that integrates cultural context, cognitive-load adaptation, time-decayed behavioural memory, causal uplift re-ranking, and just-in-time explainability. The system is implemented as a working web application and evaluated with baseline comparisons, ablation analysis, external validation, fairness monitoring, and automated tests. The findings show that the project is not simply an accuracy-oriented recommender; it is a defensible reference implementation for recommendation systems that are culturally aware, cognitively gentle, temporally sensitive, causally honest, and explainable to users.

Future work should focus on real A/B exposure logging for CUR, user studies with SUS and NASA-TLX for CLAR and JIT-XAI, external validation on public e-commerce datasets such as RetailRocket and Amazon Reviews, and production-level architecture using PostgreSQL, Redis, observability, rate limiting, and stronger security controls. In its current form, Seyr-i Oneri provides a compact but comprehensive foundation for internationally presentable research on ethical and explainable retail recommendation systems.

ADDITIONAL TECHNICAL EVIDENCE FOR THE FULL TEXT

The full-text version should communicate not only the final metrics but also why the system is technically defensible. Seyr-i Oneri therefore separates three levels of evidence. The first level is algorithmic: formulas define how the base score, cultural distance, cognitive-load score, temporal decay, uplift score, and SHAP contribution are computed. The second level is experimental: baselines, A/B comparisons, ablation analysis, MovieLens validation, and test coverage quantify the behaviour of the system. The third level is product evidence: the interface shows how a user, evaluator, or congress participant would actually experience these layers in a working application.

This three-level structure is important for a software-engineering paper. If the study reported only interface screenshots, it would be a demo rather than a scientific contribution. If it reported only model tables, it would ignore the user-facing and ethical character of recommendation systems. If it reported only ethical claims, it would remain a declaration rather than an implementation. The contribution of the project is that these three surfaces are connected: mathematical design, measured behaviour, and user-facing explanation point to the same system.

Operational recommendation workflow

At runtime, the system first retrieves the user profile and recent interaction statistics. It then estimates cognitive load from behavioural signals, computes temporal familiarity from recent events, builds the ethical feature frame, and checks whether trained model artefacts are available. If the model artefacts are missing, the fallback ranker uses popularity and explicit preference signals so that the application

remains usable. If the models are available, product and store probabilities are predicted, hybrid bonuses are added, cultural context is applied, temporal familiarity is subtracted, and causal uplift re-ranking is optionally performed.

The last step is explanation generation. For the top-ranked products, the explanation service computes the strongest feature contributions and packages them for the recommendation card. This is deliberately placed at the end of the flow because explanations must describe the final recommendation actually shown to the user, not an intermediate model score. In other words, the explanation surface follows the ranking decision rather than describing a partial submodel.

Table 15. Runtime workflow and scientific purpose

Step	Runtime operation	Scientific purpose
1	Load user profile and interaction statistics.	Creates the behavioural context for recommendation.
2	Estimate CLAR cognitive-load band.	Adapts list length to the user's attention budget.
3	Aggregate recent events through TDM.	Prevents stale behaviour from dominating current preference.
4	Build ethical model feature frame.	Keeps sensitive fields outside model inference.
5	Predict product and store probabilities.	Provides the baseline hybrid ranking signal.
6	Apply CCE, temporal penalty, and CUR.	Adds cultural, temporal, and causal reasoning.
7	Generate JIT-XAI explanation payload.	Makes the final recommendation understandable to the user.

Evaluation protocol

The evaluation protocol is deliberately multi-metric. Ranking performance is measured with NDCG@10, MRR@10, and HR@10. Binary engagement is measured with accuracy, AUC, and F1. Cognitive adaptation is measured with average top-N. Temporal memory is measured with recency strength. Causal uplift is measured with uplift dispersion. Explainability is evaluated through p99 latency overhead and availability of feature-contribution payloads. This design avoids a common error in recommender-system reporting: using accuracy as if it were the only relevant form of system quality.

For the congress version, the most important numerical conclusion is not that every layer improves the same metric. The stronger conclusion is that each layer changes the property it is designed to control. CLAR shortens lists when cognitive load is high. TDM makes recency decay measurable. CUR creates non-zero heterogeneity where the baseline has none. JIT-XAI remains fast enough for user-facing interaction. CCE is neutral in direct engagement accuracy but contributes interpretability and cultural transfer.

Table 16. Metric families used in the study

Metric family	Metrics	Question answered
Ranking quality	NDCG@10, MRR@10, HR@10	Does the system rank relevant products near the top?
Engagement prediction	Accuracy, AUC, F1	Can the system separate engaged and non-engaged cases?
Cognitive adaptation	Average top-N, load band	Does the list adapt to attention pressure?
Temporal behaviour	Recency strength, half-life response	Does older interaction lose influence?
Causal reasoning	Uplift mean and standard deviation	Does the system distinguish incremental effect?
Explainability	p99 overhead, contribution payload	Can explanations be shown without harming interaction?
Fairness monitoring	Group-level accuracy, HR@10, F1 disparity	Can demographic performance be observed?

Why the selected figures were kept

The long technical report contains more visual material than a twenty-page congress paper can reasonably include. For the full-text submission, the retained figures were selected according to evidential value rather than decoration. The innovation showcase explains the overall research architecture. The globe demonstrates the cultural layer. The CCE, CLAR, TDM, CUR, and JIT-XAI pages show that the five scientific layers are implemented and inspectable. The recommendation page proves that the layers converge in the actual user flow. The dashboard proves that ethical and fairness indicators are not hidden outside the product.

Some visuals were intentionally not used. Any venue or personal photograph unrelated to the system was excluded because it does not strengthen the scientific argument and could create permission concerns. Decorative screenshots were also deprioritised. The aim is to use visual space for scientific traceability: every retained figure should answer the question 'What part of the method or result can the reader observe here?'

DEPLOYMENT AND PRESENTATION READINESS

The system is suitable for a congress demonstration because it has a clear local execution path, a compact SQLite-backed demo database, deterministic product visuals, visible scientific modules, and fallback behaviour when optional external services are missing. This matters because conference environments are often unstable: network access may fail, API keys may be unavailable, and live model artefacts may not load as expected. The design avoids making the demonstration dependent on a single fragile component.

From an engineering perspective, the next version should replace SQLite with PostgreSQL, use asynchronous data access, introduce Redis caching for frequent recommendation requests, add structured observability, and harden authentication with CSRF protection and rate limiting. These production improvements are outside the present congress prototype but follow naturally from the modular architecture. The current prototype is intentionally small enough to be inspectable, reproducible, and explainable.

From a research perspective, the most important next step is a real exposure log. CUR is architecturally ready for causal re-ranking, but stronger causal claims require randomised treatment-control exposure data. Similarly, CLAR should be calibrated with user studies that include SUS, NASA-TLX, and

qualitative interviews. CCE should be evaluated not only with accuracy but also with diversity, cross-country cold-start, and long-tail exposure. JIT-XAI should be evaluated with user trust and decision-quality measures rather than latency alone.

The project is therefore best understood as a reference implementation. It shows how multiple responsible recommendation principles can be engineered together in a working system, and it defines the empirical work required to make each principle stronger. This is appropriate for an interdisciplinary congress because the contribution sits between software architecture, machine learning, human-computer interaction, ethics, and data-driven decision support.

Final academic synthesis

The study's strongest academic position is its refusal to hide trade-offs. CCE does not always improve direct accuracy. CUR cannot prove causal effect without exposure logs. CLAR requires calibration beyond synthetic signals. Hofstede vectors must not be interpreted as individual cultural truth. These points are not weaknesses in the writing; they are part of the scientific defence. A trustworthy paper should show where the system works, where it is limited, and how the next experiments should be designed.

Consequently, the full text frames Seyr-i Oneri as a transparent and expandable prototype. The current results support the feasibility of integrating cultural context, cognitive adaptation, temporal decay, uplift re-ranking, and just-in-time explanation into the same recommender. The remaining work concerns stronger external validation, real user studies, and production-grade infrastructure. This balance between implementation, measurement, and limitation makes the study suitable for an international proceedings volume.

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NATURAL GUM-MEDIATED GREEN SYNTHESIS AND CHARACTERIZATION OF CuTiNi TERNARY NANOCOMPOSITE

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ABSTRACT

In this study, a CuTiNi (CuO-TiO_2-NiO) ternary nanocomposite was successfully synthesized through an environmentally friendly green synthesis approach. Kenger gum obtained from Gundelia tournefortii was employed as a natural reducing and stabilizing agent during the synthesis process. The structural, morphological, and thermal properties of the synthesized nanocomposite were comprehensively characterized using X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), Fourier transform infrared spectroscopy (FTIR), and differential thermal/thermogravimetric analysis (DTA-TGA). The XRD analysis confirmed the successful formation of CuO, TiO_2, and NiO phases within the ternary nanocomposite structure. Diffraction peaks corresponding to monoclinic CuO, anatase TiO_2, and FCC-structured NiO were clearly identified, indicating the crystalline nature of the synthesized material. In addition, the presence of a carbon-related phase originating from the natural gum matrix was observed. FE-SEM images revealed that the nanoparticles possessed a homogeneous spherical morphology with dense agglomerated structures. Particle size analysis demonstrated that the nanocomposite particles ranged between 7.04 and 12.23 nm, with an average particle size of approximately 10 nm. The narrow particle size distribution indicates that the green synthesis route is controllable and reproducible. The obtained findings demonstrate that Kenger gum can be effectively utilized as a sustainable bioagent for the green synthesis of CuTiNi ternary nanocomposites. The synthesized nanostructure exhibited desirable physicochemical characteristics, including nanoscale particle size, homogeneous morphology, and crystalline structure, highlighting the potential of natural gum-mediated synthesis methods in nanomaterial production.

Keywords: CuTiNi nanocomposite; Green synthesis; Kenger gum

INTRODUCTION

Nanotechnology has emerged as one of the most significant scientific advancements in recent decades due to its wide-ranging applications in environmental remediation, catalysis, electronics, energy storage, and biomedicine (Khatoon and Velidandi, 2025). The unique physicochemical properties exhibited by nanomaterials, such as high surface area, enhanced reactivity, and tunable optical and electrical characteristics, have attracted considerable attention from researchers worldwide. However, conventional methods used for nanoparticle synthesis often involve toxic chemicals, high energy consumption, and environmentally hazardous by-products, creating the need for sustainable and eco-friendly alternatives (Dikshit et al., 2021).

Green synthesis has emerged as an environmentally friendly and cost-effective approach for the production of metal and metal oxide nanoparticles (Jeevanandam et al., 2022). As a bottom-up synthesis strategy, it employs natural and renewable resources, such as plant leaves, fruits, roots, bark, and seeds, instead of the toxic reducing and stabilizing agents commonly used in conventional chemical methods (Jain et al., 2024). Plant extracts are particularly attractive for nanoparticle synthesis due to their rich phytochemical composition, including phenolic compounds, flavonoids, tannins, terpenoids, and alkaloids (Thatyana et al., 2023). These bioactive molecules not only facilitate the reduction of metal

ions but also act as capping and stabilizing agents during nanoparticle formation, making plant-mediated synthesis an efficient and sustainable route for producing metal oxide nanomaterials (El Shafey, 2020).

Among the various plant-derived resources used in green synthesis, Gundelia tournefortii (thistle, kenger) has attracted attention because of its rich phytochemical content. This perennial herbaceous plant, naturally distributed throughout the Eastern Mediterranean and Middle Eastern regions, produces a natural gum from its roots that is abundant in phenolic compounds, tannins, and essential oils (Mehrzadeh et al., 2024). These constituents exhibit strong antioxidant and antimicrobial activities and can effectively participate in the reduction and stabilization processes during nanoparticle synthesis. Therefore, Gundelia tournefortii gum represents a promising natural agent for the environmentally friendly synthesis of nanomaterials. Recent studies have demonstrated the successful green synthesis of various mono-, binary-, and ternary-metal oxide nanomaterials using plant-derived extracts as reducing and stabilizing agents. These environmentally friendly approaches have enabled the production of nanomaterials with promising catalytic, antimicrobial, cytotoxic, and environmental applications. Despite the increasing number of studies on plant-mediated synthesis of multicomponent metal oxide nanocomposites, the utilization of Gundelia tournefortii gum for the green synthesis of CuTiNi nanocomposites has not yet been reported. Therefore, the development of a CuTiNi nanocomposite using this natural biopolymer represents a novel contribution to the field of sustainable nanomaterial synthesis and expands the potential applications of plant-based green synthesis strategies.

Composite materials are multiphase systems formed by combining two or more materials with different properties to obtain enhanced performance compared to their individual components (Sadeghi and Cavaliere, 2023). Owing to their improved structural stability, superior functional properties, lower production costs, and broad application potential, nanocomposites have become an important class of advanced materials. In particular, multicomponent metal oxide nanocomposites have attracted significant interest because synergistic interactions among their constituents can lead to improved physicochemical characteristics and enhanced functional performance. Copper oxide (CuO), titanium dioxide (TiO_2), and nickel oxide (NiO) are among the most extensively studied metal oxides due to their remarkable catalytic, optical, electrical, and antimicrobial properties. Since these oxides possess different crystal structures and physicochemical characteristics, their integration into a single nanocomposite system can generate unique structural and surface properties. Furthermore, interfacial interactions among the constituent metal oxides may significantly influence crystal growth, crystallinity, morphology, and overall material performance. Consequently, CuO-TiO_2-NiO based nanocomposites have emerged as promising materials for advanced environmental, catalytic, and biological applications.

Therefore, the aim of the present study was to synthesize a CuTiNi nanocomposite using Gundelia tournefortii gum through an environmentally friendly green synthesis route. The structural, morphological, and thermal properties of the synthesized nanocomposite were systematically investigated using X-ray diffraction (XRD), field-emission scanning electron microscopy (FE-SEM), differential thermal analysis-thermogravimetric analysis (DTA-TGA), and Fourier transform infrared spectroscopy (FT-IR).

MATERIALS AND METHODS

Characterization

The structural properties of the synthesized CuTiNi nanocomposite were investigated using X-ray diffraction (XRD, Bruker D8 Advance) with Cu Kα radiation (λ = 0.154 nm). The surface morphology of the nanocomposite was examined by field-emission scanning electron microscopy (FE-SEM, Zeiss Supra 55). Fourier transform infrared (FT-IR) spectra were recorded in the wavenumber range of 4000-400 cm^{-1} using a PerkinElmer Spectrum 400 spectrometer to identify the functional groups present in the material. Thermal behavior and stability were evaluated through thermogravimetric analysis (TGA, PerkinElmer Pyris 1) and differential thermal analysis (DTA, PerkinElmer DSC 4000).

The CuTiNi nanocomposite was synthesized via a green synthesis approach using Kenger gum extract as a natural reducing and stabilizing agent. Initially, 5 g of Kenger gum was dispersed in 50 mL of distilled water and stirred magnetically at 55 °C for 2 h. Following the extraction process, the gum was removed, and a beige-colored gel-like extract was obtained. Subsequently, titanium(III) chloride ($TiCl_3$, 20% solution in hydrochloric acid, Sigma-Aldrich), copper(II) acetate monohydrate ($Cu(CH_3COO)_2 \cdot H_2O$, Sigma-Aldrich), and nickel(II) chloride hexahydrate ($NiCl_2 \cdot 6H_2O$, Sigma-Aldrich) were added to the extract at a molar ratio of 1:1:1. The resulting mixture was continuously stirred at 75 °C overnight to facilitate the formation of the nanocomposite precursor. The obtained precipitate was separated by centrifugation at 5000 rpm, followed by repeated washing to remove residual impurities and unreacted precursors. The purified precipitate was then dried at room temperature. Finally, the dried powder was annealed in a muffle furnace at 450 °C, resulting in the formation of the CuTiNi nanocomposite. A schematic illustration of the experimental procedure employed for the green synthesis of the CuTiNi nanocomposite is presented in Figure 1.

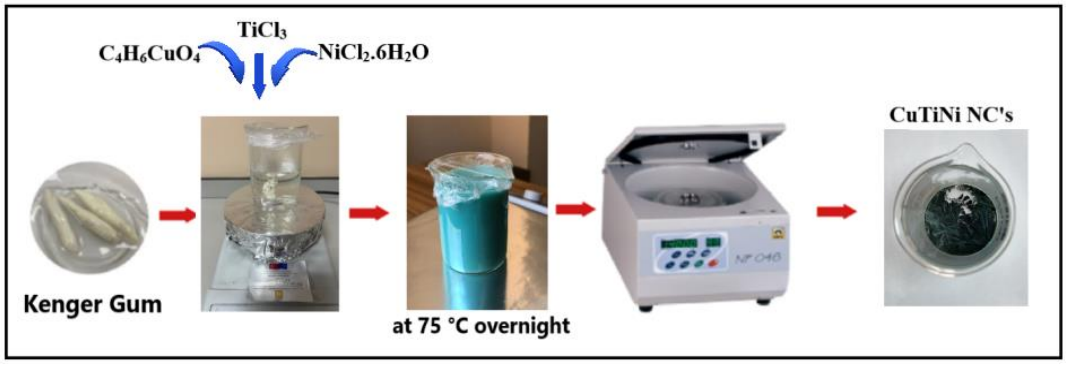


Figure 1. Schematic illustration of the CuTiNi nanocomposites synthesis process.

RESULTS

XRD Analysis of the CuTiNi Nanocomposite

A thorough examination of the XRD pattern of the CuTiNi nanocomposite revealed a crystalline structure with prominent diffraction peaks corresponding to CuO, TiO_2, and NiO phases (Figure 2). The diffractogram was recorded over a 2θ range of 10°-80°, and several characteristic diffraction peaks corresponding to different crystal planes were observed. The detected peaks confirmed the presence of the three main components, namely CuO, TiO_2, and NiO, together with a carbon (C) phase. The diffraction peaks located at $2\theta \approx 32.36°$, 35.65°, 39.72°, 47.80°, and 68.44° were indexed to the (110), (−111), (200), (−202), and (220) crystal planes of monoclinic CuO, respectively (Arulkumar et al., 2025). In addition, the peaks observed at $2\theta \approx 25.20°$, 37.91°, and 54.23° corresponded to the (101), (004), and (105) planes of the anatase TiO_2 phase (Papitha et al., 2024). Furthermore, diffraction peaks appearing at approximately $2\theta \approx 37.91°$, 62.65°, and 75.03° were assigned to the (111), (220), and (311) planes of NiO, confirming the presence of a face-centered cubic (FCC) crystal structure within the nanocomposite (Niskanen et al., 2019). The presence of these characteristic peaks demonstrates the successful formation of the CuTiNi nanocomposite through the green synthesis process.

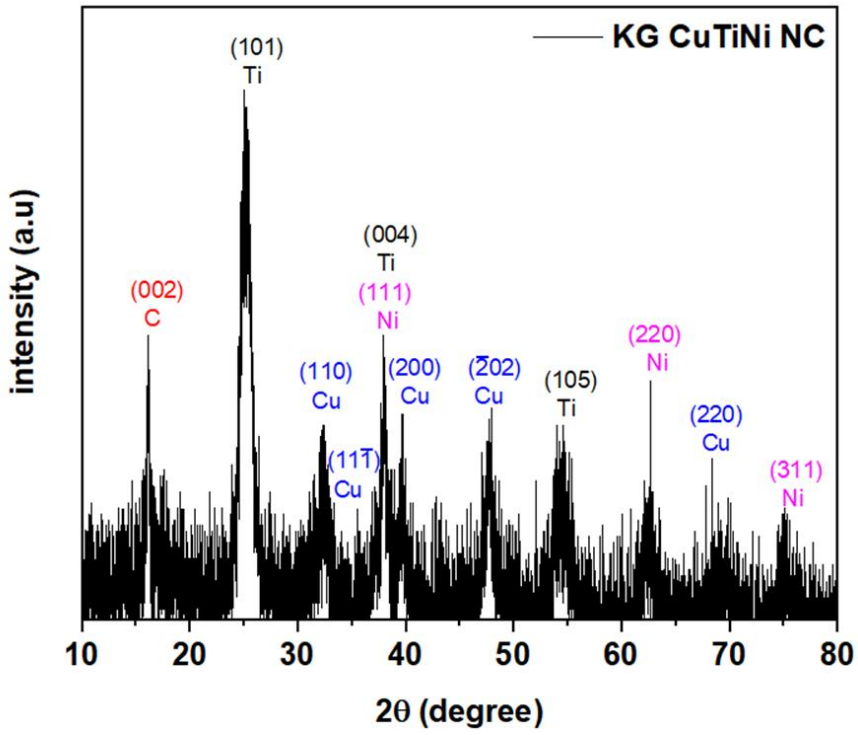


Figure 2. XRD pattern of the synthesized CuTiNi nanocomposite.

These results indicate the successful incorporation of Cu, Ti, and Ni nanoparticles into the nanocomposite. The presence of multiple phases within the CuTiNi nanocomposite structure suggests the potential for synergistic interactions between different metal oxides, which may contribute to the enhanced properties of the material. The crystallite size can be estimated by examining the peak widths and utilizing the Debye-Scherrer formula. The crystallite size was calculated using the Debye-Scherrer equation (Eq. 1) (Stokes and Wilson 1944; Masho et al. 2024).

$$D = \frac{0.9\lambda}{\beta cos\theta} \qquad (1)$$

Where λ is the X-ray wavelength (0.15406 nm for Cu Kα), θ is Bragg's diffraction angle, and β is the peak's full width at half maximum (FWHM) in radians.

D is the grain size, λ is the wavelength, β is the full width at half maximum (FWHM) of the peak shown in the X-ray diffraction pattern, and θ is the Bragg reflection angle. As illustrated in Table 1, the XRD structural parameters of CuTiNi NC are presented. The crystallite sizes, as determined by the calculations, ranged from 5.48 to 13.84 nanometers. The mean crystallite size was determined to be approximately 8.19 nanometers.

Table 1. XRD structural parameters of CuTiNi NCs

Bragg's angle (2θ)	(hkl)	FWHM	Crystalline size (nm)	PDF Card No	Structure
16.16	(002)	0.30	26.74	03-065-1528	Hexagonal Carbon
25.20	(101)	1.18	6.89	00-064-0863	Tetragonal TiO_2
32.36	(110)	1.27	6.51	00-048-4548	Monoclinic CuO
35.65	(-111)	1.31	6.40	00-048-4548	Monoclinic CuO

37.91	(004)	0.63	13.33	00-064-0863	Tetragonal TiO_2
37.91	(111)	0.63	13.33	00-004-0835	Cubic NiO
39.72	(200)	0.61	13.84	00-048-4548	Monoclinic CuO
47.80	(-202)	1.10	7.89	00-048-4548	Monoclinic CuO
62.65	(220)	1.32	7.04	00-004-0835	Cubic NiO
54.23	(105)	1.64	5.44	00-064-0863	Tetragonal TiO_2
68.44	(220)	1.76	5.48	00-048-4548	Monoclinic CuO
75.03	(311)	1.75	5.72	00-004-0835	Cubic NiO

FE-SEM Analysis of the CuTiNi Nanocomposite

The FE-SEM image presented in Figure 3 reveal the morphological characteristics of the synthesized CuTiNi nanocomposite at magnifications of 300.00 KX. The micrographs show densely packed nanoparticles with a predominantly spherical morphology and a relatively homogeneous distribution. The particles exhibit a tendency to form agglomerated clusters, which is commonly attributed to the high surface energy and strong interparticle interactions of nanoscale materials. Particle size analysis revealed that the nanoparticle diameters ranged from 7.04 to 12.23 nm, with an average particle size of approximately 10 nm. The obtained size range confirms the successful formation of a nanostructured material and suggests a high surface area, which may enhance the physicochemical properties of the nanocomposite. Furthermore, the relatively narrow particle size distribution indicates that the green synthesis method provides controlled and reproducible nanoparticle formation. The FE-SEM images also show distinct particle boundaries and well-defined crystalline features, suggesting successful crystallization of the material. The observed agglomeration behavior further indicates strong interactions among the Cu, Ti, and Ni oxide components, supporting the formation of an integrated CuTiNi nanocomposite structure.

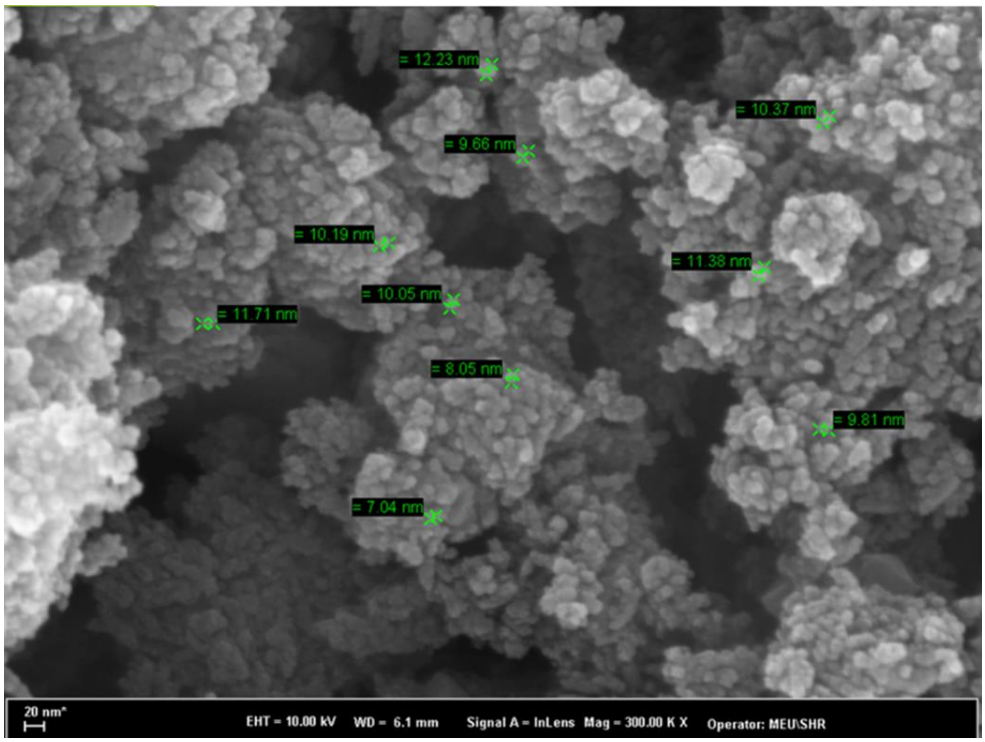


Figure 3. FE-SEM image of the synthesized CuTiNi nanocomposite.

FT-IR Analysis of the CuTiNi Nanocomposite

The FTIR spectrum of the synthesized CuTiNi nanocomposite is presented in Figure 4. A broad absorption band centered at 3329 cm^{-1} is attributed to the stretching vibration of hydroxyl (O–H) groups, indicating the presence of surface-adsorbed water molecules and residual phytochemical compounds originating from the plant extract used during the green synthesis process.

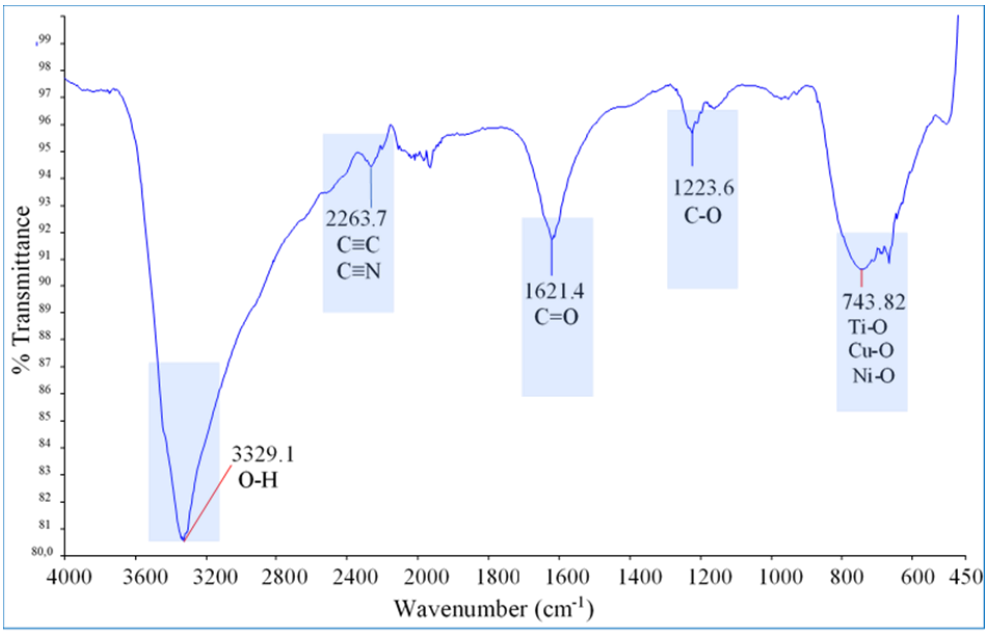


Figure 4. FTIR Spectrum of the Synthesized CuTiNi Nanocomposite.

The weak band observed around 2264 cm^{-1} may be associated with C≡N or C≡C stretching vibrations, which can arise from trace organic residues remaining on the nanocomposite surface. The absorption peak at 1621 cm^{-1} corresponds to the bending vibration of adsorbed water molecules (H–O–H) and may also overlap with C=O stretching vibrations of oxygen-containing organic functional groups (Bala et al., 2023). The band located at 1224 cm^{-1} is assigned to C–O stretching vibrations, indicating the presence of alcohol, phenolic, or ether groups derived from the phytochemicals acting as reducing and stabilizing agents during synthesis. A strong absorption band observed in the low-wavenumber region at approximately 744 cm^{-1} is attributed to metal-oxygen (M-O) vibrations, confirming the formation of the mixed metal oxide nanocomposite (Papitha et al., 2024). This band is associated with the characteristic stretching vibrations of Cu-O, Ti-O, and Ni-O bonds. The presence of these metal-oxygen vibrations confirms the successful synthesis of the CuTiNi nanocomposite structure.

TGA/DTA Analysis of the CuTiNi Nanocomposite

The thermal behavior of the synthesized CuTiNi nanocomposite was investigated by TGA/DTA analysis, and the results revealed a two-step weight-loss pattern associated with the decomposition of different components within the material (Figure 5). The first weight-loss stage occurred between 111 and 238°C, with a mass reduction of approximately 3.9%. This loss is mainly attributed to the evaporation of physically adsorbed water molecules and residual solvents trapped within the nanocomposite structure during the synthesis process. A second and more pronounced weight-loss stage was observed in the temperature range of 336–648°C, corresponding to a mass loss of approximately 6.3%. This behavior is associated with the thermal decomposition of residual organic constituents originating from the Kenger gum used during the green synthesis process. At elevated temperatures, the degradation of polysaccharides and other organic compounds leads to the release of volatile products and the removal of carbonaceous residues from the nanocomposite surface.

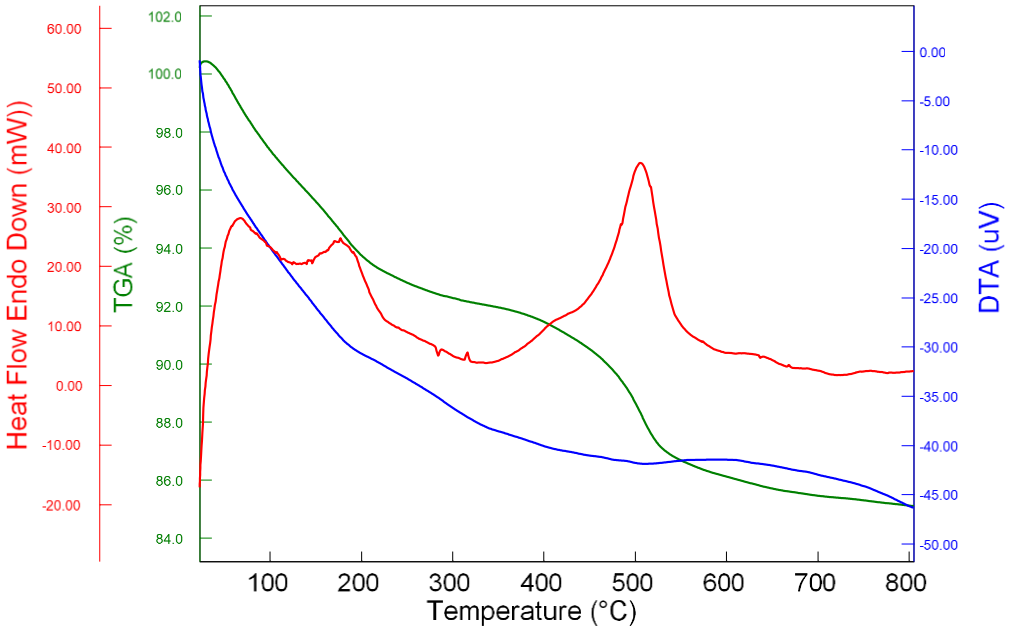


Figure 5. TGA and DTA curves of the synthesized CuTiNi nanocomposite.

Beyond this temperature range, no significant mass loss was detected, indicating the high thermal stability of the metal oxide phases present in the nanocomposite. The remaining residue is attributed to thermally stable CuO, TiO_2, and NiO phases, which do not undergo substantial decomposition under the applied heating conditions. The relatively low total weight loss and the high residual mass confirm the successful formation of a thermally stable CuTiNi nanocomposite. These findings demonstrate that the organic components involved in the green synthesis process are effectively removed upon heating, while the metal oxide framework remains structurally stable at elevated temperatures.

DISCUSSION

The successful synthesis of the CuTiNi ternary nanocomposite demonstrates the effectiveness of Kenger gum as a natural reducing and stabilizing agent in a green synthesis process. The coexistence of CuO, TiO_2, and NiO phases within the nanocomposite suggests the formation of a multifunctional material in which the individual metal oxides may contribute synergistically to its overall performance. The crystallite sizes obtained from XRD and the particle sizes observed in FE-SEM analysis were in good agreement, confirming the formation of nanocrystalline particles. The nanoscale dimensions and relatively homogeneous morphology are expected to provide a high surface area, which is advantageous for catalytic, photocatalytic, and environmental applications. Although some particle agglomeration was observed, this behavior is commonly reported for nanomaterials due to their high surface energy. FTIR analysis revealed the presence of residual phytochemical functional groups originating from Kenger gum, indicating their role in nanoparticle formation and stabilization. Furthermore, the characteristic metal–oxygen vibrations confirmed the successful formation of the CuO, TiO_2, and NiO phases. The TGA/DTA results demonstrated good thermal stability, with only limited weight loss associated with moisture evaporation and the decomposition of residual organic compounds. The high residual mass at elevated temperatures confirms the stability of the metal oxide framework. Overall, the combination of crystalline structure, nanoscale particle size, homogeneous morphology, and thermal stability indicates that the synthesized CuTiNi nanocomposite is a promising material for future applications in environmental remediation, photocatalysis, and other nanotechnology-based fields.

CONCLUSION

In this study, a CuTiNi (CuO–TiO_2–NiO) ternary nanocomposite was successfully synthesized using an environmentally friendly green synthesis approach with Kenger gum as a natural reducing and stabilizing agent. XRD analysis confirmed the formation of crystalline CuO, TiO_2, and NiO phases,

while FE-SEM observations revealed predominantly spherical nanoparticles with a homogeneous distribution and an average particle size of approximately 10 nm. FTIR results verified the presence of characteristic metal–oxygen bonds and phytochemical functional groups involved in the synthesis process. Furthermore, TGA/DTA analysis demonstrated that the synthesized nanocomposite possesses good thermal stability, with only minor weight loss associated with moisture evaporation and residual organic components. The combination of crystalline structure, nanoscale particle size, homogeneous morphology, and thermal stability suggests that the synthesized CuTiNi nanocomposite has significant potential for applications in photocatalysis, environmental remediation, and other advanced nanotechnology fields.

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PLANT-MEDIATED GREEN SYNTHESIS OF CuO NANOPARTICLES FOR METHYL RED DYE DEGRADATION

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ABSTRACT

In this study, copper oxide (CuO) nanoparticles (NPs) were successfully synthesized via a green synthesis approach using *Mentha arvensis* plant extract as a natural reducing and stabilizing agent. Green synthesis methods have attracted considerable attention due to their environmentally friendly, cost-effective, and sustainable characteristics compared with conventional chemical synthesis routes. The synthesized CuO NPs were characterized by Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD) analyses to investigate their structural and chemical properties. FTIR spectra confirmed the presence of various phytochemical functional groups originating from the plant extract, which played a significant role in the stabilization of the NPs. XRD results revealed the crystalline nature and phase purity of the synthesized CuO NPs. The photocatalytic performance of the obtained CuO NPs was evaluated through the degradation of Methyl Red (MR) dye under irradiation conditions. UV-Vis spectroscopic measurements demonstrated a gradual decrease in dye absorbance intensity throughout the reaction period. After 105 minutes of photocatalytic treatment, the degradation efficiency of MR dye was determined to be approximately 41%. These results demonstrate that the synthesized CuO NPs possess measurable photocatalytic activity against organic dye pollutants. These results demonstrate that the synthesized CuO NPs possess measurable photocatalytic activity against organic dye pollutants. In addition, the study provides preliminary insights into the applicability of green-synthesized CuO NPs for environmental remediation studies.

Keywords: Green synthesis, CuO nanoparticles, Methyl Red dye, Dye degradation

INTRODUCTION

The rapid expansion of industrial activities has resulted in the continuous release of hazardous organic pollutants into aquatic environments, posing a serious threat to ecosystems and human health (Saxena V 2025). Among these pollutants, synthetic dyes are considered one of the major contributors to water contamination due to their widespread use in textile, paper, printing, and chemical industries. Many of these dyes exhibit high chemical stability and resistance to biodegradation, making their removal from wastewater a significant environmental challenge (Lin et al., 2023). Advanced oxidation processes have gained considerable attention as effective methods for the elimination of persistent organic contaminants. Among these technologies, photocatalytic degradation is regarded as a promising and sustainable approach because it can mineralize organic pollutants into harmless products such as carbon dioxide and water under light irradiation (Al Miad et al., 2024). The efficiency of photocatalytic systems largely depends on the properties of the semiconductor materials employed as catalysts.

Metal oxide NPs have emerged as highly effective photocatalysts due to their unique structural and electronic characteristics (Geldasa et al., 2023). In particular, CuO has attracted increasing interest because it is a p-type semiconductor with a narrow band gap ranging from approximately 1.2 to 1.9 eV. This property enables efficient absorption of visible light and enhances photocatalytic activity under solar irradiation. Furthermore, CuO NPs possess several advantageous features, including low cost, chemical stability, environmental compatibility, and high surface reactivity. These characteristics have

led to their extensive investigation in applications such as photocatalysis, sensing, antimicrobial treatments, energy storage, and environmental remediation.

The physicochemical properties of NPs are strongly influenced by their synthesis route. Conventional physical and chemical synthesis methods often require elevated temperatures, sophisticated equipment, and toxic reagents, which may generate environmentally harmful residues. Consequently, there has been growing interest in the development of green synthesis approaches that provide safer and more sustainable alternatives for NP production. Green synthesis utilizes naturally occurring biomolecules as reducing and stabilizing agents, thereby minimizing the use of hazardous chemicals and reducing environmental impact (Salem and Fouda, 2021). Plant extracts have become particularly attractive in green nanotechnology because they are rich sources of bioactive compounds capable of facilitating NP formation. These phytochemicals, including phenolic compounds, flavonoids, terpenoids, and essential oils, participate in the reduction of metal ions and contribute to NP stabilization. Among various medicinal and aromatic plants, Mentha arvensis has received considerable attention due to its abundance of biologically active constituents. The plant contains significant amounts of phenolic acids, flavonoids, and essential oil components that exhibit strong antioxidant activity, making it an effective natural reducing and capping agent for NP synthesis (El Shafey, 2020). In addition, its widespread availability, low cost, and renewable nature further support its utilization in environmentally friendly nanomaterial production.

Methyl Red is an azo dye commonly used as a coloring agent in numerous industrial processes and is frequently selected as a model pollutant in photocatalytic studies (Alamzeb et al., 2026). Due to its complex aromatic structure and high stability, MR can persist in aquatic environments for extended periods. The presence of such dyes in water bodies decreases light penetration and may generate toxic effects on aquatic organisms. Therefore, the development of efficient photocatalysts for the degradation of MR remains an important objective in environmental research.

In this study, CuO NPs were synthesized through a green synthesis method using Mentha arvensis extract as a natural reducing and stabilizing agent. The synthesized NPs were characterized by X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) analyses to evaluate their structural and chemical properties. Furthermore, their photocatalytic performance was investigated through the degradation of MR dye under irradiation conditions. The study aims to contribute to the development of sustainable NP synthesis strategies and to evaluate the potential of green-synthesized CuO NPs for wastewater treatment and environmental remediation applications.

MATERIALS AND METHODS

Characterization

The synthesized CuTiNi nanocomposite was characterized by X-ray diffraction (XRD, Bruker D8 Advance) using Cu Kα radiation (λ = 0.154 nm) to determine its phase structure and crystallinity. In addition, Fourier transform infrared spectroscopy (FT-IR, PerkinElmer Spectrum 400) was employed in the 4000–400 cm^{-1} region to identify the functional groups involved in the nanocomposite structure.

Green Synthesis of CuO Nanocomposite

Fresh Mentha arvensis leaves were thoroughly washed with tap water followed by distilled water to remove dust and other impurities. The cleaned plant material was shade-dried at room temperature and subsequently ground into a fine powder using a mechanical grinder. For extract preparation, 10 g of the powdered plant material was mixed with 100 mL of distilled water and incubated at 40 °C for 60 min. The resulting mixture was filtered to remove solid residues, and the obtained extract was used as the stock solution for NP synthesis. The pH of the extract was measured as 6.6. CuO NPs were synthesized using the prepared Mentha arvensis extract as a natural reducing and stabilizing agent. Subsequently, 2.41 g of $CuSO_4 \cdot 5H_2O$ was dissolved in 100 mL of the plant extract and subjected to ultrasonic treatment for 30 min to ensure homogeneous dispersion. The reaction mixture was then maintained at 70 °C and allowed to react overnight. Following the completion of the reaction, the formed NPs were collected by centrifugation and repeatedly washed with distilled water to remove residual impurities. The obtained

precipitate was dried and subsequently calcined at 400 °C for 1 h to enhance crystallinity and promote the formation of crystalline CuO NPs.

Photocatalytic Activity

The photocatalytic activity of the synthesized CuO NPs was evaluated using MR dye as a model organic pollutant. An aqueous MR solution with a concentration of 100 mg/L was prepared for the photocatalytic experiments. Before light irradiation, the dye solution containing the catalyst was magnetically stirred in the dark for 1 h to establish adsorption–desorption equilibrium between the dye molecules and the catalyst surface (Vindhya and Kavitha, 2023). Subsequently, 0.1 g of CuO NPs was added to the dye solution, and the suspension was continuously stirred under visible-light irradiation provided by a 300 W Xenon lamp equipped with a solar simulator system. The photocatalytic reaction was carried out for 105 min. During the experiment, 2 mL aliquots were withdrawn from the reaction mixture at 15 min intervals and analyzed using a UV–Vis spectrophotometer. The changes in the characteristic absorption peak of MR were monitored to determine the degradation behavior of the dye. The photocatalytic degradation efficiency was calculated according to Equation (1) based on the Beer-Lambert law (Shu Set al., 2023).

$$efficiency\ of\ degradation\ (\%) = \left(\frac{C_0 - C_t}{C_0}\right) \times 100 \qquad (1)$$

The concentration changes obtained from the UV-Vis measurements were used to evaluate the degradation performance of the synthesized CuO NPs as a function of irradiation time.

RESULTS

XRD Characterization of CuO NPs

The XRD pattern of the green synthesized CuO NPs is presented in Figure 1. The diffraction peaks observed at approximately 35.5°, 36.7°, 38.8°, 49.0°, 61.6°, 66.2°, and 68.1° correspond to the (-111), (002), (111), (-202), (-113), (31-1), and (113) crystallographic planes of monoclinic CuO, respectively. These diffraction peaks are in good agreement with the standard CuO phase (JCPDS No. 48-1548), confirming the successful formation of crystalline CuO NPs (Mohamed et al., 2021). The absence of additional diffraction peaks indicates that no significant impurity phases, such as Cu_2O or metallic Cu, were present in the synthesized sample, demonstrating the phase purity of the obtained NPs. The relatively broad diffraction peaks suggest the formation of nanosized crystallites, which is a characteristic feature of nanostructured materials. Peak broadening may also be associated with lattice strain and the small crystallite size resulting from the green synthesis process. The high intensity of the diffraction peaks confirms the crystalline nature of the synthesized CuO NPs. Furthermore, the successful formation of a single-phase CuO structure indicates that the phytochemicals present in the Mentha arvensis extract effectively facilitated the reduction and stabilization processes during NP synthesis.

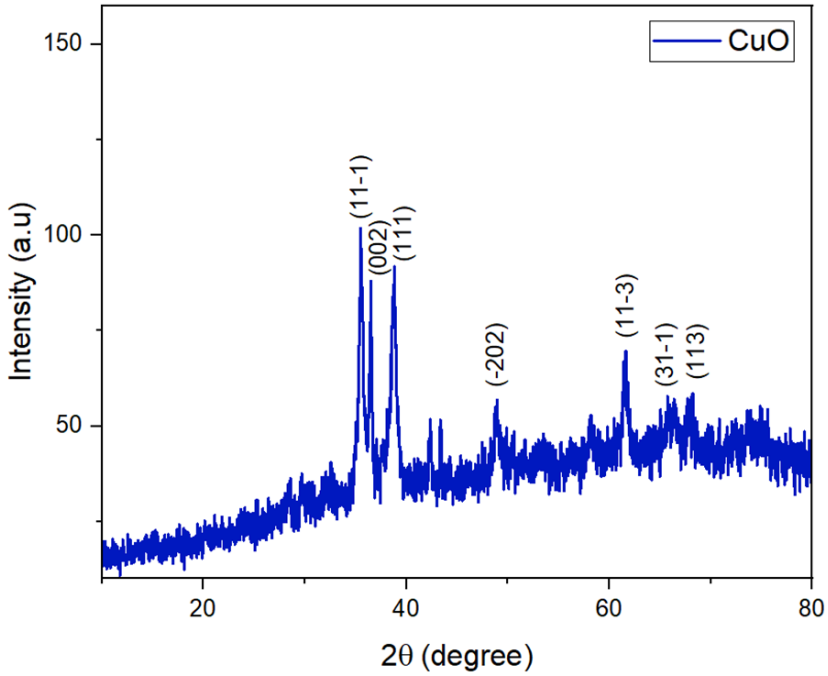


Figure 1. XRD pattern of the synthesized CuO NPs

FT-IR Analysis of the CuO NPs

Figure 2 presents the FT-IR spectrum of the CuO NPs synthesized using Mentha arvensis extract. The spectrum exhibits several absorption bands associated with the chemical groups present on the NP surface. A weak band detected near 2350 cm^{-1} is attributed to the asymmetric stretching vibration of atmospheric carbon dioxide. In addition, absorption bands observed between 1080 and 950 cm^{-1} can be assigned to C–O and C–O–C stretching vibrations, indicating the presence of trace organic compounds derived from the plant extract. These phytochemical residues are believed to have played an important role during NP synthesis by facilitating the reduction of Cu^{2+} ions and assisting in the stabilization of the formed particles. The retention of a small amount of these biomolecules on the NP surface is commonly observed in plant-mediated synthesis processes. A prominent absorption band appears at approximately 520 cm^{-1}, which is characteristic of the Cu–O bond stretching vibration. This band is considered a distinctive feature of CuO and provides strong evidence for the successful formation of copper oxide NPs (Swamy et al., 2025). The observed metal–oxygen vibration is in agreement with previously reported studies on CuO nanomaterials and supports the XRD findings regarding the crystalline CuO phase. The FT-IR results suggest that the calcination and purification steps effectively removed most of the organic constituents originating from the plant extract. Nevertheless, a limited amount of surface-bound biomolecules remained after synthesis, contributing to NP stabilization.

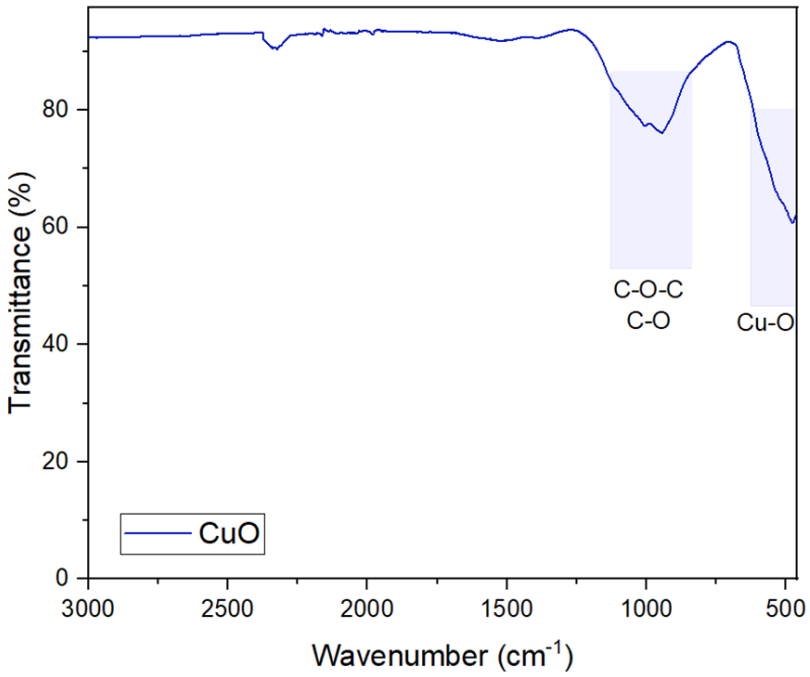


Figure 2. FTIR Spectrum of the Synthesized CuO NPs

Photocatalytic Activity of CuO NPs

The photocatalytic activity of the synthesized CuO NPs was evaluated through the degradation of MR dye under light irradiation over a period of 105 min. Figure 3 illustrates the time-dependent UV-Vis absorbance spectra of the MR solution in the presence of CuO NPs. A progressive decrease in the characteristic absorption peak of MR was observed with increasing exposure time, confirming the photocatalytic breakdown of the dye molecules. The degradation efficiency exhibited a regular and continuous increase as the reaction progressed. Quantitatively, the degradation percentages were calculated as 7%, 16%, 20%, 29%, 33%, 38%, and 41% at 15, 30, 45, 60, 75, 90, and 105 min, respectively. Notably, a maximum photocatalytic degradation efficiency of 41% was achieved at the end of the 105-min reaction period. The degradation rate was considerably higher during the initial stages of the reaction, which subsequently slowed down and exhibited a tendency to approach an equilibrium state toward the later intervals. This deceleration can be attributed to the gradual occupation of active catalytic sites on the CuO surface by degradation by-products and the decreasing concentration of initial dye molecules available for reaction.

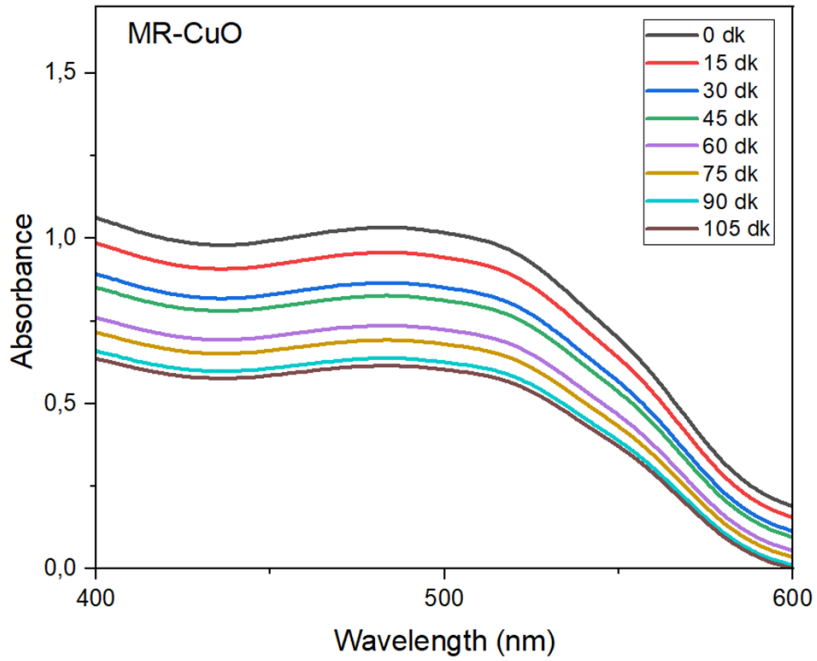


Figure 3. Photocatalytic Degradation Performance of CuO NPs toward MR Dye

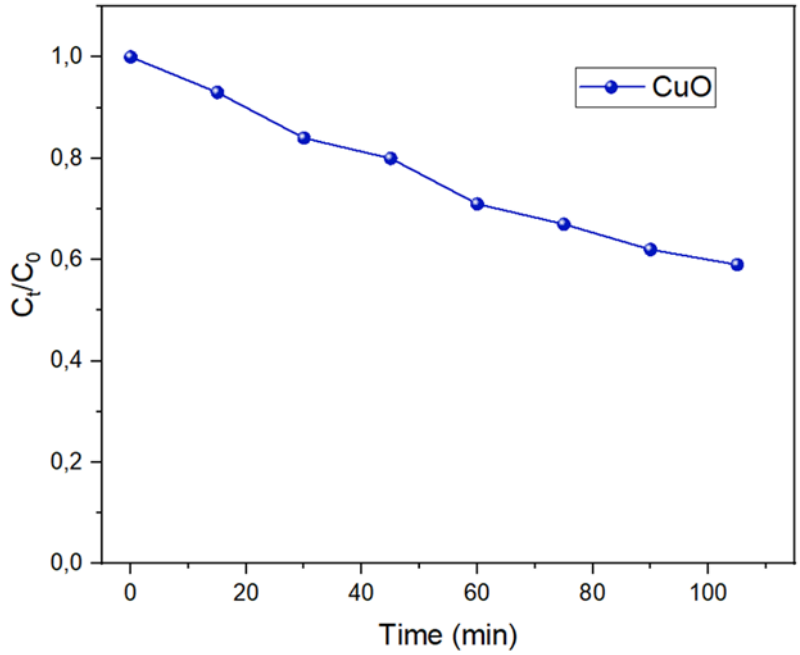


Figure 4. Degradation Efficiency of MR Using CuO NPs

Figure 4 illustrates the variation in the relative concentration (C_t/C_0) of MR dye as a function of irradiation time in the presence of the synthesized CuO NPs. The gradual decrease in the C_t/C_0 values throughout the reaction indicates the effective photocatalytic degradation of MR under visible light irradiation. The calculated C_t/C_0 ratios were 0.93, 0.84, 0.80, 0.71, 0.67, 0.62, and 0.59 after 15, 30, 45, 60, 75, 90, and 105 min of irradiation, respectively. These results clearly demonstrate a continuous reduction in dye concentration with increasing reaction time. The observed decrease in MR concentration confirms the photocatalytic activity of the synthesized CuO NPs under visible-light irradiation. Upon light exposure, CuO generates electron–hole pairs that participate in oxidation–reduction reactions on the catalyst surface, leading to the formation of reactive oxygen species such as hydroxyl (•OH) and superoxide ($O_2^{\bullet -}$) radicals (Shaw et al., 2022). These highly reactive species attack

and degrade the dye molecules, resulting in a progressive decrease in MR concentration throughout the irradiation period. A more pronounced reduction in C_t/C_0 was observed during the early stages of the reaction, indicating a relatively higher degradation rate when the concentration of MR was high and a larger number of active sites were available on the catalyst surface. As the reaction proceeded, the degradation rate gradually decreased, which may be attributed to the lower concentration of dye molecules and the possible accumulation of intermediate degradation products on the catalyst surface. After 105 min of visible-light irradiation, the C_t/C_0 value reached 0.59, corresponding to a degradation efficiency of approximately 41%. This finding demonstrates that the green-synthesized CuO NPs possess appreciable photocatalytic activity toward the degradation of MR dye. The photocatalytic performance can be attributed to the visible light responsive nature of CuO, its nanoscale dimensions, and its high surface reactivity. Overall, the results suggest that the synthesized CuO NPs have potential applications in the treatment of dye-contaminated wastewater and other environmental remediation processes.

DISCUSSION

The results obtained in this study demonstrate that Mentha arvensis extract can successfully serve as both a reducing and stabilizing agent in the green synthesis of CuO NPs. The XRD analysis confirmed the formation of a highly crystalline monoclinic CuO phase without detectable impurity peaks, indicating that the plant-mediated synthesis route was effective in producing phase-pure CuO NPs. The absence of secondary phases such as Cu_2O or metallic copper suggests that the synthesis and calcination conditions were sufficient to promote complete conversion to CuO. FT-IR analysis further supported the successful formation of CuO NPs by revealing the characteristic Cu–O stretching vibration in the low-wavenumber region. In addition, the presence of weak organic bands associated with C–O and C–O–C groups indicates that a small amount of phytochemical residues remained on the NP surface after synthesis. These biomolecules likely played an important role during NP formation by facilitating the reduction of Cu^{2+} ions and preventing excessive particle aggregation. Such surface-bound phytochemicals may also contribute to the stability and surface reactivity of the NPs. The photocatalytic experiments demonstrated that the synthesized CuO NPs were capable of degrading MR under visible-light irradiation. The gradual decrease in the relative dye concentration throughout the reaction period confirms the photocatalytic functionality of the synthesized material (Riaz et al., 2020). The observed degradation behavior can be attributed to the semiconductor nature of CuO, which enables the absorption of visible light and the generation of electron hole pairs (Baran et al., 2021). These charge carriers subsequently participate in the formation of reactive oxygen species, including hydroxyl and superoxide radicals, which are responsible for the oxidative degradation of dye molecules. The photocatalytic efficiency observed in this study may be associated with several factors, including the crystalline nature of the synthesized NPs, their nanoscale dimensions, and the availability of active surface sites. High crystallinity generally enhances charge transport and reduces the recombination rate of photogenerated electron-hole pairs, thereby improving photocatalytic performance. Furthermore, the nanoscale structure provides a larger surface area for dye adsorption and photocatalytic reactions. The residual phytochemicals derived from the plant extract may have also influenced the surface properties of the NPs, potentially contributing to their photocatalytic activity. Although a degradation efficiency of approximately 41% was achieved after 105 min of irradiation, complete degradation was not attained under the experimental conditions employed. This may be related to factors such as catalyst dosage, irradiation time, initial dye concentration, light intensity, and electron hole recombination processes. Therefore, further optimization of reaction parameters may enhance the photocatalytic efficiency of the synthesized CuO NPs (Nouren et al., 2024). Overall, the findings highlight the potential of Mentha arvensis-mediated green synthesis as a simple, sustainable, and environmentally benign approach for producing CuO NPs. The combination of high phase purity, crystalline structure, and measurable photocatalytic activity suggests that these NPs may be considered promising candidates for wastewater treatment and environmental remediation applications. Furthermore, the study contributes to the growing body of research focused on the development of green nanomaterials for sustainable environmental technologies.

CONCLUSION

In this study, CuO NPs were successfully synthesized through a green synthesis approach using Mentha arvensis extract as a natural reducing and stabilizing agent. The structural characterization results confirmed the successful formation of crystalline and phase-pure CuO NPs. XRD analysis verified the monoclinic CuO structure, while FT-IR analysis revealed the characteristic Cu–O vibration band and indicated the involvement of plant-derived phytochemicals in the synthesis process. The photocatalytic performance of the synthesized CuO NPs was evaluated using MR dye as a model pollutant under visible-light irradiation. The gradual decrease in dye concentration and the achieved degradation efficiency of approximately 41% after 105 min demonstrated the photocatalytic capability of the synthesized material. The observed activity was attributed to the visible-light-responsive nature, crystallinity, and surface reactivity of the CuO NPs. Overall, the results indicate that Mentha arvensis mediated synthesis provides a simple, cost-effective, and environmentally friendly route for the production of functional CuO NPs. The synthesized NPs show potential for application in the treatment of dye-contaminated wastewater and other environmental remediation processes. Future studies may focus on optimizing synthesis and reaction parameters to further enhance photocatalytic efficiency and broaden the practical applications of these green-synthesized nanomaterials.

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IS REALISM SUCCESSFUL IN EXPLAINING CHANGE IN INTERNATIONAL RELATIONS?

REALİZM ULUSLARARASI İLİŞKİLERDEKİ DEĞİŞİMİ AÇIKLAMADA BAŞARILI MIDIR?

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ÖZET

Uluslararası ilişkiler disiplininin temel teorik sorunlarından biri değişim problemidir. Uluslararası sistemin neden ve nasıl değiştiği sorusu, farklı teorik yaklaşımlar tarafından farklı biçimlerde açıklanmaktadır. Realizm, uluslararası siyasetin temel dinamiklerinde sürekliliği vurgulayan en etkili teorik geleneklerden biri olmasına rağmen, özellikle Soğuk Savaş'ın sona ermesinden sonra değişimi açıklama kapasitesi bakımından yoğun eleştirilere maruz kalmıştır. Sovyetler Birliği'nin dağılması, Doğu Avrupa'daki komünist rejimlerin çökmesi ve iki kutuplu sistemin büyük bir savaş yaşanmadan sona ermesi, realizmin açıklayıcı gücüne ilişkin tartışmaları yeniden gündeme taşımıştır. Bu çalışma, realizmin uluslararası ilişkilerde değişimi açıklama kapasitesini değerlendirmeyi amaçlamaktadır. Çalışmanın temel argümanı, realizmin değişimi bütünüyle reddeden bir teori olmadığı; Buna karşın açıklayıcı gücünün büyük ölçüde güç dağılımı ve güvenlik dinamiklerinden kaynaklanan değişimlerle sınırlı olduğudur. Bu çerçevede çalışma, Soğuk Savaş'ın sona ermesi etrafında gelişen teorik tartışmaları incelemekte ve realizmin güçlü ve zayıf yönlerini karşılaştırmalı biçimde değerlendirmektedir. Sonuç olarak realizmin değişimi açıklamada tamamen başarısız olmadığı, ancak normatif ve ideasyonel dönüşümleri açıklamada önemli sınırlılıklar taşıdığı ileri sürülmektedir.

Anahtar Kelimeler: Realizm, değişim, Soğuk Savaş, uluslararası ilişkiler teorisi, uluslararası sistem

ABSTRACT

One of the fundamental theoretical problems in the discipline of International Relations is the problem of change. The question of why and how the international system changes has been explained in different ways by competing theoretical approaches. Although realism is one of the most influential theoretical traditions emphasizing continuity in the fundamental dynamics of international politics, it has been subjected to intense criticism regarding its capacity to explain change, particularly after the end of the Cold War. The dissolution of the Soviet Union, the collapse of communist regimes in Eastern Europe, and the peaceful termination of the bipolar system without a major war revived debates concerning the explanatory power of realism. This study aims to evaluate the capacity of realism to explain change in international relations. Its central argument is that realism is not a theory that completely rejects change; rather, its explanatory power is largely limited to changes arising from shifts in the distribution of power and security dynamics. Within this framework, the study examines the theoretical debates surrounding the end of the Cold War and comparatively assesses the strengths and weaknesses of realism. It concludes that realism is not entirely unsuccessful in explaining change; however, it faces significant limitations in accounting for normative and ideational transformations.

Keywords: Realism, change, Cold War, international relations theory, international system.

GİRİŞ

Uluslararası ilişkiler teorisinin temel amaçlarından biri uluslararası sistemin işleyişini açıklamak olduğu kadar, bu sistemde meydana gelen değişimleri de anlamlandırmaktır. Devletlerin dış politika davranışlarında ortaya çıkan dönüşümler, uluslararası güç dağılımındaki değişiklikler, yeni uluslararası kurumların ortaya çıkışı ve uluslararası düzenin yeniden şekillenmesi disiplinin merkezî araştırma alanları arasında yer almaktadır. Bununla birlikte değişimin nedenleri ve mekanizmaları konusunda teorik yaklaşımlar arasında önemli görüş ayrılıkları bulunmaktadır. Bu durum değişim problemini uluslararası ilişkiler teorisinin en tartışmalı konularından biri hâline getirmektedir.

Uluslararası sistem tarih boyunca önemli dönüşümler yaşamıştır. Avrupa güç dengesi sisteminin ortaya çıkışı, iki dünya savaşı sonrasında kurulan yeni uluslararası düzenler, sömürge imparatorluklarının çözülmesi ve Soğuk Savaş'ın sona ermesi bu dönüşümlerin başlıca örnekleri arasında yer almaktadır. Bu tür büyük tarihsel değişimler yalnızca uluslararası siyaseti değil, aynı zamanda bu siyaseti açıklamaya çalışan teorileri de sınamaktadır. Çünkü bir teorinin açıklayıcı gücü yalnızca mevcut düzeni açıklayabilmesine değil, aynı zamanda bu düzenin nasıl değiştiğini açıklayabilmesine de bağlıdır.

Değişim problemi, uluslararası ilişkiler disiplininde uzun süredir tartışılmasına rağmen üzerinde ortak bir uzlaşı sağlanabilmiş bir konu değildir. Holsti'ye göre teorisyenler değişimin gerçekleştiği konusunda hemfikir olsalar da değişimin ne olduğu ve hangi mekanizmalar aracılığıyla ortaya çıktığı konusunda ortak bir teorik çerçeve geliştirememişlerdir (Holsti, 1998). Dolayısıyla değişim problemi yalnızca belirli teorilerin değil, disiplinin genel teorik sınırlarının bir göstergesi olarak değerlendirilebilir.

Uluslararası ilişkiler teorileri değişimin kaynakları konusunda farklı açıklamalar sunmaktadır. Liberal yaklaşımlar ekonomik karşılıklı bağımlılık, uluslararası kurumlar ve demokratikleşme süreçlerini ön plana çıkarırken, inşacı yaklaşımlar normların, kimliklerin ve fikirlerin dönüştürücü etkisini vurgulamaktadır (Keohane & Nye, 1977; Keohane, 1984; Wendt, 1999; Finnemore, 1996). Buna karşılık realizm, değişimin temel kaynağını büyük ölçüde güç dağılımındaki dönüşümlerde ve güvenlik dinamiklerinde aramaktadır. Bu bakımdan realizm, uluslararası sistemde sürekliliği açıklama kapasitesi yüksek olmakla birlikte, değişimi açıklama kapasitesi bakımından sıklıkla eleştirilmektedir (Lebow, 1994; Gaddis, 1992).

Realizm, uluslararası ilişkiler disiplininin en etkili teorik geleneklerinden biridir. Klasik realizmden neorealizme kadar uzanan geniş literatürde uluslararası siyasetin temel özelliklerinin tarih boyunca büyük ölçüde değişmeden kaldığı ileri sürülmektedir. Güç mücadelesi, güvenlik kaygıları, çıkar çatışmaları ve anarşi gibi kavramlar realist düşüncenin temelini oluşturmaktadır. Morgenthau bu sürekliliğin kaynağını insan doğasında görürken, Waltz uluslararası sistemin anarşik yapısına vurgu yapmaktadır. Her iki yaklaşım da uluslararası siyasette belirli davranış örüntülerinin tekrarlandığını savunmaktadır (Morgenthau, 1948; Waltz, 1979).

Bu sebeple realizm çoğu zaman değişimden çok sürekliliği açıklayan bir teori olarak değerlendirilmiştir. Bununla birlikte realizmin değişimi tamamen reddettiğini söylemek doğru değildir. Özellikle Gilpin'in çalışmaları, realist düşünce içerisinde değişimin önemli bir yer tuttuğunu göstermektedir. Güç geçişleri, hegemonik yükseliş ve gerileyişler ile uluslararası düzenlerin dönüşümü realist literatürde ayrıntılı biçimde incelenmiştir (Gilpin, 1981; Schweller, 1994). Dolayısıyla realizme yönelik temel eleştiri değişimi tamamen reddetmesi değil, değişimin nedenlerini büyük ölçüde maddi güç unsurlarına dayandırmasıdır.

Realizmin değişimi açıklama kapasitesine yönelik tartışmaların yoğunlaşmasında Soğuk Savaş'ın sona ermesi belirleyici bir rol oynamıştır. Sovyetler Birliği'nin dağılması, Doğu Avrupa'daki komünist rejimlerin çökmesi ve iki kutuplu sistemin büyük bir savaş yaşanmadan sona ermesi, birçok araştırmacı tarafından realist teorilerin öngöremediği gelişmeler olarak değerlendirilmiştir. Özellikle Richard Ned Lebow, realizmin yalnızca Soğuk Savaş'ın sonunu öngöremediğini değil, aynı zamanda bu dönüşümün nedenlerini açıklamakta da başarısız olduğunu ileri sürmüştür (Lebow, 1994).

Buna karşılık realist düşünürler söz konusu eleştirileri kabul etmemiştir. Kenneth Waltz'a göre teorilerin temel amacı belirli tarihsel olayları tahmin etmek değil, olayların ortaya çıktığı yapısal koşulları açıklamaktır (Waltz, 2000). Bu bakış açısına göre Sovyetler Birliği'nin hangi tarihte çökeceğini

öngörememek, teorinin bütünüyle başarısız olduğu anlamına gelmemektedir. Benzer şekilde Gaddis, Soğuk Savaş'ın sonunun yalnızca realizmi değil, uluslararası ilişkiler alanındaki hemen hemen bütün teorik yaklaşımları hazırlıksız yakaladığını belirtmektedir (Gaddis, 1992–1993). Realizmin Soğuk Savaş'ın sonunu açıklamakta başarısız olduğu yönündeki yaygın görüşe karşı çıkan Schweller ve Wohlforth (2000), söz konusu olayın realizmi geçersiz kılmadığını, aksine realist teorilerin bu karmaşık dönüşümü açıklamada önemli bir açıklayıcı kapasiteye sahip olduğunu ileri sürmektedirler.

Bu çalışma, realizmin uluslararası değişimi açıklama kapasitesini Soğuk Savaş'ın sona ermesi örneği üzerinden değerlendirmeyi amaçlamaktadır. Çalışmanın temel araştırma sorusu, realizmin uluslararası değişimi açıklamada ne ölçüde başarılı olduğu ve bu başarının hangi koşullar altında sınırlandığıdır. Çalışmanın temel argümanı, realizmin değişimi açıklamada tamamen başarısız olmadığı; öte yandan açıklayıcı gücünün büyük ölçüde güç dağılımı ve güvenlik dinamiklerinden kaynaklanan değişimlerle sınırlı kaldığıdır. Buna karşılık normatif, kurumsal ve düşünsel dönüşümlerin açıklanmasında realizmin daha önemli sınırlılıklarla karşılaştığı ileri sürülmektedir.

Bu çerçevede çalışma dört bölümden oluşmaktadır. İlk bölümde uluslararası ilişkiler teorisinde değişim problemi ele alınacaktır. İkinci bölümde realizmin değişime yaklaşımı klasik realizm, neorealizm ve Gilpin'in hegemonik değişim yaklaşımı üzerinden incelenecektir. Üçüncü bölümde Soğuk Savaş'ın sona ermesi sonrasında realizme yöneltilen eleştiriler ve neorealist savunular değerlendirilecektir. Dördüncü bölümde ise realizmin değişimi açıklamadaki güçlü ve zayıf yönleri tartışılarak genel bir değerlendirme yapılacaktır.

1. ULUSLARARASI İLİŞKİLER TEORİSİNDE DEĞİŞİM PROBLEMİ

Yukarıda da belirtildiği gibi değişimi anlamak disiplin açısından önemlidir. Devlet davranışlarının, uluslararası kurumların, normların ve güç dağılımının zaman içerisinde nasıl dönüştüğünü açıklamak, teorilerin açıklayıcı kapasitesinin önemli bir göstergesi olarak kabul edilmektedir. Bu çerçevede değişim problemi, disiplinin kuruluşundan itibaren teorik tartışmaların merkezinde yer almıştır.

Bununla birlikte değişim kavramı uluslararası ilişkiler literatüründe üzerinde uzlaşılmış bir içeriğe sahip değildir. Holsti'ye göre alanın düşünürleri değişimin gerçekleştiği konusunda aynı fikirde buluşsalar da değişimin ne olduğu, hangi seviyelerde meydana geldiği ve hangi işleyişler aracılığıyla gerçekleştiği konusunda ortak bir teorik bağlam ortaya koyamamışlardır (Holsti, 1998). Bu durum değişim problemini disiplinin en karmaşık teorik meselelerinden biri hâline getirmektedir. Değişim probleminin teorik önemi, yalnızca kavramsal bir tartışma olmasından kaynaklanmamaktadır. Bir teorinin açıklayıcı gücü, mevcut düzeni açıklayabilmesinin yanı sıra bu düzenin nasıl dönüştüğünü de açıklayabilmesine bağlıdır. Uluslararası sistemin belirli dönemlerde istikrar göstermesi kadar, belirli dönemlerde neden ve nasıl değiştiğinin anlaşılması da teorik analiz açısından önem taşımaktadır. Dolayısıyla büyük tarihsel dönüşümler, teorilerin açıklama kapasitesini sınayan kritik olaylar olarak değerlendirilmektedir.

Uluslararası ilişkiler literatüründe değişim farklı düzeylerde ele alınmaktadır. İlk olarak sistemik değişimlerden söz etmek mümkündür. Sistemik değişim, uluslararası sistemin temel yapısında meydana gelen dönüşümleri ifade etmektedir. Kutupluluk yapısındaki değişiklikler, hegemon güçlerin yükselişi ve gerileyişi veya uluslararası düzenin yeniden şekillenmesi sistemik değişim kapsamında değerlendirilmektedir. İki kutuplu sistemin sona ermesi ve Soğuk Savaş sonrası dönemin başlaması bu tür değişimlere önemli bir örnek oluşturmaktadır.

İkinci olarak davranışsal değişimler dikkat çekmektedir. Davranışsal değişim, devletlerin dış politika tercihlerinde meydana gelen dönüşümleri ifade etmektedir. Daha önce çatışma içerisinde bulunan devletlerin iş birliğine yönelmesi, yeni ittifakların kurulması veya mevcut ittifakların dağılması bu kapsamda değerlendirilebilir. Örneğin, ABD ile Vietnam arasındaki ilişkiler Soğuk Savaş sonrasında önemli ölçüde değişmiş; savaş dönemindeki düşmanlık yerini diplomatik ve ekonomik iş birliğine bırakmıştır. Davranışsal değişimler her zaman uluslararası sistemin yapısını dönüştürmese de uluslararası siyasetin işleyişi üzerinde önemli etkiler yaratabilmektedir.

Üçüncü olarak normatif değişimler uluslararası ilişkiler literatüründe giderek daha fazla önem kazanmaktadır. İnsan hakları normlarının yaygınlaşması, sömürgeciliğin meşruiyetini kaybetmesi,

demokratik değerlerin uluslararası düzeyde daha geniş kabul görmesi ve uluslararası hukukun etkisinin artması normatif değişim örnekleri arasında yer almaktadır. Bu tür değişimler özellikle Soğuk Savaş sonrasında normların ve fikirlerin uluslararası siyaset üzerindeki etkisini vurgulayan çalışmaların artmasına yol açmıştır.

Farklı teorik yaklaşımlar değişimin kaynakları konusunda farklı açıklamalar sunmaktadır. Liberal teoriler ekonomik karşılıklı bağımlılık, uluslararası kurumlar ve iş birliği mekanizmalarına vurgu yaparken, inşacı yaklaşımlar normlar, fikirler ve kimliklerin dönüştürücü rolünü ön plana çıkarmaktadır. Buna karşılık realizm, değişimin temel kaynağını güç ilişkilerinde ve güvenlik dinamiklerinde aramaktadır. Bu çerçevede değişimin nasıl açıklanacağı sorusu aynı zamanda teoriler arasındaki temel farklılıkları da ortaya koymaktadır.

Değişim probleminin önemini artıran en önemli gelişmelerden biri Soğuk Savaş'ın sona ermesi olmuştur. Sovyetler Birliği'nin dağılması, Doğu Avrupa'daki komünist rejimlerin çökmesi ve iki kutuplu sistemin beklenmedik biçimde sona ermesi, uluslararası ilişkiler teorilerinin açıklama kapasitelerini yeniden tartışmaya açmıştır. Bu gelişmeler yalnızca realizmin değil, disiplinin genel teorik araçlarının da sorgulanmasına yol açmıştır. Nitekim Gaddis, Soğuk Savaş'ın sonunun uluslararası ilişkiler teorilerinin büyük bölümünü hazırlıksız yakaladığını belirtmektedir (Gaddis, 1992–1993).

Bu bağlamda değişim problemi belirli bir teorinin başarısızlığına indirgenemeyecek kadar geniş bir teorik meseledir. Bununla birlikte realizm, uluslararası siyasette sürekliliği vurgulayan yaklaşımı nedeniyle değişimi açıklama kapasitesi bakımından en yoğun tartışmalara konu olan teorilerden biri olmuştur. Özellikle Soğuk Savaş'ın sona ermesinden sonra realizmin değişim karşısındaki performansı, disiplin içerisinde önemli bir tartışma alanı hâline gelmiştir. Bu çerçevede bir sonraki bölümde realizmin değişime nasıl yaklaştığı, değişimi hangi mekanizmalar üzerinden açıkladığı ve realist düşünürlerin değişim kavramını nasıl değerlendirdikleri incelenecektir.

2. REALİZMİN DEĞİŞİME YAKLAŞIMI

Realizm, uluslararası ilişkiler disiplininin en köklü ve etkili teorik geleneklerinden biridir. Bununla birlikte realizm çoğu zaman uluslararası siyasette sürekliliği vurgulayan ve değişimi açıklamakta zorlanan bir yaklaşım olarak değerlendirilmektedir. Buna karşın realist literatür dikkatle incelendiğinde, realizmin değişimi bütünüyle reddetmediği; aksine değişimin belirli mekanizmalar üzerinden gerçekleştiğini kabul ettiği görülmektedir. Realist düşünürler açısından temel mesele değişimin varlığı değil, değişimin kaynağıdır. Dolayısıyla realist teoriler uluslararası değişimin temel açıklayıcı değişkeni olarak güç dengesini görmekte ve Soğuk Savaş'ın sonunu büyük ölçüde Sovyetler Birliği'nin göreli gücündeki gerilemeyle açıklamaktadır (Wohlforth, 1994).

Realizmin ortak varsayımı, uluslararası siyasetin anarşik bir ortamda gerçekleştiğidir. Devletlerin üzerinde bağlayıcı bir otoritenin bulunmaması, güvenliği uluslararası siyasetin temel sorunu hâline getirmektedir. Bu nedenle realistler, devlet davranışlarının büyük ölçüde güvenlik kaygıları ve güç ilişkileri tarafından şekillendirildiğini ileri sürmektedir. Değişim mümkündür; ancak bu değişim çoğu zaman uluslararası siyasetin temel mantığını ortadan kaldırmamaktadır.

2.1. Klasik Realizm ve Değişim

Klasik realizmin en önemli temsilcilerinden biri olan Hans J. Morgenthau, uluslararası siyasetin temelinde insan doğasının bulunduğunu savunmaktadır. Morgenthau'ya göre güç elde etme arzusu insan doğasının değişmeyen özelliklerinden biridir ve bu durum devlet davranışlarına da yansımaktadır (Morgenthau, 1948). Dolayısıyla uluslararası siyasetteki rekabet ve çıkar çatışmaları geçici değil, kalıcı özelliklerdir.

Morgenthau değişimin mümkün olduğunu kabul etmektedir. Devletler yükselebilir veya gerileyebilir, ittifaklar değişebilir ve uluslararası düzenler dönüşebilir. Bunun yanında bütün bu değişimlerin arkasında güç mücadelesi devam etmektedir. Bu sebeple klasik realizm açısından değişim, uluslararası siyasetin özünü dönüştüren bir süreçten çok güç ilişkilerinin yeniden dağılımı anlamına gelmektedir.

Morgenthau'nun yaklaşımı realizmin değişimi reddetmediğini göstermektedir. Ancak değişim, normların veya fikirlerin dönüştürücü etkisinden çok, güç mücadelelerinin doğal sonucu olarak görülmektedir (Morgenthau, 1948). Bu bağlamda klasik realizm değişimi kabul etmekte, fakat değişimin uluslararası siyasetin temel mantığını değiştirebileceği fikrine kuşkuyla yaklaşmaktadır.

2.2. Neorealizm ve Değişim

Kenneth Waltz tarafından geliştirilen neorealizm ya da yapısal realizm, klasik realizmden farklı olarak uluslararası siyasetin açıklanmasında insan doğasından çok sistemin yapısına odaklanmaktadır. Waltz'a göre uluslararası sistemin temel özelliği anarşidir. Devletlerin üzerinde bağlayıcı bir otoritenin bulunmaması, onları kendi güvenliklerini sağlamak zorunda bırakmaktadır. Bu durum, devletlerin davranışlarında belirli düzenliliklerin ortaya çıkmasına neden olmaktadır (Waltz, 1979).

Neorealizm açısından değişimin temel kaynağı sistemdeki güç dağılımında meydana gelen dönüşümlerdir. Büyük güçlerin göreli kapasitelerinde yaşanan değişimler, uluslararası sistemin yapısını ve devletlerin davranışlarını etkileyebilmektedir. Bu bağlamda Waltz, uluslararası sistemde meydana gelen önemli dönüşümlerin anlaşılmasında kutupluluk kavramına özel önem vermektedir. Tek kutuplu, iki kutuplu veya çok kutuplu sistemler devletlerin güvenlik stratejilerini ve dış politika tercihlerini doğrudan etkilemektedir.

Waltz'ın yaklaşımı, değişimi tamamen reddetmekten ziyade onu sistem düzeyinde açıklamaya çalışmaktadır. Öte yandan neorealizm çoğu zaman değişimden çok sürekliliği açıklayan bir teori olarak değerlendirilmiştir (Keohane, 1986). Bunun temel nedeni, Waltz'ın teorisinin devlet davranışlarında tekrar eden örüntülere odaklanmasıdır. Neorealizm, devletlerin neden benzer güvenlik kaygıları geliştirdiğini ve neden benzer stratejik davranışlar sergilediğini açıklamada güçlüdür. Buna karşılık normların, fikirlerin ve kimliklerin etkisi gibi maddi olmayan değişkenleri açıklamada daha sınırlı kalmaktadır. (Waltz, 1979; Wendt, 1999)

Soğuk Savaş'ın sona ermesinden sonra neorealizme yöneltilen eleştirilerin önemli bir bölümü de bu noktada yoğunlaşmıştır. Eleştirmenler, Waltz'ın teorisinin Sovyetler Birliği'nin çöküşünü ve Doğu Avrupa'daki dönüşümleri açıklamakta yetersiz kaldığını ileri sürmüşlerdir. Buna karşılık Waltz, teorilerin temel görevinin belirli tarihsel olayları tahmin etmek değil, bu olayların ortaya çıktığı yapısal koşulları açıklamak olduğunu savunmuştur (Waltz, 2000). Bu açıdan neorealizmin değişim konusundaki temel sorunu değişimi reddetmesi değil, değişimin nedenlerini büyük ölçüde maddi güç unsurlarına indirgeme eğilimidir.

2.3. Gilpin ve Hegemonik Değişim

Realist literatürde değişim sorununu en kapsamlı biçimde ele alan düşünürlerden biri Robert Gilpin'dir. Gilpin, *War and Change in World Politics* adlı eserinde uluslararası sistemin tarihsel olarak sürekli bir değişim içerisinde bulunduğunu ileri sürmektedir (Gilpin, 1981). Bu yönüyle Gilpin'in çalışması, realizmin yalnızca sürekliliği açıklayan bir teori olduğu yönündeki görüşlere önemli bir alternatif sunmaktadır.

Gilpin'e göre uluslararası sistemdeki düzenler kalıcı değildir. Güçlü devletlerin yükselişi ve gerileyişi zaman içerisinde mevcut düzenin dönüşmesine yol açmaktadır. Uluslararası sistemde baskın konumda bulunan devletler mevcut düzenin korunmasından yarar sağlarken, yükselen güçler zamanla bu düzenin maliyetlerini sorgulamaya başlamaktadır. Bu durum sistem içerisinde gerilim yaratmakta ve belirli koşullar altında uluslararası düzenin yeniden şekillenmesine neden olmaktadır (Kugler & Organski, 1989). Örneğin, 19. yüzyılın sonları ile 20. yüzyılın başlarında Birleşik Krallık'ın göreli gücünün azalması ve Amerika Birleşik Devletleri'nin yükselişi, uluslararası güç dağılımında önemli bir dönüşüm yaratmıştır. Bu süreç sonunda küresel liderlik kademeli olarak İngiltere'den ABD'ye geçmiştir (Gilpin, 1981).

Gilpin'in hegemonik değişim teorisinde savaş önemli bir rol oynamaktadır. Tarihsel olarak büyük sistemik dönüşümlerin çoğu, büyük güçler arasındaki çatışmaların ardından ortaya çıkmıştır. Ancak Gilpin yalnızca savaşlara değil, ekonomik ve teknolojik dönüşümlere de dikkat çekmektedir. Devletlerin ekonomik kapasitelerinde meydana gelen değişimler, zamanla askerî ve siyasal güç dağılımını da etkileyerek uluslararası sistemin yeniden yapılandırılmasına yol açabilmektedir (Gilpin, 1981).

Gilpin'in yaklaşımı realizmin değişimi açıklama kapasitesinin düşünüldüğünden daha güçlü olduğunu göstermektedir. Çünkü burada değişim istisnai bir durum değil, uluslararası siyasetin doğal bir parçası olarak ele alınmaktadır. Öte yandan Gilpin'in analizlerinde de değişimin temel kaynağı normlar veya fikirler değil, maddi güç unsurlarındaki dönüşümlerdir. Bu nedenle Gilpin'in çalışması realizmin değişimi reddetmediğini göstermesine rağmen, değişimin düşünsel boyutlarını açıklama konusunda realizmin genel sınırlılıklarını aşamamaktadır.

Sonuç olarak klasik realizm, neorealizm ve Gilpin'in hegemonik değişim yaklaşımı birlikte değerlendirildiğinde realizmin değişimi bütünüyle reddeden bir teori olmadığı görülmektedir. Realist düşünürler değişimi kabul etmekte, ancak değişimin temel nedenlerini büyük ölçüde güç dağılımı ve güvenlik dinamikleri üzerinden açıklamaktadır. Bu sebeple realizmin değişim konusundaki temel sorunu değişimi inkâr etmesi değil, değişimin normatif ve düşünsel boyutlarını ikincil planda değerlendirmesidir.

Bu noktada realizmin açıklayıcı kapasitesini değerlendirmek için en önemli tarihsel örneklerden biri Soğuk Savaş'ın sona ermesidir. Çünkü Sovyetler Birliği'nin dağılması ve iki kutuplu sistemin büyük bir savaş yaşanmadan sona ermesi, realizmin değişimi açıklama gücü hakkında yoğun teorik tartışmaların ortaya çıkmasına neden olmuştur. Bu bağlamda bir sonraki bölümde Soğuk Savaş'ın sonu sonrasında realizme yöneltilen eleştiriler ve bu eleştirilere verilen neorealist yanıtlar incelenecektir.

3. SOĞUK SAVAŞ'IN SONU: ELEŞTİRİLER VE SAVUNULAR

Soğuk Savaş'ın sona ermesi, uluslararası ilişkiler disiplininin karşı karşıya kaldığı en önemli tarihsel dönüşümlerden biri olarak kabul edilmektedir. Yaklaşık yarım yüzyıl boyunca uluslararası siyasetin temel yapısını belirleyen iki kutuplu sistemin büyük bir savaş yaşanmadan sona ermesi, yalnızca dünya siyasetini değil, bu siyaseti açıklamaya çalışan teorileri de derinden etkilemiştir. Özellikle Sovyetler Birliği'nin dağılması ve Doğu Avrupa'daki komünist rejimlerin çökmesi, realizmin değişimi açıklama kapasitesine yönelik yoğun eleştirilerin ortaya çıkmasına neden olmuştur.

Soğuk Savaş boyunca realizm, uluslararası sistemin istikrarını ve iki kutuplu yapının dayanıklılığını açıklamada önemli bir teorik çerçeve sunmuştur. Bununla birlikte sistemin beklenmedik biçimde sona ermesi, realist teorilerin öngörü ve açıklama kapasitesinin yeniden değerlendirilmesine yol açmıştır. Bu süreçte bazı araştırmacılar realizmin ciddi bir teorik başarısızlık yaşadığını savunurken, bazıları ise teorinin yanlış ölçütlerle değerlendirildiğini ileri sürmüştür.

3.1. Lebow ve Realizme Yönelik Eleştiriler

Soğuk Savaş sonrasında realizme yöneltilen en etkili eleştirilerden biri Richard Ned Lebow tarafından ortaya konulmuştur. Lebow'a göre realizm yalnızca Soğuk Savaş'ın sonunu öngörememiş değil, aynı zamanda bu dönüşümün nedenlerini açıklamakta da başarısız olmuştur (Lebow, 1994).

Lebow'un ilk eleştirisi, realist teorinin büyük güç davranışlarına ilişkin beklentileriyle ilgilidir. Realist yaklaşıma göre büyük güçler sahip oldukları nüfuz alanlarını korumaya çalışırlar. Tarihsel deneyimler de çoğu zaman bu beklentiyi doğrulamaktadır. Öte yandan Sovyetler Birliği, Doğu Avrupa üzerindeki kontrolünü sürdürmek için askerî müdahaleye başvurmamış ve bölgedeki dönüşümlere büyük ölçüde izin vermiştir. Bu durum Lebow'a göre realist beklentilerle uyumlu değildir (Lebow, 1994).

İkinci eleştiri, değişimin gerçekleşme biçimine ilişkindir. Realist teoriler genellikle büyük sistemik dönüşümlerin savaşlar veya yoğun güç mücadeleleri sonucunda ortaya çıktığını varsaymaktadır. Oysa Soğuk Savaş'ın sonu büyük güçler arasında doğrudan bir savaş yaşanmadan gerçekleşmiştir. Bu durum uluslararası sistemde barışçıl değişimin mümkün olduğunu göstermekte ve değişimin yalnızca güç dengelerindeki dönüşümler üzerinden açıklanamayacağını ortaya koymaktadır (Lebow, 1994).

Üçüncü eleştiri ise fikirlerin ve liderliğin rolüne yöneliktir. Lebow'a göre Gorbaçov döneminde ortaya çıkan yeni siyasal düşünce, Sovyet dış politikasında köklü bir değişim yaratmıştır. Ortak güvenlik anlayışı, ideolojik rekabetin azaltılması ve uluslararası iş birliğine daha fazla önem verilmesi gibi gelişmeler yalnızca maddi güç değişkenleriyle açıklanamaz. Bu nedenle normlar, fikirler ve liderlik tercihleri değişim süreçlerinin önemli belirleyicileri arasında yer almaktadır (Lebow, 1994).

Lebow'un eleştirileri, realizmin özellikle normatif ve düşünsel değişimleri açıklamadaki yetersizliklerini görünür hâle getirmiştir. Bununla birlikte bu eleştiriler realist düşünürler tarafından bütünüyle kabul edilmemiştir.

3.2. Waltz ve Neorealist Savunular

Kenneth Waltz ve diğer neorealist düşünürler, Soğuk Savaş sonrasında realizme yöneltilen eleştirilerin önemli bir bölümünün teorinin amacı hakkında yanlış varsayımlara dayandığını ileri sürmüşlerdir. Waltz'a göre teorilerin temel görevi belirli tarihsel olayları tahmin etmek değil, olayların ortaya çıktığı genel yapısal koşulları açıklamaktır. Bu bakış açısından değerlendirildiğinde, Sovyetler Birliği'nin hangi tarihte çökeceğini veya Gorbaçov'un hangi kararları alacağını öngörememek teorinin başarısızlığı anlamına gelmemektedir. Sosyal bilim teorileri belirli tarihsel olayların ayrıntılı seyrini tahmin etmekten çok, bu olayları mümkün kılan yapısal dinamikleri ortaya koymaktadır. (Waltz, 2000).

Neorealist savunuların ikinci boyutu Sovyetler Birliği'nin karşı karşıya kaldığı yapısal sorunlara ilişkindir. Sovyet ekonomisindeki uzun dönemli durgunluk, Amerika Birleşik Devletleri ile yürütülen maliyetli askerî rekabet ve teknolojik gerilik, Sovyet liderliğini reform arayışına yönelten temel faktörler arasında yer almaktaydı. Bu sebeple Gorbaçov'un politikaları tamamen bireysel tercihler olarak değil, yapısal baskılara verilen tepkiler olarak da değerlendirilebilir (Wohlforth, 1994).

Neorealistlere göre Soğuk Savaş'ın sonunu açıklamak için normlara ve fikirlere başvurmak mümkündür; ancak bu unsurların ortaya çıkışını sağlayan maddi koşulların da dikkate alınması gerekmektedir. Dolayısıyla realizm değişimi açıklamakta tamamen yetersiz değildir; yalnızca değişimin temel nedenlerini farklı bir düzeyde aramaktadır. Bu savunular realizmin eleştiriler karşısında tamamen savunmasız olmadığını göstermektedir. Bununla birlikte aynı zamanda teorinin açıklama alanının sınırlarını da ortaya koymaktadır. Çünkü yapısal baskılar ile liderlik tercihleri arasındaki ilişkinin nasıl kurulacağı konusu hâlen tartışmalıdır (Wohlforth, 1994).

3.3. Gaddis ve Değişim Problemi

Soğuk Savaş'ın sona ermesine ilişkin tartışmalarda önemli bir ara pozisyon John Lewis Gaddis tarafından geliştirilmiştir. Gaddis'e göre yaşanan dönüşüm yalnızca realizmin değil, uluslararası ilişkiler alanındaki hemen hemen bütün teorik yaklaşımların açıklama ve öngörü kapasitesini sınamıştır (Gaddis, 1992–1993).

Gaddis'in yaklaşımı önemlidir çünkü değişim problemini yalnızca realizmin başarısızlığına indirgememektedir. Ona göre Soğuk Savaş'ın sonu o kadar kapsamlı ve beklenmedik bir dönüşümdür ki, ne realistler ne liberaller ne de diğer teorik yaklaşımlar bu süreci tam anlamıyla öngörebilmiştir. Bu nedenle yaşanan gelişmeler belirli bir teorinin eksikliğinden çok, sosyal bilim teorilerinin genel sınırlarını göstermektedir.

Gaddis ayrıca Soğuk Savaş'ın sonunun uluslararası ilişkiler teorilerinde uzun süredir ihmal edilen bazı değişkenleri yeniden gündeme taşıdığını belirtmektedir. Liderlik tercihleri, ideolojik dönüşümler ve iç siyasal süreçler gibi unsurların uluslararası sistem üzerindeki etkisi bu dönemde daha görünür hâle gelmiştir. Bu durum teorilerin açıklama çerçevelerini genişletmeleri gerektiğine işaret etmektedir.

Gaddis'in değerlendirmesi Holsti'nin değişim problemine ilişkin yaklaşımıyla da uyumludur. Her iki yazar da değişim sorununu belirli bir teorinin eksikliği olarak değil, disiplinin genel teorik sınırlarından biri olarak görmektedir (Gaddis, 1992; Holsti, 1998). Bu çerçevede Soğuk Savaş'ın sonu realizmin tamamen başarısız olduğunu değil, değişimi açıklamanın uluslararası ilişkiler teorisinin en zor problemlerinden biri olduğunu göstermektedir. Bu tartışmalar ışığında asıl soru realizmin doğru ya da yanlış olup olmadığı değil, hangi tür değişimleri açıklamada daha başarılı olduğudur. Bu nedenle bir sonraki bölümde realizmin güçlü ve zayıf yönleri sistematik biçimde değerlendirilecektir.

4. REALİZMİN GÜÇLÜ VE ZAYIF YÖNLERİ

Soğuk Savaş'ın sona ermesi sonrasında realizme yöneltilen eleştiriler teorinin uluslararası ilişkiler disiplinindeki yerini yeniden tartışmaya açmıştır. Bununla birlikte realizmin değişimi açıklamada tamamen başarısız olduğu yönündeki değerlendirmeler de çok fazla ikna edici görünmemektedir. Daha

dengeli bir yaklaşım, realizmin belirli değişim türlerini açıklamada güçlü, bazı değişim türlerini açıklamada ise sınırlı bir teorik çerçeve sunduğunu kabul etmektedir.

Saldırgan realizm yaklaşımına göre uluslararası sistemin anarşik yapısı, büyük güçleri yalnızca güvenliklerini korumaya değil, aynı zamanda güçlerini azami seviyeye çıkarmaya yöneltmektedir. Mearsheimer'a göre devletler diğer aktörlerin niyetlerinden hiçbir zaman tam olarak emin olamadıkları için göreli güçlerini artırmaya çalışırlar ve uygun fırsatlar ortaya çıktığında güç dağılımını kendi lehlerine değiştirmeye yönelirler. Bu nedenle uluslararası siyasette değişim, yalnızca istisnai bir durum değil, büyük güç rekabetinin doğal bir sonucu olarak görülebilir (Mearsheimer, 2001)

Realizmin en önemli güçlü yönü, güç ve güvenlik dinamiklerinden kaynaklanan değişimleri açıklamadaki başarısıdır. Büyük güçlerin yükseliş ve gerileyiş süreçleri, ittifakların oluşumu ve çözülmesi, güvenlik rekabetleri ve hegemonik mücadeleler realist literatürün uzun süredir üzerinde çalıştığı konular arasında yer almaktadır. Güç dengesi, güvenlik ikilemi ve kutupluluk gibi kavramlar uluslararası sistemde meydana gelen birçok dönüşümün anlaşılmasında önemli analitik araçlar sunmaktadır (Jervis, 1978; Waltz, 1979; Gilpin, 1981).

Özellikle büyük güç siyaseti söz konusu olduğunda realizm hâlen önemli bir açıklama kapasitesine sahiptir. Çin'in yükselişi, Amerika Birleşik Devletleri ile Çin arasındaki stratejik rekabet, Rusya'nın uluslararası sistemde yeniden etkili bir aktör olmaya çalışması ve bölgesel güç mücadeleleri realist analizlerin güncelliğini koruduğunu göstermektedir. Uluslararası sistemde güvenlik kaygılarının devam etmesi ve devletlerin askerî kapasitelerini artırma eğilimleri, realizmin temel varsayımlarının hâlen geçerliliğini sürdürdüğünü ortaya koymaktadır.

Realizmin ikinci önemli avantajı, uluslararası siyasette süreklilikleri açıklayabilmesidir. Tarihsel koşullar değişse bile devletlerin güvenlik arayışı, güç biriktirme eğilimi ve stratejik rekabet davranışları büyük ölçüde devam etmektedir. Waltz'ın yapısal realizmi, devlet davranışlarında neden belirli örüntülerin tekrarlandığını açıklamada güçlü bir teorik çerçeve sunmaktadır (Waltz, 1979). Bu sebeple realizm yalnızca değişimi değil, değişim içerisinde varlığını sürdüren süreklilikleri de açıklayabilmektedir. Bununla birlikte realizmin değişimi açıklama kapasitesi bazı alanlarda önemli sınırlılıklar göstermektedir. Bu sınırlılıkların başında normatif değişimler gelmektedir. İnsan hakları normlarının yaygınlaşması, sömürgeciliğin meşruiyetini kaybetmesi, uluslararası hukukun güçlenmesi ve uluslararası örgütlerin etkisinin artması yalnızca güç dengeleri üzerinden açıklanabilecek gelişmeler değildir. Bu tür dönüşümler normların ve fikirlerin uluslararası siyasette bağımsız bir etkiye sahip olabileceğini göstermektedir (Waltz, 1979).

Realizmin açıklamakta zorlandığı ikinci alan kimlik ve fikir temelli dönüşümlerdir. Devletlerin tehdit algıları, çıkar tanımları ve dış politika öncelikleri zaman içerisinde değişebilmektedir. Avrupa bütünleşmesi bu açıdan dikkat çekici bir örnek oluşturmaktadır. Tarih boyunca yoğun savaşlar yaşamış devletlerin egemenliklerinin belirli alanlarını ortak kurumlara devretmeleri ve güvenlik ilişkilerini iş birliği temelinde yeniden tanımlamaları, yalnızca güç dengesi mantığıyla açıklanması güç gelişmelerdir (Keohane & Martin, 1995).

Realizmin açıklama ve öngörü kapasitesine yönelik eleştiriler yalnızca Soğuk Savaş'ın sona ermesiyle sınırlı kalmamıştır. Benzer tartışmalar 11 Eylül 2001 saldırılarının ardından da yeniden gündeme gelmiştir. Realist teoriler uluslararası siyaseti büyük ölçüde egemen devletler arasındaki güç rekabeti çerçevesinde analiz ettikleri için, El Kaide gibi devlet dışı aktörlerin uluslararası sistemi dönüştürebilecek ölçekte etkiler yaratmasını öngörmekte zorlanmışlardır. 11 Eylül sonrasında güvenlik gündeminin terörizm, asimetrik tehditler ve devlet dışı aktörler etrafında yeniden şekillenmesi, uluslararası ilişkiler teorilerinin açıklama ve öngörü kapasitelerine ilişkin yeni tartışmalar doğurmuştur. Cox'a (2002) göre 11 Eylül, uluslararası ilişkiler araştırma gündemini önemli ölçüde etkilemiş ve disiplinin daha önce yeterince önem vermediği uluslararası terörizm, radikal ideolojiler ve devlet dışı aktörler gibi konulara yönelmesine yol açmıştır. Benzer şekilde Der Derian (2004), saldırıların ardından uluslararası ilişkiler disiplininin temel varsayımlarının yeniden sorgulanmaya başlandığını ve teorilerin yeni güvenlik tehditlerini açıklama kapasitesinin yoğun biçimde tartışıldığını belirtmektedir. Bu gelişme, özellikle devlet dışı aktörlerin artan etkisinin realist analizlerde yeterince dikkate alınmadığı yönündeki eleştirileri güçlendirmiştir. Sümer'e (2007) göre ise 11 Eylül sonrasında ortaya çıkan

güvenlik ortamı, realizmin devlet merkezli varsayımlarını yeniden tartışmaya açmış ve teorinin devlet dışı aktörlerden kaynaklanan tehditleri açıklama kapasitesine yönelik soru işaretlerini artırmıştır. Bununla birlikte realist düşünürler, saldırıların ardından devletlerin sergilediği davranışların – askerî güç kullanımının artması, güvenlik önlemlerinin genişletilmesi ve ulusal çıkar söyleminin yeniden ön plana çıkması gibi – realizmin temel varsayımlarıyla uyumlu olduğunu savunmuşlardır. Dolayısıyla 11 Eylül saldırıları realizmi tamamen geçersiz kılmamış, buna karşın teorinin devlet dışı aktörlerden kaynaklanan beklenmedik dönüşümleri öngörmedeki sınırlılıklarını ortaya koymuştur. Bu yönüyle 11 Eylül, Soğuk Savaş'ın sonuyla birlikte realizmin tahmin kapasitesine yönelik eleştirilerin en sık başvurulan örneklerinden biri hâline gelmiştir.

Üçüncü olarak realizm, liderlik tercihlerinin ve iç siyasal dönüşümlerin uluslararası sonuçlarını açıklamada sınırlı kalabilmektedir. Soğuk Savaş'ın sona ermesine ilişkin tartışmalar bu durumu açık biçimde göstermektedir. Sovyetler Birliği'nin karşı karşıya olduğu ekonomik sorunlar uzun süredir mevcut olmasına rağmen, Gorbaçov döneminde verilen siyasal tepkiler önceki liderlerden farklı olmuştur. Bu durum değişimin yalnızca yapısal baskılarla değil, liderlik tercihleri ve fikirsel dönüşümlerle de ilişkili olabileceğini göstermektedir.

Ancak bu eleştiriler realizmin bütünüyle geçersiz olduğu anlamına gelmemektedir. Realizme yöneltilen bazı eleştiriler, teoriden başlangıçta üstlenmediği görevlerin beklenmesinden kaynaklanmaktadır. Özellikle neorealizm belirli tarihsel olayları tahmin etmekten çok, uluslararası sistemde tekrar eden davranış örüntülerini açıklamayı amaçlamaktadır. Bu sebeple realizmin başarısı yalnızca Soğuk Savaş'ın sonunu tahmin edip etmediği üzerinden değerlendirilemez.

Bu çerçevede realizmin açığının sadece Soğuk Savaş'ın sonunu öngörememesi olmadığı söylenebilir. Asıl mesele, değişimin normatif ve düşünsel boyutlarını açıklamada sınırlı kalmasıdır. Buna karşılık güç dağılımı, güvenlik rekabeti ve büyük güç siyaseti gibi alanlarda realizm hâlen güçlü açıklamalar sunmaktadır. Dolayısıyla realizm ne eleştirmenlerinin iddia ettiği kadar başarısız ne de savunucularının ileri sürdüğü kadar kapsayıcı bir teoridir.

SONUÇ

Uluslararası ilişkiler teorisinin en önemli tartışma alanlarından biri değişim problemidir. Devlet davranışlarının, uluslararası sistemin ve uluslararası düzenin nasıl değiştiği sorusu farklı teorik yaklaşımlar tarafından farklı biçimlerde açıklanmaktadır. Bu çalışma, realizmin değişimi açıklama kapasitesini Soğuk Savaş'ın sona ermesi örneği üzerinden değerlendirmiştir.

Çalışmada görüldüğü üzere realizm değişimi bütünüyle reddeden bir teori değildir. Morgenthau, Waltz ve Gilpin gibi realist düşünürler değişimin mümkün olduğunu kabul etmekte, öte yandan bu değişimin temel kaynağını güç dağılımındaki dönüşümlerde, güvenlik kaygılarında ve büyük güç rekabetlerinde aramaktadırlar. Bu açıdan realizm özellikle sistemik dönüşümleri, güç geçişlerini ve hegemonik değişimleri açıklamada önemli bir teorik kapasiteye sahiptir. Nitekim Waltz'ın yapısal realizminden farklı olarak Mearsheimer'ın saldırgan realizmi, devletlerin sürekli olarak güçlerini artırmaya çalıştıklarını ve bu durumun uluslararası sistemde değişim yaratan dinamikleri beslediğini ileri sürmektedir (Mearsheimer, 2001).

Bununla birlikte Soğuk Savaş'ın sona ermesi realizmin bazı sınırlarını görünür hâle getirmiştir. Sovyetler Birliği'nin dağılması, Doğu Avrupa üzerindeki kontrolün büyük ölçüde gönüllü biçimde terk edilmesi ve Gorbaçov döneminde ortaya çıkan yeni siyasal düşünce, yalnızca güç ve güvenlik değişkenleriyle açıklanması zor gelişmeler olarak ortaya çıkmıştır. Bu durum özellikle Lebow'un realizme yönelik eleştirilerini güçlendirmiş ve normlar, fikirler ile liderlik tercihlerinin uluslararası değişim üzerindeki rolünü yeniden gündeme getirmiştir.

Öte yandan bu eleştiriler realizmin tamamen başarısız olduğu sonucuna götürmemektedir. Gaddis'in belirttiği gibi Soğuk Savaş'ın sonu yalnızca realizmin değil, uluslararası ilişkiler teorisinin genel açıklama kapasitesini sınayan bir gelişme olmuştur. Benzer şekilde Holsti'nin vurguladığı üzere değişim problemi disiplinin genel teorik sorunlarından biridir ve yalnızca realizme özgü değildir.

Bu çalışmanın ulaştığı temel sonuç, realizmin uluslararası ilişkilerde değişimi açıklamada tamamen başarısız olmadığıdır. Realizm güç politikaları, güvenlik rekabeti ve sistemik dönüşümler konusunda

güçlü açıklamalar sunmaya devam etmektedir. Buna karşılık normatif değişimler, kimlik dönüşümleri, fikirlerin etkisi ve iç siyasal süreçlerden kaynaklanan uluslararası değişimler söz konusu olduğunda açıklayıcı gücü daha sınırlı kalmaktadır.

Dolayısıyla realizmin temel sorunu Soğuk Savaş'ın sonunu öngörememesi değil, değişimin normatif ve düşünsel boyutlarını açıklamada sınırlı kalmasıdır. Bu bağlamda realizmin geleceği, değişimi reddetmesinde değil; değişimin maddi ve düşünsel boyutlarını birlikte değerlendirebilecek yeni yorumlara açık olmasında yatmaktadır.

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THE EFFECTS OF MANAGEMENT ACCOUNTING TOOLS IN SMEs PERFORMANCE. EMPIRICAL EVIDENCE FROM ELBASAN, ALBANIA.

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ABSTRACT

The present study investigates the effects of management accounting (MA) tools on the performance of small and medium-sized enterprises (SMEs) in Albania. The performance of SMEs is measured using several dimensions such as such as financial performance, market competitiveness, operational efficiency and innovation and adaption ability. To empirically investigate this relationship 430 questionnaires were distributed to 346 targeted SMEs operating in Elbasan city. A structural equation model was utilized to evaluate the impact of MA tools on SMEs performance. The findings reveal that the adoption of management accounting tools positively affect the SMEs performance in Elbasan, Albania. These results highlight the strategic role of management accounting in enhancing SMEs performance in Albania. The study offers practical insights by validating the MA tools which can help to improve SMEs' management accounting systems and their performance. Beyond its practical implications, this study offers valuable theoretical insight in existing literature by empirically validating the positive impact of MA tools on performance of SMEs in emerging economies.

Keywords: Management accounting tools, decision making, SMEs' performance, SEM.

INTRODUCTION

Small and medium-sized enterprises (SMEs) play a significant role in the economy of a country in terms of income generation, job creation and entrepreneurship. According to Kayani & Alzaid (2025), the share of economic contribution of SMEs is higher in developing countries compared to the developed countries. In this regard this study assumes significant relevance by exploring the performance drivers of SMEs within the context of an emerging economy such as Albania. Despite the economic and social contribution of SMEs, there is a lack of research exploring the extent to which these enterprises utilize MA practices. In Albania, SMEs constitute 99.9% of the total active companies providing 82% of the employment and contributing in 78.1% of the added value (INSTAT). SMEs are classified differently in various countries. The classification of SMEs in Albania is governed by Law No. 43/2022 in alignment with the EU recommendation 2003/361/EC. Under this framework, SMEs are defined as firms that employee between 10 - 250 employees and reporting an annual turnover or balance sheet totals ranging between 10 to 250 million Albanian lek (ALL). Firms whose parameters fall below these thresholds are classified as micro enterprises withing the Albanian legislation framework.

Management accounting (MA) practices are designed to support the management to make informed managerial decisions which includes planning and monitoring analyses and can utilize both financial and non-financial data (Pedroso & Gomes 2020; Ahmad 2017). From this perspective MA utilizes a range of tools that encompass costing, performance measurement, forecasting and strategic analysis (Dahal, 2022; Ahmad & Mohamed, 2015; Fuadah et al., 2020). In costing analysis MA offers a variety of different tools such as activity-based costing, standard costing, live-cycle costing and break-even analysis to provide accurate insights that enable accurate costing and effective resource allocation (Fuadah & Safitri, 2020). In performance measurement balanced scorecard, variance analysis and benchmarking are among key performance indicators to assess efficiency within and outside firms'

boundaries by integrating both financial and non-financial dimensions. Forecasting techniques such as budgeting systems, cash flows projections, cost-volume-profit analysis are among MA tools that are mostly utilized in testing and anticipating future outcomes under uncertainty (Indriani & Nadirsyah, 2015). Finally, strategic analysis approaches utilize tools such as value chain analysis, environmental management accounting and investment appraisal methods like net present value (NPV) and internal rate of return (IRR) to strategically link accounting insights to long-term competitiveness and sustainability (Khatoon et al., 2023; Oladele et al., 2023; Lucas et al., 2013). These MA tools are interrelated in order to provide to the management a comprehensive support system to analyze costs, evaluate firm's performance , predict financial outcomes and coordinate strategic choices. MA tools have a pivotal role in providing strategic information to decision-making which can include a range of broad-scope set of tools providing both financial and non-financial information, which are designed to enhance the effectiveness of the decision-making process (Chenhall, 2003; Soobaroyen & Poorundersing, 2008). Therefore, it is widely accepted that MA tools enhance SMEs performance (Ylä-Kujala et al., 2023; Fuadah & Safitri, 2020; Ahmad & Zabri, 2015; Ahmad et al., 2025; Almatarneh et al., 2022; Oladele et al., 2023).

This research examines the key MA tools utilized by SMEs and their effect on SMEs' performance across various sectors located in Elbasan, Albania. The empirical findings of the study provide valuable insights for both managers and policy makers in developing economies in understanding the role of external pressures (EP) in the enhancement of EMA implementation by Albanian SMEs.

LITERATURE REVIEW AND RESEARCH HYPOTHESIS

Although the MA practices are often perceived to be associated and implemented in large organizations, due to their complexity of their operations, their application within SMEs are not deeply studied. Recent literature has emphasized the pivotal role of MA tools in the process of SMEs management in the development of dynamics of the internal and external factors. As MA tools are presumed to provide relevant information in assisting in the process of decision-making, their effectiveness in achieving the targeted goals has become an important research topic (Lucas et al., 2013; Chenhall, 2003; Soobaroyen & Poorundersing, 2008). According to Porter (1985) MA tools scan and monitor the internal and external factors regarding the threats and opportunities regarding market competitiveness, innovation and adaptability. Therefore, providing strategic advantage in a competitive market which in return leads to an increase in market share. It is widely argued that the expansion of market share is a key indicator of sustainable profitability and an essential indicator of firm's performance (Oladele et al., 2023; Ahmad & Mohamed 2024). Demong & Croll (1981) stated that in contrast to larger businesses that utilize sophisticated MA tools, most of small and medium-sized enterprises (SMEs) tend to rely on basic or broad scope MA tools. This approach is based in the simplicity and ease of the understanding and implementation of such tools, as they do not necessitate the use of advanced software or complex systems (Tuan et al., 2022). There is a contradiction on related literature regarding the tools adopted and implemented by SMEs. Various authors such as Garengo et al. (2005) and Sousa et al., (2006) while emphasizing the importance of performance measurement utilization, their empirical evidences indicates that a limited number of SMEs adopt performance management tools. Instead, the most commonly utilized MA tools among SMEs are cost assessment tools utilized for efficiency monitoring and pricing decisions. In addition, Pedroso and Gomes (2020), introduced a multidimensional tool to measure the effectiveness of MA systems in SMEs, focusing on specific managerial information characteristics. Based on these insights scholars suggest that the adoption of MA tools should be tailored to the specific characteristics of SMEs such as firm size, industry sector, resource availability and managerial expertise. Nandan (2010) and Lucas et al. (2013) have suggested that failure to underperformance of SMEs is often due to their failure to utilize appropriate MA tools. The authors suggest that there is a need to ensure awareness and to educate the staff among SMEs to adopt and implement most appropriate MA tools according to the firm's specifics. In contrast to these findings, authors such as Dahal (2022) and Khatoon et al. (2023) argue that there is not necessarily a direct relationship between MA tools and firm's performance, and other factors can influence this relationship. In a study of Dahal (2022) conducted among Nepalese manufacturing companies, the authors conclude that there is no association of MA practices with organizational performance of Nepalese manufacturing firms. Similar results were obtained by Khatoon et al., 2023, where the authors in their study indicated

that there is no tendency to suggest that SMEs implementation of performance management accounting is associated with the achievement of higher profit margins, and this relationship can vary depending on the size of the organization (Kamilah et al., 2011). Although divergent views regarding the relationship between MA tools and firm's performance, the majority of empirical findings converge on the conclusion that MA tools have a direct and positive effect on firm's performance. Different authors such as Fuadah & Safitri (2020); Ahmad & Zabri (2015); Ylä-Kujala et al. (2023) found that SMEs face different organizational, resource and personnel challenges which can affect the implementation and adoption of MA tools. These limitations include: management style, firms' size and intensity of market competition. Their study also, highlights the positive and significant correlation between the adoption of MA tools and firms' performance. Concretely, Fuadah & Safitri (2020) and Ahmad & Zabri (2015) have studied the role of MA tools as a mediator between various variables and SMEs performance. Their study empirically confirms the positive relationship between MA tools and SMEs performance. Authors such as Oppi et al. (2020); Oladele et al., (2023) have studied the direct relationship between MA tools' utilization and the firm's performance where the authors have found a direct and significant relationship between two variables. In a study of Najera & Collazzo (2021), the authors found that micro and small firms consistently used MA tools in planning, to set objectives, to implement a functional costing system and partially to monitor the firm's performance. Oladele et al.(2023), conducted research among 207 SMEs in Oyo state, Nigeria, the authors examined the link between MA techniques (represented by benchmarking, value chain accounting and balanced scorecard) and SMEs performance. The study empirically found a positive and significant relationship between the proposed MA techniques and the performance of SMEs. Ahmad (2017), conducted a study among SMEs in manufacturing sector in Malaysia, the author stated that costing systems and performance measurement systems are the most common tools utilized by SMEs, and that MA practices are found to have significant relationships with firms' performance. In a subsequent study, conducted in Malaysian SMEs across different sectors Ahmad et al. (2025); conclude that risk orientation and MA can affect the positive outcomes of organizational performance. Similar results were obtained by Tran & Tran (2025); conducted among 700 Vietnamese enterprises, where the authors conclude that MA has a strong and positive impact on business efficiency of SMEs. The authors provide empirical evidence of MA practices in enhancing decision-making and operational effectiveness in SMEs. The authors offer practical insights on how to improve SME competitiveness through effective accounting practices. Similarly, Ngo (2021) conducted a study among 159 SMEs located in Cantho, Vietnam. The author revel that broad-scope MAS fully mediates the link between market orientation and firm's performance. The study provides exploratory evidence of the crucial role of the sophisticated MA systems design in the performance of small businesses. Gyamera et al. (2023) conducted a study among 365 SMEs in Ghana, the authors found a relationship between SMEs' performance and MA methods. In a study of Quang-Huy (2021) conducted among 131 SMEs located in Cantho, Vietnam, the author explored the relationship of broad scope MA tools with SMEs' performance. The research empirically proved that broad scope MA tools positively affect the SMEs performance by serving as a mediator between prospecting strategy and the performance of SMEs.

Grounded on the above literature review, the authors propose the following hypotheses:

Hypothesis 1: Management accounting tools (MAT) have a positive and significant effect on SMEs' performance

The hypothesized model proposal of this study is illustrated in Figure 1.

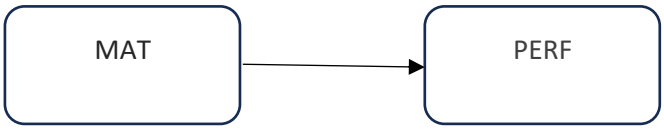


Figure 1. Research model representing the direct relationship between variables

METHODOLOGY

The objective of this empirical study aims to measure the effect management accounting tools (MAT) on SMEs' performance (PERF). To address this research goal, the study collected data from targeted SMEs operating across various sectors in Elbasan city, Albania.

Sampling and data collection

According to the Albanian Institute of National Statistics (INSTAT, 2024) there are approximately 5.000 SMEs operating in Elbasan, Albania. To ensure the relevance and implementation of EMA practices, the subjects of this study were selected by taking into consideration different specifics such as size and accounting structure, managerial competence and strategic orientation.

In structural equation modeling, Hair et al., (2006) suggested that the sample size needs to be a minimum of five times larger than the number of variables for factor analysis. As a general rule, larger sample sizes are highly preferred. A sample size between 200 and 400 is normally recommended and accepted as a critical sample size. The questionnaires were distributed to the owners and decision-makers of SMEs, who were more likely to be knowledgeable and engaged in strategic decision making. For data collection 430 questionnaires were distributed across 346 selected SMEs, resulting in 239 valid responses and 16 unengaged responses within a period of approximately four weeks, representing a valid response rate of 55.5%.

Measures

To measure the constructs proposed by the model, a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree") was utilized. To measure the components of managerial accounting tools (MAT) specifically for SMEs, six items were selected by taking into consideration dimensions like planning and control tools, decision supporting tools and performance and strategy tools. Concretely the authors adopted the scales based on the previous research of Sousa et al. (2006), Ahmad & Zabri (2015), Najera & Collazzo (2021), Fuadah & Safitri (2020), Gyamera et al. (2023). For the construct, SMEs performance (PERF) six items were selected taking in consideration different dimensions such as financial outcomes, market competitiveness, operational efficiency and innovation, based on the scales adopted by Quang-Huy (2021), Tran & Tran (2025), Oladele et al.(2023), Najera & Collazzo (2021) and Ahmad & Zabri (2015), see Table 1.

RESULTS

The data analyses were conducted using IBM SPSS Statistics 23.0 for descriptive statistics and reliability and AMOS Graphics 23.0 for hypothesis testing, utilizing structural equation modeling (SEM). The descriptive statistic indicates that approximately 57% of the respondents were male and 43% female. Of the SMEs surveyed, 24% were established within the past five years, 42% between five and ten years, and 34% for more than ten years. Regarding the level of education 56.3% had completed a bachelor's degree, 31.2% a master's degree, and 12.5% possessed postgraduate certifications.

Measurement Model

The first step in data analyzing is variable screening for missing data, unengaged responses and outliers. There were no outliers and 16 unengaged responses were detected. The unengaged responses were identified and removed from the dataset to safeguard the validity of the findings. The missing data were less than 5% so the mean imputation method was utilized. The items were subject to normal distribution as skewness and kurtosis of all the items resulted between the accepted range of -2 and +2.

The exploratory factor analysis (EFA) was performed using principal axis factoring analysis with varimax rotation. An essential step involved assessing the overall significance of the correlation matrix using Bartlett's Test of Sphericity, which evaluates whether the correlations among the variables are statistically significant. Bartlett's test (χ^2= 1,427.906; $p < 0.000$) indicates the suitability for factor analysis and Kaiser–Meyer–Olkin (KMO=0.876) which measures the sampling adequacy, indicates a satisfactory level of sampling adequacy for conducting factor analysis ($0 < KMO=0.879 < 1$). The communality of the scale, representing the proportion of variance explained by each factor, was also examined to ensure acceptable levels of explanation. The results indicated that all items demonstrated strong communalities within the threshold of ≥ 0.50. Kaiser's rule identified two factors, that correspond

to MAT and PERF as defined by the research. The results of EFA analysis, based on the factor rotation matrix, with all factor loadings exceeding benchmark value of 0.5, confirmed the two-dimensional structure, theoretically defined in the research , see table 1.

Table 1. Measurement model results

code	Constructs and items description	Factor loading	Cronbach's alpha	Composite reliability	AVE
Management Accounting Tools (MAT)			**0.889**	**0.892**	**0.574**
MAT1	Our firm prepares and uses annual budgets to plan financial activities	0.734			
MAT2	We use cost-volume-profit (CVP) analysis to support pricing and sales decisions	0.755			
MAT3	Our managers employ activity-based costing (ABC) to allocate overhead costs more accurately.	0.770			
MAT4	We apply standard costing to monitor production efficiency and cost control.	0.716			
MAT5	Our firm uses performance measurement tools such as the Balanced Scorecard.	0.712			
MAT6	We use target costing when designing or launching new products/services.	0.851			
Performance (PERF)			**0.921**	**0.922**	**0.665**
PERF1	Our firm has achieved steady revenue growth in recent years.	0.849			
PERF2	Our business demonstrates strong customer retention and satisfaction.	0.698			
PERF3	Our operations show efficiency in resource utilization and cost control.	0.854			
PERF4	Our employees exhibit high productivity and commitment.	0.744			
PERF5	Our firm adapts quickly to changes in the external environment.	0.833			
PERF6	Overall, our business performance meets management expectations.	0.899			

Source: Author's computation

After the assessment of EFA, Confirmatory Factor Analysis (CFA) was computed using IBM AMOS 23.0 to test the measurement models. As part of confirmatory factor analysis, factor loadings were assessed for each item, and all items resulted over the acceptable range (> .50). The model-fit measures were used to assess the model's overall goodness of fit (CMIN/df: <2, CFI: >0.90, TLI: >0.90, SRMR: <0.08, and RMSEA: <0.08) and all values were within their respective common acceptance levels CMIN/df = 1.169, CFI = 0.995, TLI = 0.974, SRMR = 0.0330, and RMSEA= 0.025 (Ullman, 2001; Hu & Bentler 1998; Bentler, 1990). Table 2., reports the mean and Pearson's Correlation of the factors utilized in the current study. To address potential multicollinearity issues, the guideline proposed by Hair et al. (2013) was followed, which suggests that Pearson's correlation coefficients should be underneath 0.90 benchmark. Accordingly, the results confirmed the absence of multicollinearity among the variables, see Table 2, (Hair et al., 2021; Frooghi et al. 2015). Construct Reliability was assessed using Cronbach's Alpha and Composite Reliability. Cronbach's Alpha is utilized to measure internal consistency reliability to show how closely related a set of items are as a group (Hoyle, 2014; Hair et al., 2021). Cronbach's Alpha for each construct in the study was calculated utilizing the following formula:

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum_{i=1}^{n} \sigma_{Y_i}^2}{\sigma_X^2}\right) \quad (1)$$

Where:

n: number of items in the scale

$\sigma_{Y_i}^2$: variance of each individual item

σ_X^2 : variance of the total score

Cronbach's Alpha for each construct was over the minimum required limit of 0.70 (Nunnally & Bernstein, 1994). Composite reliabilities (CR) accounts for standardized factor loadings and error variances and was calculated utilizing the following formula:

$$CR = \frac{(\sum_{i=1}^{n} \lambda_i)^2}{(\sum_{i=1}^{n} \lambda_i)^2 + \sum_{i=1}^{n} \varepsilon_i} \quad (2)$$

Where:

n: number of items for the construct

λ_i : standardized factor loading of item i

ε_i : error variance of item i

Composite reliabilities ranged were above the 0.70 benchmark (Hair et al., 2021). Hence, construct reliability was established for each construct in the study.

Table 2. Pearson Correlations

	MAT	**PERF**
MAT		
PERF	0.372	
N=239,		
***** Correlations significant at the 0.05 level (2-Tailed)**		

Source: Author's computation

Convergent and Discriminant Validity

Convergent validity of scale items was estimated using Average Variance Extracted (AVE) utilizing the following formula:

$$AVE = \frac{\sum_{i=1}^{n} \lambda_i^2}{n} \quad (3)$$

Where:

λi = standardized factor loading of indicator i

n = number of indicators for the construct

The AVE values for the latent MAT (AVE=0.574) and PERF (AVE=0.665) were above the recommended threshold of 0.5 (Fornell & Larcker 1981; Hair et al., 2012). Discriminant validity in the study was estimated using both the Fornell and Larcker Criterion and the Heterotrait-Monotrait (HTMT) Ratio. According to the Fornell and Larcker criterion, discriminant validity is confirmed when the square root of AVE for each construct exceeds its correlations compared with the other constructs in the model (Kim & Kim, 2010). Recently, Fornell and Larcker criterion has recently been subject to several critics, leading to the HTMT ratio which is widely accepted as a more robust technique. When assessed using HTMT ratio, all ratios were below the recommended threshold of 0.85 (Henseler et al., 2015). Hence, discriminant validity among constructs was established (Table 3 & Table 4).

Table 3. Discriminant validity results based on Fornell and Larcker criterion

	MAT	**PERF**
MAT	0.757	
PERF	0.372	0.815

Source: Author's computation

Table 4. Discriminant validity results based on Heterotrait-monotrait ratio (HTMT)

	MAT	**PERF**
MAT		
PERF	0.384	

Source: Author's computation

Structural Model

In the final stage, the structural model specified by the proposed research model was examined, consisting of two latent constructs: MAT and PERF each measured through six indicators. The latent constructs are measured as follows:

$MATi = \lambda i \cdot \text{MAT} + \varepsilon i; \qquad i = 1, 2, 3, 4, 5, 6$ (4)

$\text{PERF}j = \lambda j \cdot \text{PERF} + \varepsilon j; \qquad j = 1, 2, 3, 4, 5, 6$ (5)

Where:

λ = standardized factor loadings

ε = measurement error terms

The structural model shows that MAT is measured by six indicators (MAT1-MAT6) and PERF is measured by six indicators (PERF1-PERF6). All indicators loaded positively into the respective latent constructs with standardized factor loading within acceptable thresholds, indicating satisfactory convergent validity. Measurement errors for each indicator are explicitly specified to account the unexplained variance, thus ensuring rigorous model representation. The structural model in Figure 2, illustrates the hypothesized relationship between the latent constructs. Coefficient of determination (R^2) represents the proportion of variance explained by the predictors and was calculated utilizing the following formula:

$$R^2_{PERF} = 1 - \frac{Var(\zeta_2)}{Var(PERF)} \qquad (6)$$

Where, R^2 represents the proportion of variance explained by the predictors. In our case $R^2_{EMA} = 0.14$. This indicates that MAT explain 14% of the variance in PERF. Given the coefficient of determination (R^2) we can derive the disturbance term for PERF as following:

$$\text{Var}(\zeta 1) = 1 - R^2_{PERF} = 1 - 0.14 = 0.86 \quad (7)$$

The relationship between MAT and PERF can be expressed as:

$$PERF = \beta_1 \cdot MAT + \zeta_1 \quad (8)$$

Where:

β = standardized regression weights (path coefficients)

ζ = structural error terms (disturbances)

Following the assessment of the measurement model, the structural equations indicate that PERF is predicted by MAT ($\beta_1 = 0.372$) with a disturbance term of 0.86. The relationship between constructs is demonstrated through the direct path in the structural model represented in the Figure 2.

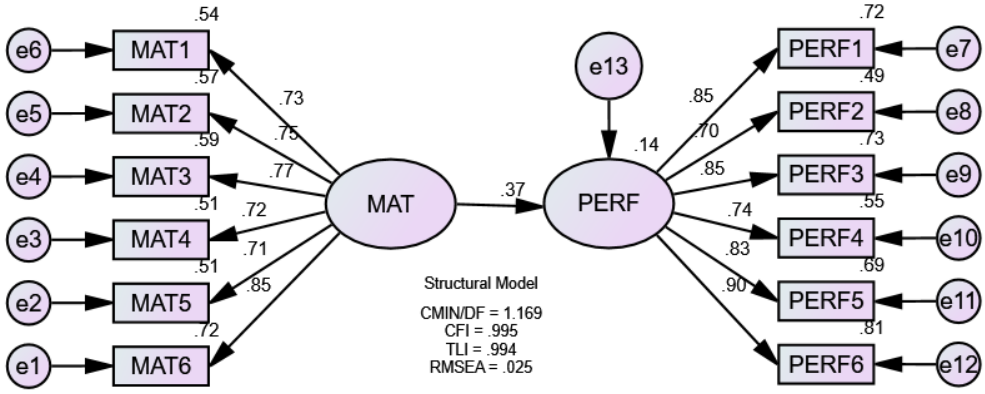


Figure 1. Structural model depicting the corresponding standardized regression weights with factor loadings and residual values associated

The standard model-fit measures were used to assess the model's overall goodness of fit (CMIN/df: <2, CFI: >0.90, TLI: >0.90, SRMR: <0.08, and RMSEA: <0.08) and all values were within their respective common acceptance levels (Ullman, 2001; Hu and Bentler, 1998, Bentler, 1990). The two-factor model (EP and EMA) yielded good fit for the data: CMIN/df = 1.169, CFI = 0.995, TLI = 0.994, SRMR = 0.0330, and RMSEA= 0.025. The model fit data confirm the integrated model is congruent with actual data. Table 5 presents the beta coefficients, t-statistics, and their P-value along the remarks about the theory testing. The results of the structural equation modelling, confirmed the findings through regression path coefficient, t-statistics, probability values (P-values) and related interpretations of the tested hypothesis. Thus, the research model was consistent with the collected data.

Table 5. Results of structural model

Hypothesized path	Path coefficient	t-value	p-value	R^2	Remarks
PERF<--MAT	0.372	5.583	0.001	0.14	Supported

Source: Author's computation

The empirical investigation confirmed that:

MAT exerts a positive and statistically significant influence on PERF ($\beta_1 = 0.372$, $p < 0.001$), hence affirming hypothesis H1.

In conclusion, the results of SEM confirm that MAT positively affects PERF in SMEs operating across various sectors located in Elbasan, Albania.

DISCUSSION AND CONCLUSION

The present study aims to empirically validate the relationship between managerial accounting tools (MAT) and the performance of SMEs (PERF) located in Elbasan city, Albania. The findings are consistent with the conclusions of previous studies which converge on the direct and positive relationship of MAT with firms' performance. This alignment reinforces the concept that managerial accounting practices not only increases operational efficiency but also have a pivotal role in enhancing firm's overall performance. By reducing employing non-financial data alongside with financial data in the process of decision-making the management not only is able to reduce costs but also to adapt more effectively to external and dynamic conditions such as market competition, customer demand and preferences, economic conditions, technological changes etc.

The empirical findings contribute to validate the positive effects of MAT on SMEs performance operating across various sectors in Elbasan, Albania, where similar studies are limited. The results highlight the significance of MAT, whose role is often neglected by the management of SMEs. Practically the results emphases the importance of implementation of MAT by SMEs where the implementation of such practices directly contribute in enhancing firm's performance. The present study combines different theoretical insights with management accounting practices applied by Albanian SMEs, offering valuable insight about this relationship from emerging economies.

There are several limitations in this study that should be acknowledged. To have a more complete understanding on how managerial accounting tools (MAT) influence organizational performance, future research could include additional variables that can act as moderating or mediating mechanism. Different moderating variables such as firm size, industry sector, information technology, uncertainty, organizational culture etc. could contribute in a more comprehensive perspective to examine this relationship. Likewise, mediators including innovation capability, information technology, knowledge management and strategic alignment may better elevate the connection between MAT and PERF. Future studies should focus in validating these findings across specific sectors separately where the MAT application may exhibit distinctive characteristics. This approach could reveal specific patterns of MAT utilization depending on sectorial contexts, thereby offering a more tailored approach for managerial practices.

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SOME RESULTS ON THE SETS OF QUADRATIC RESIDUES AND QUADRATIC NON-RESIDUES MODULO PRIME NUMBER p WITH $p \equiv 3(mod\ 4)$

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ABSTRACT

Let p be a prime number such that $p \equiv 3 (\mathrm{mod}\, 4)$. We denote by R_p the set of quadratic residues and by N_p the set of non-quadratic residues modulo p. We also denote by $H_p = \{1, 2, \ldots, p-1\}$ and all computations are carried out modulo p. The sum of the sets A and B, denoted symbolically by $A + B$, is defined by the set

$$A + B = \{a + b \mid a \in A, b \in B\}.$$

Also, if, during a certain procedure, every element of a given set A is repeated exactly m times, then we shall denote this by the symbol $A^{\{m\}}$.

In this pape we prove that for every prime p in the form $p \equiv 3(mod 4)$, the equality holds

$$R_p + N_p = H_p^{\{k\}} \bigcup \{0\}^{\{2k+1\}}.$$

Also, for $p = 8k + 7$ we will prove that

$$R_p + R_p = N_p + N_p = H_p^{\{k+1\}},$$

and for $p = 8k + 3$ we will prove that

$$R_p + R_p = H_p^{\{k\}} \bigcup N_p$$

and

$$N_p + N_p = H_p^{\{k\}} \bigcup R_p.$$

Keywords: Quadratic residue, quadratic non-residue, modulo on prime $p \equiv 3(mod 4)$.

1. INTRODUCTION AND PRELIMINARIES

Let p be a prime such that $p = 4k + 3$, $k \in \square$. We denote by

$$R_p = \{r_1, r_2, \ldots, r_{2k+1}\} \text{ and } N_p = \{n_1, n_2, \ldots, n_{2k+1}\},$$

the set of quadratic residues and quadratic non-residues modulo p. We also denote by

$$H_p = \{1, 2, \ldots, p-1\}$$

and all computations in this paper are carried out modulo p.

For completeness, we recall the definitions introduced in [1].

Definition 1.1. *Let n be an integer and let A and B be sets of integers. The sum of the integer n with the set A, denote by $n+A$, is defined by the set*

$$n+A=\{n+a \mid a\in A\}.$$

The product of the integer n with the set A, denoted by the nA, is defined by the set

$$nA=\{na \mid a\in A\}.$$

The sum of the sets A and B, denoted symbolically by $A+B$, is defined by the set

$$A+B=\{a+b \mid a\in A, b\in B\}.$$

Note 1.2. We note that, if in the sets A and B, there exist elements $u, v\in A\cap B$, then in the set $A+B$ the elements $u+v$ and $v+u$, naturally, are considered identical, therefore, they appear only once in it. In this way, we obtain

$$|A+B|=|A|\cdot|B|, \text{ with } A\cap B=\varnothing,$$

and

$$|A+A|=\frac{|A|\cdot(|A|+1)}{2}.$$

Definition 1.3. *Let A be a set. If, during a certain procedure, every element of the set A is repeated exactly m times, then we shall denote this by the symbol*

$$A^{\{m\}}.$$

According to Definition 1.2, we shall write

$$\{a,a,a\}=\{a\}^{\{3\}} \text{ and } \{a,a,b,b,c,c\}=\{a,b,c\}^{\{2\}}.$$

Example 1.4. Let $A=\{11,12,13\}$ and $B=\{21,22\}$ be sets. Based on the Definition 1.1., Definition 1.2. and the above note, we have

$$A+B=\{11+21,11+22,12+21,12+22,13+21,13+22\}=\{32,35\}\cup\{33,34\}^{\{2\}},$$

$$A+A=\{11+11,11+12,11+13,12+12,12+13,13+13\}=\{22,23,25,26\}\cup\{24\}^{\{2\}}.$$

The results of the following two theorems will be required in subsequent arguments.

Theorem 1.5. [2] (*Euler's criterion*) *Let p be an odd prime. Then for all n we have*

$$(n/p)\equiv n^{\frac{p-1}{2}} \pmod p.$$

Theorem 1.6. [3] *2 is a quadratic residue of primes of the form $8n\pm1$ and a non-quadratic residue of primes of the form $8n\pm3$.*

By applying Euler's criterion, one can easily demonstrate that the product of two quadratic residues, remains a quadratic residue modulo p. Indeed, if $r_1, r_2\in R_p$ we have $(r_1, r_2)=1$, $(r_1/p)=(r_2/p)=1$ and

$$(r_1r_2/p)=(r_1/p)(r_2/p)=1\cdot1=1.$$

In the same way, it can be shown that the product of two non-quadratic residues is a quadratic residue modulo p, while the product of a quadratic residue with a non-quadratic residue is a non-quadratic residue modulo p.

2. MAIN RESULTS

Let us first prove that the equality holds

$$R_p + N_p = H_p^{\{k\}} \bigcup \{0\}^{\{2k+1\}}.$$

We begin by proving the following theorem.

Theorem 2.1. *In the set*

$$1 + N_p = \{1 + n_1, 1 + n_2, \ldots, 1 + n_{2k+1}\},$$

k elements are quadratic residues, k elements are quadratic non-residues and an element is congruent to 0 modulo p.

Proof. For every prime $p \equiv 3(mod4)$, the number $p-1$ is a quadratic non-residue modulo p. This follows from Euler's criterion:

$$\left(\frac{-1}{p}\right) \equiv (-1)^{\frac{p-1}{2}} \equiv (-1)^{2k+1} \equiv -1 (\mathrm{mod}\, p).$$

Hence,

$$1 + (p-1) = 1 + n_{2k+1} \equiv 0 (\mathrm{mod}\, p).$$

Moreover, $p-1$ is the only quadratic non-residue modulo p that is self-inverse with respect to multiplication modulo p. Since the multiplicative inverse modulo p of any quadratic non-residue is a quadratic non-residue, then the $2k$ elements $n_1, n_2, \ldots, n_{2k}$, can be partitioned into k pairs of distinc elements n_a and n_b, such that $n_a \cdot n_b \equiv 1(modp)$. We have

$$(1 + n_a)(1 + n_b) = 1 + n_a + n_b + n_a n_b = 2 + n_a + n_b (\mathrm{mod}\, p).$$

The integer $2 + n_a + n_b$ is a quadratic non-residue modulo p since

$$n_a(2 + n_a + n_b) = 2n_a + n_a^2 + n_a n_b \equiv n_a^2 + 2n_a + 1 \equiv (n_a + 1)^2 (\mathrm{mod}\, p),$$

and the product of two quadratic non-residues is a quadratic residue modulo p. Since the integer $(1 + n_a)(1 + n_b)$ is a quadratic non-residue modulo p, it follows that among the numbers $1 + n_a$ and $1 + n_b$, one is a quadratic residue and the other is a quadratic non-residue modulo p. Consequently, the $2k$ elements of the set $1 + N_p$, except for the element $1 + n_{2k+1}$, can be partitioned into k pairs of elements, where, in each pair, one element is a quadratic residue and the other is a quadratic non-residue modulo p. This shows that, in this set, k elements are quadratic residues, k elements are quadratic non-residues and an element is congruent to 0 modulo p. □

Theorem 2.2. [1] *For every $r \in R_p$, the equality holds*

$$r \cdot N_p = N_p.$$

Theorem 2.3. *For every $r \in R_p$, in the set*

$$r + N_p = \{r + n_1, r + n_2, \ldots, r + n_{2k+1}\},$$

k elements are quadratic residues, k elements are quadratic non-residues and an element is congruent to 0 modulo p.

Proof. Based on Theorem 2.2., the equality holds

$$r(1 + N_p) = \{r(1 + n_1), \ldots, r(1 + n_{2k+1})\} = \{r + rn_1, \ldots, r + rn_{2k+1}\} = r + r \cdot N_p = r + N_p.$$

Since by Theorem 2.1, the set $1 + N_p$ contains k quadratic residues, k quadratic non-residues and an element congruent to 0 modulo p, it follows that the set $r + N_p$ has the same property. □

In the following theorem, obtain one of the main results of this paper.

Theorem 2.4. *For every prime number of the form* $p = 4k + 3$, *we have*

$$R_p + N_p = H_p^{\{k\}} \bigcup \{0\}^{\{2k+1\}}.$$

Proof. Based on Theorem 2.3, it follows that the set $R_p + N_p$ contain $2k+1$ elements congruent to 0 modulo p. Also, among the remains elements, exactly half are quadratic residues and the other half are quadratic non-residues modulo p. To establish the equality

$$R_p + N_p = H_p^{\{k\}} \bigcup \{0\}^{\{2k+1\}},$$

it suffices to show that, within the set $R_p + N_p$, every pair of quadratic residues and every pair of quadratic non-residues modulo p, occur the same number of times in this set.

Let r_a be a quadratic residue modulo p, such that $r_a \in R_p + N_p$. We have

$$r_a \equiv r_u + n_v \pmod p,\ r_u \in R_p \text{ and } n_v \in N_p.$$

Let r_b be now an arbitrary quadratic residue modulo p. Since the congruence

$$r_a \cdot x \equiv r_b \pmod p$$

has a unique solution, then there exists a unique quadratic residue r_w such that

$$r_a \cdot r_w \equiv r_b \pmod p.$$

Multiplying both sides of the congruence $r_a \equiv r_u + n_v \pmod p$ by r_w, we obtain

$$r_b \equiv r_l + n_s \pmod p,$$

when $r_l \equiv r_u \cdot r_w \in R_p$ and $n_s \equiv n_v \cdot r_w \in R_p$. It follow that $r_b \in R_p + N_p$. Since the quadratic residue r_w is unique, it follows that every pair of quadratic residues appears the same number of times in the set $R_p + N_p$.

In the same way, it can be shown that every pair of quadratic non-residues modulo p, appears the same number of times in the set $R_p + N_p$. □

Example 2.5. *For the prime* $p = 19 = 4 \cdot 4 + 3$, *we have* $R_{19} = \{1,4,5,6,7,9,11,16,17\}$ *and* $N_{19} = \{2,3,8,10,12,13,14,15,18\}$.

$$1 + N_{19} = \{3,4,9,11,13,14,15,16,\mathbf{0}\},$$
$$4 + N_{19} = \{6,7,12,14,16,17,18,\mathbf{0},3\},$$
$$5 + N_{19} = \{7,8,13,15,17,18,\mathbf{0},1,4\},$$
$$6 + N_{19} = \{8,9,14,16,18,\mathbf{0},1,2,5\},$$
$$7 + N_{19} = \{9,10,15,17,\mathbf{0},1,2,3,6\}$$
$$9 + N_{19} = \{11,12,17,\mathbf{0},2,3,4,5,8\},$$
$$11 + N_{19} = \{13,14,\mathbf{0},2,3,4,5,7,10\},$$
$$16 + N_{19} = \{18,\mathbf{0},5,7,9,10,11,12,15\},$$
$$17 + N_{19} = \{\mathbf{0},1,6,8,10,11,12,13,16\}.$$

As we can see, we have:

$$R_{19} + N_{19} = H_p^{\{4\cdot 1\}} \bigcup \{0\}^{\{2\cdot 4+1\}} = H_{11}^{\{4\}} \bigcup \{0\}^{\{9\}}. \square$$

Let us now prove that for prime numbers of the form $p = 8k + 7$, the equality holds

$$R_p + R_p = N_p + N_p = H_p^{\{k+1\}}.$$

To establish this equality, we first prove the following theorems.

Theorem 2.6. *Let p be a prime of the form $p = 4k + 3$. In the set*

$$1 + R_p = \{1 + r_1, 1 + r_2, \ldots, 1 + r_{2k+1}\},$$

k elements are quadratic residues and $k + 1$ are quadratic non-residue modulo p.

Theorem 2.7. *Let p be an odd prime. For every $r \in R_p$, we have*

$$r R_p = R_p.$$

Proof. First, all numbers $r \cdot r_i$, $i = 1, 2, \ldots, \frac{p-1}{2}$ are quadratic residues modulo p. To prove that

$$r R_p = R_p,$$

it suffices to show that

$$r \cdot r_a \not\equiv r \cdot r_b \pmod{p},$$

for every pair of distinct elements a and b from the set $\left\{1, 2, \ldots, \frac{p-1}{2}\right\}$. Indeed, suppose that $r \cdot r_a \equiv r \cdot r_b \pmod{p}$. Since $\gcd(r, p) = 1$, it follows that $r_a \equiv r_b \pmod{p}$, which is imposible because $a \neq b$. □

Theorem 2.8. *Let p be a prime of the form $p = 8k + 7$ and $r \in R_p$. In the set*

$$r + R_p = \{r + r_1, r + r_2, \ldots, r + r_{4k+3}\},$$

$2k + 1$ elements are quadratic residues and $2k + 2$ are quadratic non-residue modulo p.

Proof. The theorem is an immediate consequence of the equality

$$r(1 + R_p) = \{r(1 + r_1), \ldots, r(1 + r_{2k+3})\} = \{r + rr_1, \ldots, r + rr_{2k+3}\} = r + r \cdot R_p = r + R_p,$$

Theorem 2.6. and that the product of two quadratic residues is a quadratic residue modulo p. □

Theorem 2.9. *For every prime number of the form $p = 8k + 7$, we have*

$$R_p + R_p = H_p^{\{k+1\}}.$$

Proof. First, we emphasize that, according to Note 1.2, the elements $r_a + r_b$ and $r_b + r_a$ are considered identical when $a \neq b$. Furthermore, by this note, we have

$$|R_p + R_p| = \frac{(4k+3)(4k+4)}{2} = (k+1)(8k+6) = (k+1)(p-1).$$

Second, since 2 is a quadratic residue modulo p by Theorem 1.6, it follows that the elements $r_a + r_a = 2r_a$ are quadratic residues modulo p.

Based on the two conclusions above, it follows that, in the set $R_p + R_p$, half of the elements are quadratic residues and the other half are quadratic nonresidues modulo p. Furthermore, by an argument analogous to that used in Theorem 2.4, one can show that in the set $R_p + R_p$, every two quadratic residues modulo p occur the same number of times. Likewise, every two quadratic non-residues modulo p occur the same number of times.

Therefore, since $|R_p + R_p| = (k+1)(p-1)$, it follows that each quadratic residue and each quadratic nonresidue occurs exactly $k+1$ times in the set $R_p + R_p$. Hence, the equality

$$R_p + R_p = H_p^{\{k+1\}},$$

holds. □

Theorem 2.10. *For every prime number of the form* $p = 8k + 7$*, we have*

$$N_p + N_p = H_p^{\{k+1\}}.$$

Proof. Combining the equalities

$$n(N_p + N_p) = n \cdot N_p + n \cdot N_p = R_p + R_p$$

and

$$n \cdot H_p = H_p,$$

we obtain the desired result, when where n is an arbitrary quadratic nonresidue modulo p. □

Example 2.11. For the prime $p = 7 = 8 \cdot 0 + 7$, we have $R_7 = \{1, 2, 4\}$ and $N_7 = \{3, 5, 6\}$.

$$\begin{aligned} 1+1 &\equiv 2, & 2+2 &\equiv 4, \\ 1+2 &\equiv 3, & 2+4 &\equiv 6, \\ 1+4 &\equiv 5, & 4+4 &\equiv 1. \end{aligned}$$

As we can see, we have

$$R_7 + R_7 = H_7^{\{0+1\}} = H_7^{\{1\}} = H_7.$$

$$\begin{aligned} 3+3 &\equiv 6, & 5+5 &\equiv 3, \\ 3+5 &\equiv 1, & 5+6 &\equiv 4, \\ 3+6 &\equiv 2, & 6+6 &\equiv 5. \end{aligned}$$

Also, we have

$$N_7 + N_7 = H_7^{\{0+1\}} = H_7^{\{1\}} = H_7. \square$$

Let us now consider the case when $p = 8k + 3$.

Theorem 2.12. *Let* p *be a prime of the form* $p = 8k + 3$ *and* $r \in R_p$*. In the set*

$$r + R_p = \{r + r_1, r + r_2, \ldots, r + r_{4k+1}\},$$

$2k$ *elements are quadratic residues and* $2k + 1$ *are quadratic non-residue modulo* p*.*

Proof. The proof proceeds in the same way as in Theorem 2.8. □

Theorem 2.13. *For every prime number of the form* $p = 8k + 3$*, we have*

$$R_p + R_p = H_p^{\{k\}} \bigcup N_p.$$

Proof. According to Note 1.2, the elements $r_a + r_b$ and $r_b + r_a$, $a \neq b$, are considered identical. Furthermore, by this note, we have

$$|R_p + R_p| = \frac{(4k+1)(4k+2)}{2} = (2k+1)(4k+1) = (4k+1) + k(p-1).$$

Since 2 is a quadratic non-residue modulo p by Theorem 1.6, it follows that the elements $r_a + r_a = 2r_a$ are quadratic non-residues modulo p.

Based on the two conclusions above, it follows that, in the set $R_p + R_p$, from which the elements $r_a + r_a = 2r_a$ have been excluded, half of the elements are quadratic residues and the other half are quadratic nonresidues modulo p. Furthermore, by an argument analogous to that used in Theorem 2.4, one can show that in the set $R_p + R_p$, from which the elements $r_a + r_a = 2r_a$ have been excluded, every two quadratic residues modulo p occur the same number of times. Likewise, every two quadratic non-residues modulo p occur the same number of times.

Therefore, since $|R_p + R_p| = (4k+1) + k(p-1)$, and the number of elements of the form $r_a + r_a = 2r_a$ is $4k+1$, the equality

$$R_p + R_p = H_p^{\{k\}} \bigcup N_p,$$

holds. □

Theorem 2.14. *For every prime number of the form $p = 8k + 3$, we have*

$$N_p + N_p = H_p^{\{k\}} \bigcup R_p.$$

Proof. Combining the equalities

$$n(R_p + R_p) = n \cdot R_p + n \cdot R_p = N_p + N_p$$

and

$$n \cdot H_p = H_p,\ n \cdot N_p = R_p$$

we obtain the desired result, when where n is an arbitrary quadratic nonresidue modulo p. □

Example 2.15. For the prime $p = 11 = 8 \cdot 1 + 3$, we have

$$R_{11} = \{1, 3, 4, 5, 9\} \text{ and } N_{11} = \{2, 6, 7, 8, 10\}.$$

$$\begin{array}{lll} 1+1 \equiv 2, & 3+3 \equiv 6, & 4+5 \equiv 9, \\ 1+3 \equiv 4, & 3+4 \equiv 7, & 4+9 \equiv 2, \\ 1+4 \equiv 5, & 3+5 \equiv 8, & 5+5 \equiv 10, \\ 1+5 \equiv 6, & 3+9 \equiv 1, & 5+9 \equiv 3, \\ 1+9 \equiv 10, & 4+4 \equiv 8, & 9+9 \equiv 7. \end{array}$$

As we can see, we have

$$R_{11} + R_{11} = H_{11}^{\{1\}} \bigcup N_{11} = H_{11} \bigcup N_{11}.$$

$$\begin{array}{lll} 2+2 \equiv 4, & 6+6 \equiv 1, & 7+8 \equiv 4, \\ 2+6 \equiv 8, & 6+7 \equiv 2, & 7+10 \equiv 6, \\ 2+7 \equiv 9, & 6+8 \equiv 3, & 8+8 \equiv 5, \\ 2+8 \equiv 10, & 6+10 \equiv 5, & 8+10 \equiv 7, \\ 2+10 \equiv 1, & 7+7 \equiv 3, & 10+10 \equiv 9. \end{array}$$

Also, we have

$$N_{11} + N_{11} = H_{11}^{\{1\}} \bigcup R_{11} = H_{11} \bigcup R_{11}. \square$$

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IMPLEMENTATION OF SMART ENVIRONMENTAL MANAGEMENT IN THE URBAN WASTE MANAGEMENT SYSTEM: A CASE STUDY OF THE MUNICIPALITY OF DURRËS

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ABSTRACT

Rapid urbanization, increasing urban consumption, and the growing generation of municipal solid waste have created significant challenges for traditional waste management systems, particularly in rapidly developing cities with limited environmental infrastructure. In this context, Smart Environmental Management has emerged as an innovative approach integrating digital technologies, real-time monitoring systems, and data analytics to improve operational efficiency and environmental performance in urban waste management systems. This study aims to analyze the potential implementation of smart environmental management in the urban waste management system of the Municipality of Durrës by evaluating technical, institutional, and environmental opportunities for integrating intelligent technologies into the local context.The research focuses on assessing the potential contribution of technologies such as the Internet of Things (IoT), Geographic Information Systems (GIS), smart environmental monitoring platforms, and data analytics systems to optimize waste collection, transportation, monitoring, and treatment processes. Particular attention is given to the role of these technologies in reducing operational costs, improving resource efficiency, minimizing environmental impacts, and strengthening institutional capacities through data-driven decision-making.The methodological approach is based on a comparative analysis of European smart waste management practices, environmental benchmarking, sustainability indicators, and a conceptual assessment of implementation opportunities within the Municipality of Durrës. The study examines experiences from European smart cities that have implemented intelligent waste monitoring systems, GIS-based route optimization, and digital platforms for environmental performance monitoring in order to identify mechanisms potentially transferable to the Albanian context.The expected findings suggest that the gradual implementation of a smart urban waste management system in the Municipality of Durrës may contribute to improved operational efficiency, reduced collection and transportation costs, lower logistics-related emissions, enhanced environmental monitoring, and increased recycling rates. Furthermore, the study highlights that the integration of smart technologies can support the transition toward a more sustainable and circular urban waste management model aligned with European environmental and circular economy objectives.

Keywords: smart environmental management; urban waste management; IoT; GIS; circular economy; Municipality of Durrës.

1. Introduction

Urban waste management represents one of the most complex challenges of environmental governance at the global level, particularly under conditions of accelerated urbanization, population growth, and changing patterns of urban consumption. According to international estimates, the amount of municipal solid waste is expected to increase significantly in the coming decades, placing considerable pressure on existing management capacities as well as on urban and natural ecosystems. Traditional waste management systems, mainly based on periodic collection, linear transportation, and final disposal, are becoming increasingly ineffective in meeting the demands for efficiency, sustainability, and the

minimization of environmental impacts (Kaza et al., 2018; United Nations Environment Programme [UNEP], 2024).

In this context, the transition toward smart cities has created new opportunities for modernizing urban waste management systems through the integration of digital technologies, automation, and real-time data analysis. The concept of Smart Environmental Management has emerged as a contemporary paradigm of urban governance aimed at optimizing environmental performance through the use of innovative technologies, intelligent monitoring systems, and data-driven decision-making mechanisms. In the field of urban waste management, this approach includes the use of Internet of Things (IoT) sensors, Geographic Information Systems (GIS), artificial intelligence, cloud platforms, and predictive analytics systems to improve operational efficiency and reduce both economic and environmental costs (Ferronato & Torretta, 2019; OECD, 2023).

International experience demonstrates that cities integrating smart technologies into waste management systems have achieved significant improvements in route optimization, reduced fuel consumption, increased recycling rates, and minimized greenhouse gas emissions. Cities such as Barcelona, Amsterdam, and Copenhagen have implemented real-time monitoring systems for container capacity through intelligent sensors, substantially reducing unnecessary collection frequency and operational costs of public services. These models are increasingly regarded as successful practices of data-driven urban management and circular economy implementation (European Environment Agency, 2023; European Commission, 2022).

In Albania, the urban waste management sector continues to face structural, institutional, and infrastructural challenges associated with limited operational efficiency, low levels of source separation, a lack of advanced monitoring systems, and insufficient capacities for environmental data analysis. Although legal and institutional reforms have been undertaken in alignment with the *acquis communautaire* of the European Union, the practical implementation of intelligent management models remains limited at the local level. In particular, urban areas with high population density and intensive tourism activity require more flexible and technologically advanced waste management systems (Ministry of Tourism and Environment, 2023; European Commission, 2024).

Within this framework, the Municipality of Durrës represents a particularly important case study due to its position as one of the most significant urban and tourist centers in Albania. Seasonal population growth, urban expansion, intensive economic activity, and increasing pressure on existing public service infrastructure have created considerable challenges for the effective management of urban waste. The current system is primarily characterized by traditional collection and transportation processes, while the need for intelligent monitoring, logistical optimization, and enhanced environmental efficiency has become increasingly evident (Local Waste Management Report, 2024).

Despite the growing international interest in smart urban waste management, Albanian scientific literature remains limited in the empirical analysis of the implementation potential of such systems at the local level. A research gap exists regarding how European smart city practices can be adapted to the Albanian institutional, economic, and infrastructural context, particularly in coastal cities with dynamic urban development such as Durrës. This study seeks to contribute to filling this gap by developing a conceptual model of smart environmental management applicable at the local level (Yigitcanlar et al., 2019; UNEP, 2024).

The main objective of this study is to analyze the implementation potential of Smart Environmental Management within the urban waste management system of the Municipality of Durrës by identifying opportunities, challenges, and potential mechanisms for integrating intelligent technologies into existing waste management processes. To achieve this objective, the study is guided by the following research questions:

RQ1: How can smart technologies contribute to optimizing the urban waste management system in the Municipality of Durrës?
RQ2: What are the most effective European smart waste management practices that can be adapted to the local context?
RQ3: What potential impact could the implementation of smart technologies have on operational

efficiency, environmental performance, and the transition toward a circular economy in the Municipality of Durrës?

Study Hypothesis (H1): The implementation of intelligent environmental management technologies in the urban waste management system of the Municipality of Durrës positively affects operational efficiency, cost reduction, and environmental performance improvement.

Structure of the paper. The study is organized into seven main sections. Following the introduction, the second section addresses the literature review on smart environmental management and smart technologies in urban waste management. The third section presents the research methodology, while the fourth section analyzes the results and discussion. The fifth section proposes a conceptual model for implementing smart environmental management in the Municipality of Durrës. Finally, the implications for local policymaking and the study conclusions are presented.

2. Literature Review

2.1 Smart Environmental Management

Smart Environmental Management refers to the use of intelligent technologies, real-time monitoring, data analysis, and automated decision-making systems to improve environmental performance and resource efficiency in urban areas. It is considered a key component of smart cities, helping optimize public services, reduce pollution, and support sustainable urban development (Bibri & Krogstie, 2020; Yigitcanlar et al., 2019). In waste management, technologies such as IoT sensors, GIS, artificial intelligence, and cloud systems are increasingly used to monitor waste generation, improve logistics, and reduce operational costs.

2.2 Smart Waste Management

Smart Waste Management aims to modernize traditional waste collection and transport systems through real-time monitoring and data-driven decision-making. Smart sensors installed in waste containers provide information about filling levels and operational conditions, enabling optimized collection routes and reducing unnecessary transportation. Research indicates that these systems can significantly lower fuel consumption, operational costs, and greenhouse gas emissions. Additionally, artificial intelligence and big data analytics help predict waste generation patterns, particularly in seasonal and tourist cities such as Durrës (Ferronato & Torretta, 2019; OECD, 2023).

2.3 European Best Practices

Several European cities have successfully implemented smart waste management systems. Barcelona uses IoT sensors for real-time monitoring of waste containers, improving collection efficiency and reducing costs. Amsterdam integrates GIS and digital platforms to optimize waste transport and promote recycling, while Copenhagen combines smart waste management with climate goals to reduce emissions. Nordic cities such as Helsinki also apply predictive systems to forecast seasonal waste flows. These experiences demonstrate that successful implementation depends not only on technology but also on institutional cooperation, public policies, and citizen engagement (European Commission, 2022; OECD, 2023).

2.4 Research Gap and Albanian Context

Although international literature on Smart Environmental Management has expanded considerably, studies in Albania remain limited, particularly regarding the local implementation of smart technologies in waste management. Existing systems are still largely based on traditional collection methods, with limited real-time monitoring and data integration. In this context, the Municipality of Durrës represents an important case study due to seasonal tourism, urban growth, and increased waste generation. This study addresses the existing research gap by exploring the potential for implementing smart environmental management practices adapted to the Albanian local context.

3. Research Methodology

3.1 Research Design

This study is based on a qualitative and exploratory research approach, combined with elements of comparative analysis and environmental benchmarking, with the aim of evaluating the implementation potential of Smart Environmental Management within the urban waste management system of the Municipality of Durrës. Considering the innovative nature of the topic and the lack of consolidated empirical data in the Albanian context, the study adopts a case study research design, which allows an in-depth analysis of complex phenomena within their real institutional and territorial context (Yin, 2018; Creswell & Creswell, 2023).

3.2 Methodological Research Strategy

To ensure a comprehensive and scientifically grounded analysis, the study combines several complementary methodological approaches, namely: (i) the analysis of international scientific literature; (ii) environmental benchmarking of European smart urban waste management practices; (iii) conceptual analysis of the local context of the Municipality of Durrës; and (iv) the assessment of sustainability and operational performance indicators. This hybrid methodological approach enables not only the identification of international best practices but also the evaluation of their transferability to the Albanian institutional and infrastructural reality (Creswell & Creswell, 2023; OECD, 2023).

The study follows a deductive research logic, where international theories and practices of Smart Environmental Management are used as an analytical basis to assess implementation opportunities in the case of Durrës. Through the comparison of European smart city practices with the existing characteristics of the local waste management system, the study seeks to identify the most realistic and potentially applicable mechanisms at the local level (Bibri & Krogstie, 2020).

The approach adopted in this study can be classified as **policy-oriented environmental research**, since its final objective is not limited solely to the production of theoretical knowledge, but also aims to formulate practical recommendations for local policymaking and the modernization of urban waste management public services (UNEP, 2024).

3.3 Data Sources

The study primarily relies on the use of secondary data, selected through a systematic process of literature review and institutional documentation analysis. Data sources include:

1. scientific articles indexed in international databases such as Scopus, Web of Science, and ScienceDirect;
2. reports from international organizations on urban management and the circular economy;
3. strategic documents and European Union policies on smart cities and waste management;
4. national and local reports on urban waste management in Albania;
5. strategic documents and local waste management plans of the Municipality of Durrës.

The use of multiple data sources aims to increase the validity of the analysis through information triangulation and the minimization of methodological bias that may result from relying on a single data source (Yin, 2018; Creswell & Creswell, 2023).

3.4 Environmental Benchmarking of European Practices

A central component of the study methodology is **environmental benchmarking**, used to analyze and compare the most advanced European smart urban waste management practices. Benchmarking is considered an important method for transferring best practices, particularly in public sectors where institutional innovation requires proven successful models (Camp, 1989; OECD, 2023).

In this study, European cities were selected according to several specific criteria:

Table 1. Benchmark City Selection Criteria

Criterion	Description
Smart technology implementation	Use of IoT, GIS, or digital platforms
Environmental performance	Reduction of costs and emissions
Urban comparability	Comparable urban characteristics
Data availability	Public documentation and empirical studies

Based on these criteria, the benchmark analysis includes the cities of **Barcelona, Amsterdam, Copenhagen, and Helsinki**, which are considered successful cases of smart urban waste management implementation (European Environment Agency, 2023; OECD, 2023).

The purpose of benchmarking is not the direct imitation of European practices, but rather the identification of functional components that can be adapted to the local context of Durrës, taking into account the financial, technological, and institutional constraints of the territory.

3.5 Sustainability Assessment Indicators

To analyze the implementation potential of Smart Environmental Management in the Municipality of Durrës, the study applies a set of sustainability indicators that enable the evaluation of possible operational, economic, and environmental impacts.

Table 2. Main Sustainability Assessment Indicators

Dimension	Indicator	Description
Operational	Collection efficiency	Optimization of routes and operational time
Economic	Cost reduction	Savings in fuel and logistics costs
Environmental	Emission reduction	Reduction of CO_2 emissions from transport
Recycling	Source separation rate	Increase in material recovery
Institutional	Decision-making quality	Use of real-time data

These indicators were selected based on international urban sustainability assessment standards and European Union environmental reporting practices. Their analysis enables a conceptual evaluation of the potential impact that smart systems implementation may have on urban waste management in the Municipality of Durrës (European Commission, 2022; UNEP, 2024).

3.6 Conceptual Framework of the Study

Based on the existing literature and the analyzed European practices, the study proposes a conceptual framework linking the integration of intelligent technologies with the improvement of urban waste management system performance.

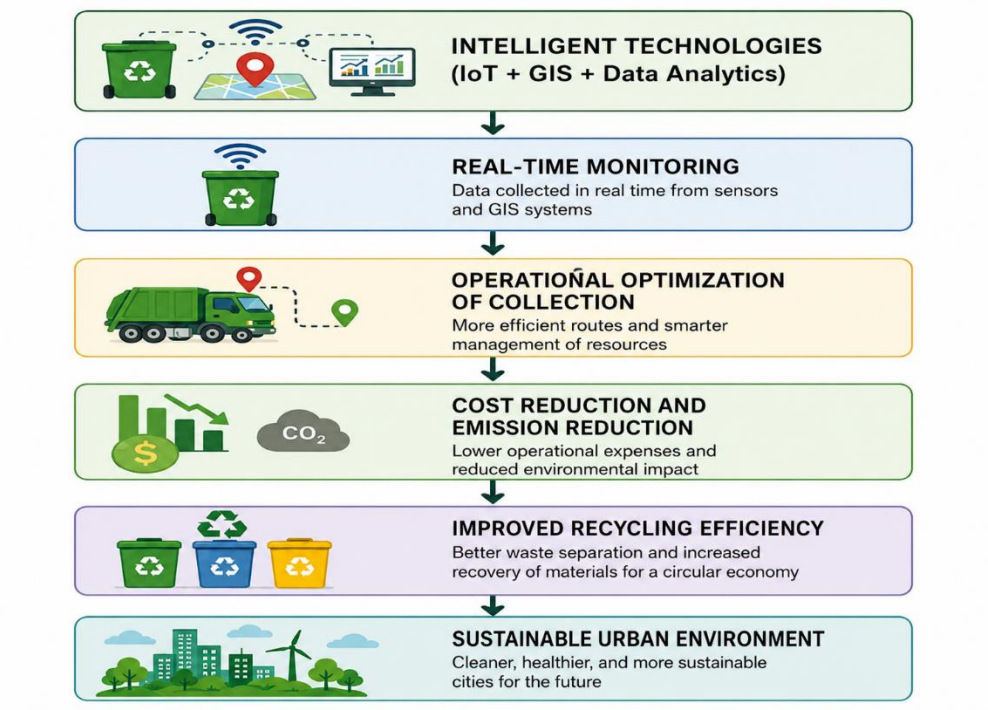


Figure 1. Conceptual Framework of Smart Urban Waste Management

This theoretical framework supports the study's main hypothesis that the integration of smart technologies into urban waste management can contribute to increased operational efficiency, reduced environmental impacts, and strengthened transition toward a circular economy at the local level (Bibri & Krogstie, 2020; European Commission, 2024).

4. Results and Discussion

4.1 Current State of Urban Waste Management in the Municipality of Durrës

The current urban waste management system in the Municipality of Durrës is mainly characterized by a traditional model of waste collection and transportation, supported by pre-planned routes and fixed service frequencies. In practice, operational processes rely on visual inspections and periodic interventions, without the integration of automated real-time monitoring systems. Although functional at a basic level, this approach limits operational flexibility and the efficient use of logistical resources, especially during periods of high tourist activity (Local Waste Management Report, 2024).

One of the major challenges identified is the seasonal variability in urban waste generation. As a coastal and tourist city, Durrës experiences a significant population increase during the summer season, accompanied by a higher volume of waste and increased pressure on the existing management infrastructure. In the absence of intelligent forecasting and monitoring systems, institutional response remains largely reactive rather than proactive, resulting in overloaded containers and reduced quality of urban services.

An additional issue relates to the lack of an integrated monitoring system for evaluating waste management performance. Currently, operational information regarding collection frequency, container filling levels, logistical costs, and problematic waste accumulation areas is not systematically generated in real time. This situation limits the capacity of local institutions to make evidence-based decisions and optimize the allocation of financial and human resources (European Commission Progress Report for Albania, 2024; UNEP, 2024).

Furthermore, the relatively limited level of waste separation at source and the low recycling rates represent significant challenges for the transition toward a circular economy at the local level. Traditional mixed waste collection systems reduce the recovery potential of recyclable materials and increase the amount of waste ending in final disposal sites. International literature suggests that integrating smart technologies, combined with public awareness and incentive mechanisms, can

significantly improve recycling rates and urban environmental performance (World Bank, 2022; European Commission, 2022).

To summarize the main challenges of the existing system in the Municipality of Durrës, the following table provides an analytical assessment of current issues and their potential impact on system efficiency.

Table 3. Main Challenges of the Current Waste Management System in the Municipality of Durrës

Challenge	Operational Impact	Environmental Impact
Fixed collection routes	Unnecessary fuel consumption	Increased CO_2 emissions
Lack of real-time monitoring	Delayed institutional response	Container overloading
Limited source separation	Low recycling efficiency	Increased final disposal
Lack of data analysis	Non-optimal decision-making	Limited environmental performance
Seasonal increase in waste	Operational overload	Pressure on infrastructure

The analysis of the current situation suggests that the existing urban waste management system in Durrës still operates under a largely linear and reactive model, where advanced monitoring and optimization technologies remain unimplemented. This creates the need to explore new intelligent management alternatives capable of significantly improving operational efficiency and the environmental sustainability of the system (Ferronato & Torretta, 2019; OECD, 2023).

4.2 Potential for the Integration of Smart Technologies in the Municipality of Durrës

Based on the analyzed European practices and the specific characteristics of the Durrës territory, the study identifies several smart technologies with high implementation potential in the local urban waste management system. These technologies include: (i) IoT sensors for container monitoring; (ii) GIS for optimizing collection routes; (iii) data analytics systems; and (iv) digital environmental monitoring platforms.

4.2.1 IoT Sensors for Real-Time Container Monitoring

One of the most feasible interventions with immediate potential impact in the case of Durrës is the installation of IoT sensors in urban waste containers. These sensors can monitor container filling levels in real time and automatically transmit information to a digital management center. In this way, collection vehicles would intervene only when containers reach predefined filling thresholds, eliminating inefficient routes and unnecessary trips (Longhi et al., 2012; European Commission, 2022).

In the context of Durrës, this technology would be particularly effective during the tourist season, when urban waste flows vary significantly from one area to another. For example, coastal areas, tourist zones, and service centers could be dynamically monitored, enabling a faster institutional response and reducing cases of container overloading.

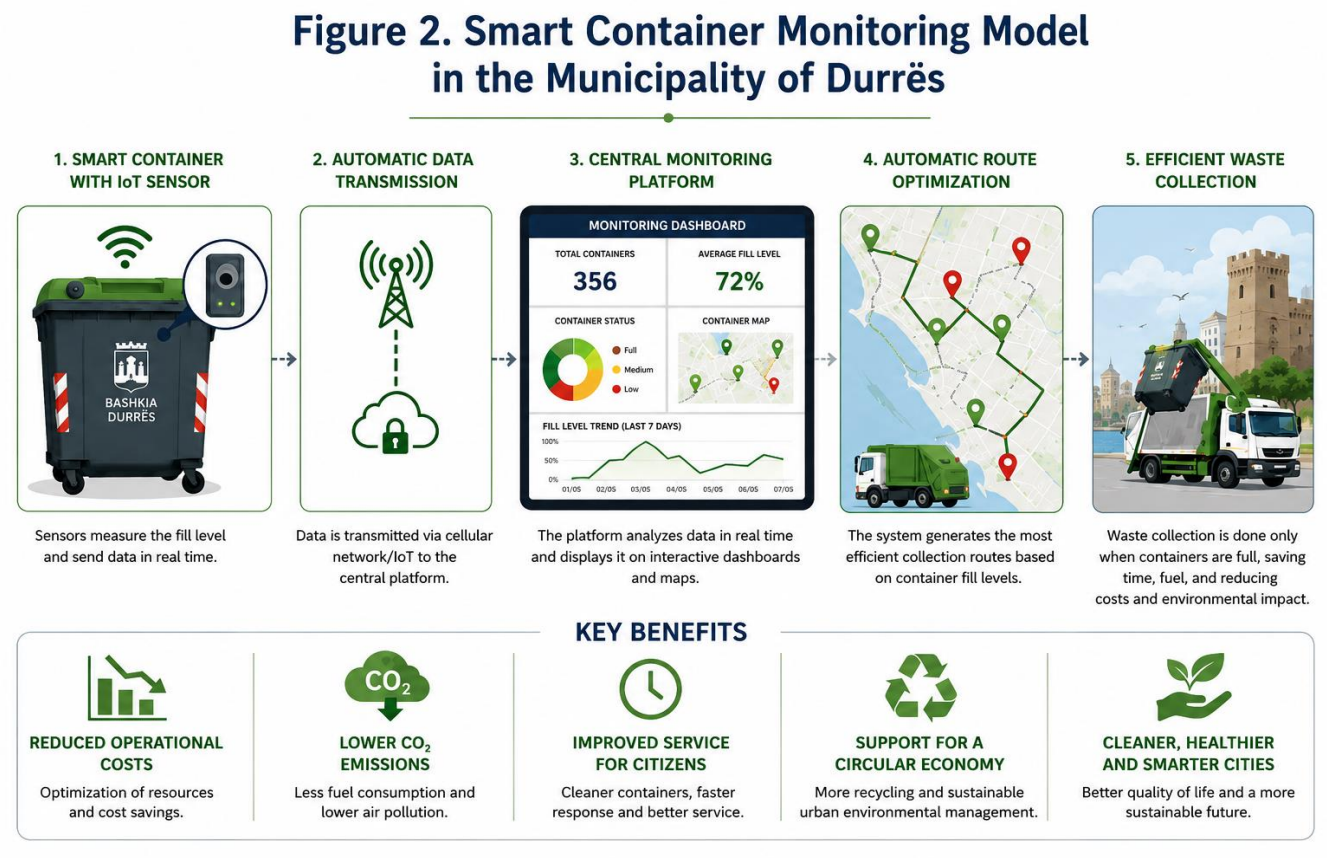


Figure 2. Smart Container Monitoring Model in the Municipality of Durrës

The literature suggests that the implementation of IoT sensors can reduce unnecessary collection frequency by up to 35%, thereby lowering operational costs and climate impacts associated with waste transportation (World Bank, 2022; UNEP, 2024).

4.2.2 Use of GIS for Collection Route Optimization

Another strategic component with high implementation potential in the Municipality of Durrës is the integration of Geographic Information Systems (GIS) for optimizing urban waste collection networks. GIS enables the spatial analysis of container distribution, urban density, waste generation intensity, and urban traffic characteristics, generating optimal vehicle movement routes (Malakahmad et al., 2017).

In the current system, collection routes are largely static and based on predefined frequencies, without taking into account the dynamic changes of the urban territory. The integration of GIS, combined with IoT sensors, would enable an adaptive and intelligent collection system, where operational routes would automatically adjust according to the actual needs of the territory.

For a city such as Durrës, where urban traffic and tourist flows vary significantly depending on the season, the spatial optimization of public services could have a considerable impact not only on operational costs but also on the overall quality of urban services and the reduction of transport-related air pollution (OECD, 2023; European Environment Agency, 2023).

Table 4. Expected Impacts of Smart Technology Integration in the Municipality of Durrës

Technology	Operational Impact	Environmental Impact
IoT Sensors	Optimization of collection frequency	Emission reduction
GIS	Reduction of operational distance	Lower fuel consumption
Data Analytics	Prediction of waste flows	More efficient management
Digital Platforms	Real-time monitoring	Improved decision-making

The analysis suggests that the integration of these technologies could create a gradual transformation from a traditional and linear system toward an intelligent model based on data, operational flexibility, and environmental sustainability.

4.2.3 Use of Data Analytics and Predictive Systems

A strategically important component in the implementation of Smart Environmental Management is the use of data analytics and predictive systems for forecasting urban waste flows. In contemporary smart waste management models, data collected from IoT sensors, GIS, and operational platforms are processed through analytical algorithms that identify waste generation patterns according to season, urban area, population density, and economic activity (Bibri & Krogstie, 2020; OECD, 2023).

In the case of the Municipality of Durrës, the use of predictive systems is of particular interest due to the city's seasonal nature. During the summer tourist season, temporary population growth directly affects the quantity and territorial distribution of urban waste. Through historical data analysis, intelligent systems can predict areas with expected increases in waste volume and recommend higher collection frequency or the redistribution of operational resources (Sharifi et al., 2021).

From an operational perspective, data analytics systems can significantly improve strategic planning and financial management of public services. Through the analysis of operational costs, fuel consumption, response time, and fleet efficiency, the municipality can identify low-performing areas and undertake more targeted corrective measures. This is especially important under conditions of limited financial resources and the need to optimize public investments (European Commission, 2022; UNEP, 2024).

From an environmental perspective, predictive systems contribute to reducing negative climate impacts through the optimization of transport operations and the minimization of inefficient trips. International literature argues that the use of intelligent data systems can significantly reduce CO_2 emissions related to waste logistics, thereby supporting urban climate neutrality objectives (European Environment Agency, 2023; World Bank, 2022).

4.2.4 Digital Environmental Monitoring Platforms

Another intervention with high potential in the local urban waste management system is the development of digital environmental monitoring platforms. These platforms function as integrated management centers where operational and environmental data related to the urban waste system are collected, analyzed, and visualized in real time (Kummitha & Crutzen, 2019).

1. In practice, such a platform may include:
2. real-time monitoring of container fill levels;
3. GPS tracking of collection vehicles;
4. analysis of operational route performance;
5. monitoring of recycling rates by area;
6. automatic reporting of operational issues;
7. dashboards for institutional decision-makers.

In the case of Durrës, an integrated platform would enable a more transparent, controllable, and flexible urban management system, reducing operational delays and improving coordination among institutions responsible for urban cleaning services (OECD, 2023; European Commission, 2024).



Figure 3. Integrated Smart Urban Waste Management Platform

The literature emphasizes that smart platforms contribute not only to improving operational efficiency but also to strengthening transparent governance and public accountability, thereby increasing citizens' trust in local institutions (Sharifi et al., 2021).

4.3 Comparative Analysis: European Practices and Adaptation Potential in the Municipality of Durrës

To assess the feasibility of implementing Smart Environmental Management in Durrës, the study develops a comparative analysis between European smart city practices and the current characteristics of the local urban waste management system. The analysis indicates that, although significant differences exist in terms of financial and technological capacities, several functional components of European models appear potentially transferable to the local context.

Table 5. Comparative Benchmarking: European Cities and the Municipality of Durrës

Element	Barcelona	Amsterdam	Copenhagen	Durrës (Potential)
IoT Sensors	Yes	Yes	Yes	Feasible
GIS for Routes	Yes	Yes	Yes	Highly feasible
Predictive Analytics	Yes	Yes	Yes	Medium-term phase
Digital Platforms	Yes	Yes	Yes	Gradually feasible
Source Separation	High	High	Very High	Needs development

The results of the analysis show that the most feasible short-term interventions for the Municipality of Durrës are the implementation of GIS for route optimization and the pilot installation of IoT sensors in areas with high urban and tourist intensity. Compared to fully automated systems, these interventions require relatively moderate investments and can generate immediate operational benefits (European Commission, 2022; OECD, 2023).

In the medium and long term, the development of integrated digital platforms and predictive analytics systems may support a more comprehensive transformation toward a smart urban waste management model. However, the literature suggests that the effectiveness of these systems depends significantly on institutional capacity, organizational readiness, and the level of coordination among local stakeholders (UNEP, 2024; World Bank, 2022).

4.4 Discussion of Findings

The findings of this study support the main hypothesis that the implementation of Smart Environmental Management can positively contribute to improving the urban waste management system in the Municipality of Durrës. The results are consistent with international studies arguing that intelligent technologies can reduce operational costs, improve logistical performance, and reduce climate impacts associated with waste transportation (Ferronato & Torretta, 2019; European Environment Agency, 2023).

In particular, the study highlights that the urban and tourist characteristics of Durrës make the city especially suitable for implementing adaptive and flexible waste management systems. Unlike traditional static models, intelligent systems provide opportunities for dynamic responses to seasonal changes in waste generation, significantly improving the efficiency of public resource utilization.

However, the discussion also highlights that successful implementation requires addressing several structural barriers, including initial financing, digital infrastructure, professional training of technical staff, and citizen involvement in source separation practices. For this reason, the study suggests a gradual implementation model, supported by pilot projects and inter-institutional partnerships.

5. Conceptual Model for the Implementation of Smart Environmental Management in the Urban Waste Management System of the Municipality of Durrës

Based on the results of the comparative analysis, European benchmarking practices, and the specific characteristics of the local context, this study proposes a conceptual model for the gradual implementation of Smart Environmental Management within the urban waste management system of the Municipality of Durrës. The model is based on the logic of progressively transforming the existing system from a traditional, linear, and reactive approach into an intelligent, adaptive, and data-driven system (European Commission, 2022; OECD, 2023).

The conceptual model proposes an integrated structure based on five main components:

1. Smart monitoring infrastructure
2. Digital optimization of operations
3. Data analytics and predictive systems
4. Evidence-based governance
5. Circular economy and citizen participation

These components are considered mutually interconnected and operate as part of an integrated urban environmental governance system.

5.1 First Phase: Pilot Implementation of Smart Technologies

The study suggests that the implementation of Smart Environmental Management in Durrës should not be carried out immediately across the entire municipal territory, but rather through a gradual and pilot-based approach. In the initial phase, the installation of IoT sensors is recommended in urban areas with high levels of waste generation, particularly in:

- central urban areas;
- coastal tourist zones;
- areas with high commercial density;
- public spaces with high seasonal activity.

A pilot approach is considered more realistic from both a financial and institutional perspective, as it allows the testing of technological performance before broader-scale expansion. International literature suggests that pilot projects reduce operational risks and increase institutional acceptance of technological innovation (Sharifi et al., 2021; UNEP, 2024).

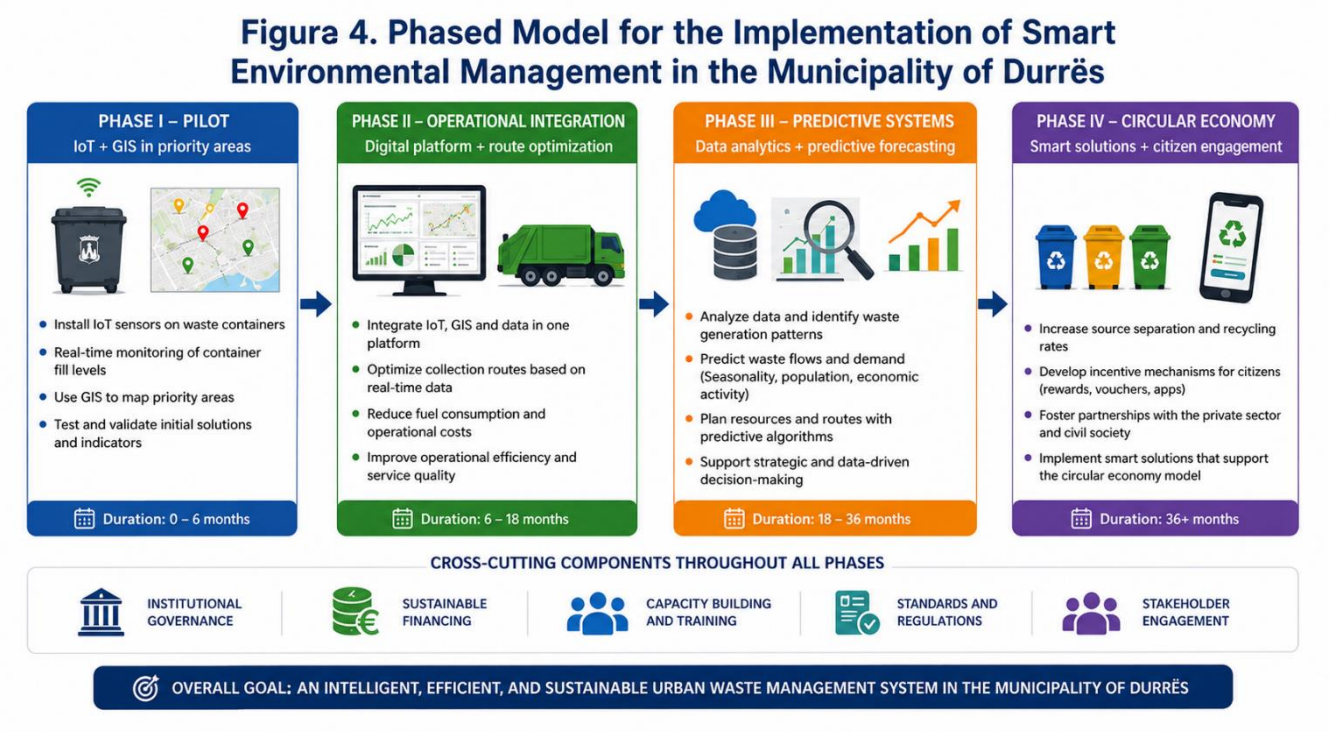


Figure 4. Phased Model for the Implementation of Smart Environmental Management in the Municipality of Durrës

5.2 Second Phase: Integration of GIS and the Digital Monitoring Platform

Following the pilot phase, the gradual integration of Geographic Information Systems (GIS) with the daily operations of urban waste collection is recommended. This phase includes the development of smart operational maps, which will enable:

- optimization of vehicle routes;
- reduction of operational time;
- minimization of traffic and logistical costs;
- identification of problematic waste accumulation areas.

Alongside GIS integration, the development of a central digital monitoring platform is recommended, where all operational data of the urban waste management system will be integrated. The platform will function as an institutional dashboard for real-time performance monitoring and support strategic decision-making (European Environment Agency, 2023).

From an institutional perspective, this phase requires strengthening the professional capacities of municipal technical staff and developing standard procedures for the management and interpretation of operational data.

5.3 Third Phase: Predictive Systems and Data Intelligence-Based Management

At a more advanced stage of transformation, the study suggests integrating data analytics systems and artificial intelligence to forecast urban waste flows and optimize operational decision-making.

In this model, the system may use historical data on:

- tourist seasonality;

- population density;
- economic activity;
- container filling frequency;
- operational performance of collection vehicles.

These data can be analyzed to develop predictive models capable of anticipating operational needs according to periods of the year and the territorial distribution of urban waste (Bibri & Krogstie, 2020; OECD, 2023).

In the case of Durrës, this approach is considered particularly relevant for managing the tourist season, where demand for public services changes significantly and requires operational flexibility.

5.4 Integration with the Circular Economy and Citizen Participation

The implementation of Smart Environmental Management should not be limited only to the operational efficiency of waste collection, but should also be integrated with the broader objectives of the circular economy and urban sustainability. For this reason, the conceptual model proposes integrating intelligent systems with policies that encourage:

- waste separation at source;
- increased recycling rates;
- public environmental awareness;
- the use of mobile applications for reporting and monitoring.

In many European cities, digital platforms are used to inform citizens about collection schedules, recycling points, and incentives for waste separation. A similar model could gradually be adopted in Durrës to increase community involvement and institutional transparency (European Commission, 2024; World Bank, 2022).

Table 6. Recommended Implementation Model for the Municipality of Durrës

Phase	Main Intervention	Priority	Timeline
I	Pilot IoT Sensors	Very High	Short-term
II	GIS for Route Optimization	Very High	Short-term
III	Digital Platform	High	Medium-term
IV	Data Analytics	Moderate	Medium-term
V	Integrated Smart System	High	Long-term

The analysis suggests that the gradual implementation of this model could create a significant transformation in the local urban waste management system, guiding it toward a smarter, more efficient, and environmentally sustainable model.

6. Implications for Public Policy

The findings of this study suggest the need for a new approach to local policymaking in the field of urban waste management, based on technological innovation, evidence-based governance, and long-term planning. In this context, it is recommended that local institutions develop specific strategies for the digital transformation of environmental public services by integrating the components of Smart Environmental Management into local strategic documents (European Commission, 2024).

An important priority is considered to be securing financing through European funds, public-private partnerships, and urban innovation programs**.** Since the initial implementation costs may constitute a barrier, the literature recommends gradual financing models and demonstration projects to minimize institutional risk (UNEP, 2024).

Furthermore, the study highlights the importance of building institutional and technical capacities for the use of intelligent systems, as well as the need to strengthen environmental education and community involvement in the transition toward a circular economy.

7. Conclusions

This study analyzed the implementation potential of Smart Environmental Management in the urban waste management system of the Municipality of Durrës**,** exploring opportunities for integrating intelligent technologies to increase operational efficiency, improve environmental performance, and support the transition toward a more sustainable model of urban governance. In a context where urbanization, tourism seasonality, and pressures on public infrastructure continue to intensify, the study findings suggest that traditional urban waste management models are no longer sufficient to guarantee high standards of performance and sustainability (European Commission, 2024; UNEP, 2024).

The analysis of international literature and the benchmarking of European practices revealed that cities integrating intelligent technologies, such as IoT sensors, Geographic Information Systems (GIS), data analytics, and digital monitoring platforms, have achieved significant improvements in reducing operational costs, optimizing waste collection logistics, lowering greenhouse gas emissions, and increasing recycling rates. The practices of European cities such as Barcelona, Amsterdam, and Copenhagen demonstrate that the digital transformation of waste management systems can create more flexible, adaptive, and environmentally performance-oriented models (OECD, 2023; European Environment Agency, 2023).

In the case of Durrë**s**, the study identified a number of structural and operational challenges, including the lack of real-time monitoring, static collection routes, relatively limited waste separation at source, and restricted capacities for operational data analysis. These limitations directly affect the efficiency of the current system and reduce the potential for optimizing public resources. However, the urban and tourist characteristics of the city also create favorable conditions for implementing adaptive smart management systems, particularly in areas with high seasonal intensity of waste generation (Local Waste Management Report, 2024).

One of the main contributions of this study is the development of a conceptual model for the gradual implementation of Smart Environmental Management for the Municipality of Durrës, based on four main phases: **(i)** piloting IoT sensors and GIS in priority areas; **(ii)** integrating digital monitoring platforms; **(iii)** applying predictive data analytics systems; and **(iv)** integrating circular economy objectives and citizen participation. This gradual approach is considered more realistic and feasible in the Albanian context, taking into account financial, technological, and institutional limitations (Sharifi et al., 2021; World Bank, 2022).

From a theoretical perspective, the study contributes to expanding the literature on Smart Environmental Management in transition economies and provides a new analysis of the transferability of European smart waste management practices to the Albanian context. From a practical perspective, the findings offer concrete recommendations for local institutions regarding the design of public policies and strategic investments in the digital transformation of urban environmental services (Bibri & Krogstie, 2020; European Commission, 2022).

However, the study also presents several methodological limitations that should be considered. Since the analysis is mainly based on conceptual benchmarking and secondary data, the absence of primary empirical data and cost-benefit economic analyses limits the possibility of accurately measuring the concrete impacts of implementing intelligent technologies in the case of Durrës. For this reason, future studies are recommended to focus on empirical pilot projects, financial analyses**,** and operational simulation models to evaluate the actual effectiveness of smart systems in urban waste management.

In conclusion, the study argues that the implementation of Smart Environmental Management in the urban waste management system of Durrës represents not only a technological opportunity but also a strategic necessity for modernizing urban governance and achieving sustainable development objectives. If supported by well-structured investments, institutional capacities, and cooperation

between public and private stakeholders, the transition toward a smart waste management system could also serve as a reference model for other municipalities in Albania.

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ACUTE AND SUB-CHRONIC TOXICOLOGICAL ASSESSMENT OF METHANOLIC LEAF EXTRACT OF *GOSSYPIUM HIRSUTUM*: BIOCHEMICAL, HEMATOLOGICAL, AND HISTOPATHOLOGICAL STUDIES IN WISTAR RATS

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ABSTRACT

The long-term safety and toxicological effects of medicinal plants have continued to raise concerns, especially due to their importance in the management and treatment of diseases. Here, we evaluate the acute and sub-chronic toxicity profile of the methanolic leaf extract of Gossypium hirsutum in Wistar rats. Oral doses of up to 5000mg/kgbw were used to assess acute toxicity, while oral administration of the extract at 200mg/kg bw and 400mg/kgbw for 28 days was used to assess sub-chronic toxicity. To determine the effect of the extract on kidney and liver functions, biochemical, haematological, and histopathological parameters were examined. No mortality or severe signs of toxicity were observed in the acute toxicity study. Sub-chronic administration of the extract did not significantly alter the serum levels of aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), sodium, potassium, urea, packed cell volume, platelet count, or hemoglobin concentration when compared with the control group. However, total protein concentration was significantly increased at 400mg/kg bw, and serum creatinine levels were also increased in both treated groups in a non-dose-dependent manner, suggesting possible impairment of the renal filtration system. Histopathological evaluation also revealed a dose-dependent effect of the extract on the kidney and liver tissues at higher doses. These results show that the methanolic extract of *G. hirsutum* shows low toxicity but may affect the renal and hepatic systems with prolonged administration at high doses. This implies that care must be taken during long-term consumption, especially for higher doses.

Keyword: Gossypium hirsutum, Sub-chronic toxicity, Histopathological evaluation

INTRODUCTION

The use of plants in the treatment of diseases has and continues to remain important. This is due to the vast potential they possess due to various phytochemicals they possess that can be repurposed into a drug via their active compounds. Another factor that enhances their appeal is availability and affordability, especially to low- and middle-income families. A 2005 report by the WHO highlighted that about 80% of deaths occurring from chronic diseases are in low and middle-income countries (WHO, 2005). Poor people are the most at risk of chronic diseases due to factors like exposure to risk factors, low or lack of access to adequate health care, and these diseases also lead to poverty through loss of capacity and income (Martin et al., 2011). This necessitates the continuous exploration and use of various plants in the treatment and prevention of various diseases.

Gossypium hirsutum is an arborous plant from the *Malvaceae* family. Cotton (*Gossypium hirsutum* L.) is an important species used as a source of fiber for the textile industry and oil for biodiesel agro-industries. The main by-product generated from the oil extraction from cottonseed is cottonseed oil processing by-products, mainly used as animal feed or fertilizer (de Oliveira Filho et al., 2021). The most economically important cotton species is *G. hirsutum*, which is grown to produce 90% of the world's cotton. Cotton fiber and oil production generate byproducts rich in fat from oil and protein, which are used for animal feeding. This plant is also known for its many medicinal properties, owing to the presence of a rich array of phytochemicals (Chimbwali, 2022). (Nix et al., 2017) also profiled the various forms of flavonoids found in *G. hirsutum*. Flavonoids are a very important class of phytochemicals with numerous medicinal properties. Other studies have also demonstrated the anti-candida properties of *G. hirsutum* and its use in the enhancement of fungal growth, biofilm production, and Antifungal Resistance (de Lima et al., 2022). (Lima et al., 2021) has also explored the antimicrobial

properties of G hirsutum along with other plants in the same genus. These make the use of *G hirsutum* a useful medicinal plant.

The purpose of this study is to evaluate the safety and toxicological properties of *G hirsutum* for long-term consumption. Considering its usefulness as a medicinal plant, it is important to ascertain that it is safe to consume in the various forms, and it's already being consumed, we explore its long-term safety in the crude form.

MATERIALS AND METHOD

2.1 Chemicals

All chemicals used in this study were of analytical grade.

2.2 Plant material

Fresh samples of *Gossypium hirsutum* leaves were collected from Ibule-soro, Ifedore local government, Ondo state, Nigeria. The plant was identified by a taxonomist by its local name, common name, scientific name and morphological descriptions. The plant was chopped into tiny bits, air-dried for some weeks at room temperature and milled with a mechanical grinder.

2.3 Preparation of *Gossypium hirsutum* Crude Extract.

200g of G. *hirsutum* powdered leaf sample was measured in a 2000 mL beaker, 800 mL of Methanol was added and stirred thoroughly and left for 72hours to infuse. The extract was filtered and kept for a few hours and later concentrated on a water bath at 50^0C to allow the evaporation of the solvent (Methanol) under reduced pressure. It was then allowed to cool, and the crude extract was recovered and kept in a sample bottle.

2.4 Animals

Albino rats were purchased from the animal house of the Department of Science Laboratory Technology, Federal Polytechnic Ile-Oluji, Ondo state, and were used. The experiments were conducted in accordance with the ethical rules and recommendations of the Federal Polytechnic Ile-Oluji committee on the care and use of laboratory animals and revised National Institute of Health Guide for Care and Use of Laboratory Animals, Pub No.85-23, revised 1985.

2.5 Acute Toxicity Test

Four groups of three rats were used. The rats were given *G. hirsutum* extract through the oral route at doses of 100, 1000, 2500 and 5000 mg/kg body weight in each group. The extract was administered once, and the rats were observed for death and signs of toxicity within 24 h.

2.6 Sub-Chronic Toxicity Test

Repeat-dose oral toxicity study was carried out according to the Organization for Economic Cooperation and Development (OECD) guidelines 407. The animals were divided into three groups of 5 animals each. Group 1 received 10 mg/kg bw of distilled water and served as the control. Groups 2 and 3 received extract doses of 200 and 400 mg/kg body weight, respectively. The extract was administered daily for 28 days at the same time and observed at least twice daily for morbidity and mortality. The animals were sacrificed, and blood was collected in an EDTA bottle for haematological analysis. Another set of blood was collected in an EDTA-free sample bottle, and the blood was allowed to clot and centrifuged at 3000 rpm for 10 min. The serum was extracted and stored in the refrigerator before being used for biochemical analysis.

2.7 Hematological parameters

The hematological parameters, were estimated using an automated hematologic analyzer (Sysmex, KX-21, Japan) as described by (Dacie & Lewis, 1991).

The activities of serum ALP, AST and ALT were determined using standard procedures (Reitman & Frankel, 1957; Tietz, N.W. 1995). The levels of serum total protein, albumin, bilirubin, serum urea and creatinine were determined using standard procedures (Blass et al., 1974; Doumas et al., 1971; Gornall et al., 1949). Na^+, K^+ and Cl^- concentrations were determined by flame photometry (Tietz, N.W. 1995).

2.8 Histopathology Analysis

Nine (9) rats were divided randomly into three (3) groups of 3 rats as follows: Group 1 served as a control (received normal saline); Group 2 was administered 200mg/kg bw of the extract of *Gossypium hirsutum,* and Group 3 received 400mg/kg bw of the extract of *Gossypium hirsutum* for twenty-eight (28) days under strict monitoring for behavioral changes. After the treatment period, the animals were sacrificed by cervical dislocation, dissected and the kidneys and liver were excised for histological study. The livers and kidneys of each animal were fixed in 10% formalin. Sections of the organs were cut at 4–5 µm with a rotary microtome, stained with hematoxylin and eosin, and analyzed at 250× magnification for histopathological changes (Mengistu, 2015).

2.9 Statistical Analysis

All quantitative data were expressed as the means ± SD (standard deviation). Statistical significance between the means of control and treated groups was determined by one-way ANOVA using GraphPad Prism. The means were pairwise compared using the Tukey test, and the differences will be considered statistically significant at $p<0.05$.

RESULTS

3.1 Acute toxicity

No mortality was recorded in any of the experimental animals at 100, 1000, 2500 and 5000 mg/kg bw. The LD_{50} is thus set to be >5000 mg/kg bw.

3.2 Effect of sub-chronic administration of crude methanol extract of *Gossypium hirsutum* on serum activities of some Liver enzymes in Wistar rats

Figure 1. shows the effect of sub-chronic administration of the crude extract of G. hirsutum on some liver enzymes of Wistar rats. The activities of ALP, AST and ALT did not differ significantly ($p>0.05$) among all groups, including the control. However, a significant ($p<0.05$) difference was observed between the 400 mg/kg dose treatment group when compared with the control group with respect to total protein concentration.

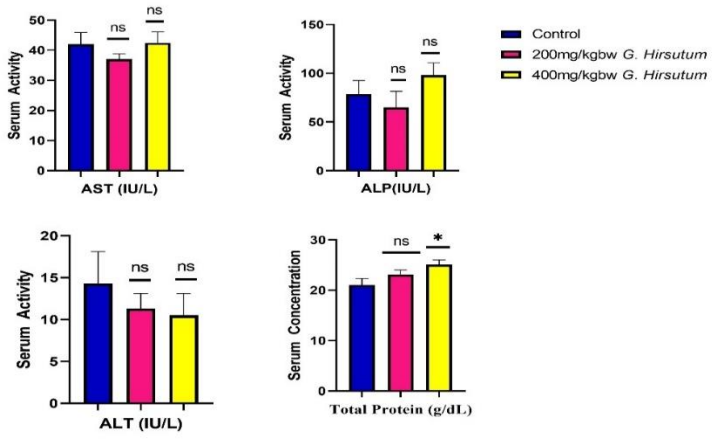


Figure 2: Effect of crude methanol extract of Gossypium hirsutum on serum activities of some Liver enzymes in Wistar rats. Values are mean ±SEM of 5 determinations.

3.3 Effect of sub-chronic administration of crude methanol extract of *Gossypium hirsutum* on kidney function biomarkers in Wistar rats

Figure 2 shows the effect of sub-chronic administration of crude methanol extract of G. hirsutum on serum urea, creatinine and electrolytes in Wistar rats. The concentrations of sodium and potassium and the serum levels of urea were not significantly ($p>0.05$) different among all the groups, including the control. However, a significant ($p<0.05$) increase in the serum concentrations of creatinine in rats treated with 200 mg/kg bw and those receiving 400 mg/kg bw of the extract was observed when compared with the control group.

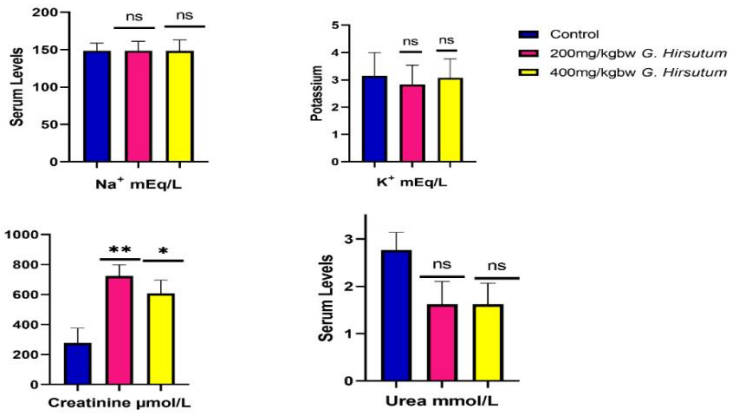


Figure 3: Effect of crude methanol extract of Gossypium hirsutum on serum urea, creatinine and electrolytes in Wistar rats. Values are mean ± SEM of 5 determinations. Na^+ = Sodium K^+ = Potassium

3.4 Effect of the crude methanol extract of *Gossypium hirsutum* on kidney histology

The Kidney section of the control (Fig 3A) shows a normal architecture of the kidney with well-formed Glomerulus (G) and tubules in the cortical portion. The group treated with 200mg/kg bw of extract showed mild degeneration from the normal architectural structure with proximal convoluted tubules (X), while the group treated with 400mg/kg bw of extract showed a degeneration from the normal architectural structure, dilation of the distal tubule (Y), Hyaline cast (HC) and proximal convoluted tubules (X).

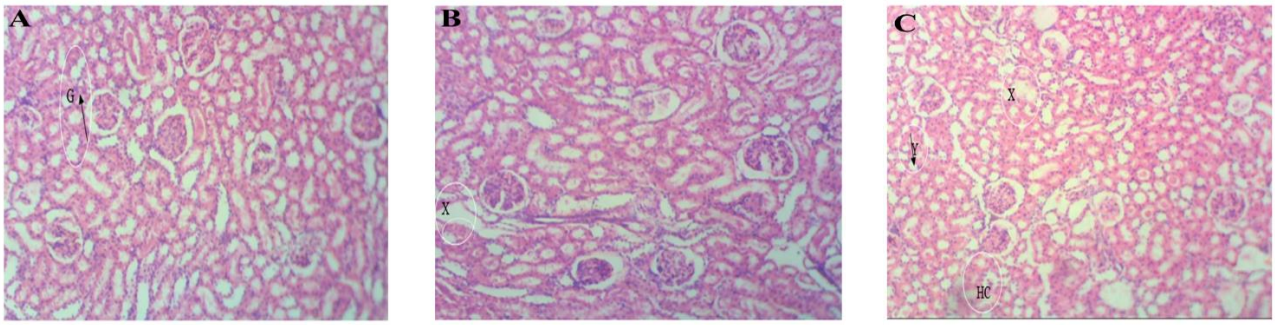


Figure 3: Effect of the crude methanol extract of *Gossypium hirsutum* on kidney histology of Wistar rats. A: Control group, B: 200 mg/kg bw G. *hirsutum*, C: 400 mg/kg bw G. *hirsutum*. Mag x400 H&E

3.5 Effect of the crude methanol extract of *Gossypium hirsutum* on liver histology

The liver histology in the control rats shows normal liver architectural structure with intact sinusoid channel (s) and hepatocytes (h). Groups treated with 200mg/kg bw showed a slight distortion of the normal architectural structure with sinusoid channel (S), and hepatocytes (H). in group treated with 400mg/kg bw, there was observed degeneration from the normal architectural structure with enlarged central vein (CV), blood congestion, and the sinusoid channels (S).

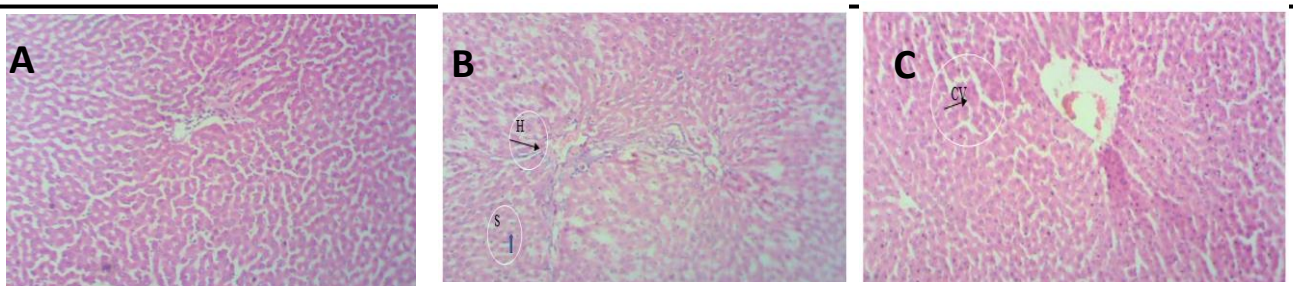


Figure 4: Effect of the crude methanol extract of *Gossypium hirsutum* on liver histology of Wistar rats. A: Control group, B: 200 mg/kg bw *G. hirsutum*, C: 400 mg/kg bw *G. hirsutum*. Mag x400 H&E.

The effects of the crude methanol extract of *Gossypium hirsutum* on the haematological parameters of rats are shown in Table 1. The white blood cell (WBC) increased ($p<0.05$) in the 400mg/kg bw group, while the 200mg/kg bw shows no significant difference when compared to the control. Other parameters like the RBC count, PCV, PLT, and HB were not significantly different ($p>0.05$) across all the groups.

Table 5:Effect of crude methanol extract of Gossypium hirsutum on hematological parameters in Wistar rats

	PCV (%)	RBC ($\times 10^{12}$/L)	PLT ($\times 10^{9}$/L)	WBC ($\times 10^{9}$/L)	HB (g/dL)
Control group	**38.75±1.77^{a}**	**5.56±1.61^{a}**	**184±31^{a}**	**3395±1179^{a}**	**12.95±0.64^{a}**
200mg/kg bw	**34.25±2.96^{a}**	**5.85±1.28^{a}**	**219±35^{a}**	**4850±1202^{a}**	**11.42±3.65^{a}**
400mg/kg bw	**29.75±3.89^{a}**	**4.84±1.01^{a}**	**285±76^{a}**	**7650±1273^{b}**	**9.92±1.29^{a}**

Values are mean ± SEM of 5 determinations. Values along the same column with different superscripts are significantly different ($p< 0.05$). PCV = Packed Cell Volume, RBC = Red blood cells, WBC = White blood cell, PLT = Platelets.

DISCUSSION

Medicinal plants have, for a long time, been well considered useful in traditional medicines for their effectiveness in the treatment of various illnesses (Searle, 1984). The specific mechanism by which these plants exert their therapeutic activity on the human physiological and biological systems is not always well understood; however, lots of concerns have always been raised about their safety, especially for long-term consumption. (Amacher, 2002). Serum biochemical indices are first-line parameters to understand whether a medicinal plant is protective, neutral or toxic. These biomarkers are useful in confirming exposure to harmful agents and serve as a quantitative means to assess the potential harmful effects of these plants (Ganta et al., 2023; Seriana et al., 2021).

The effects of the methanolic leaf extract of *Gossypium hirsutum* on serum liver enzyme parameters are presented in Figure 1**.** The administration of the crude plant extract showed no statistically significant differences ($p > 0.05$) in serum levels of AST, ALT, and ALP. However, when compared to the control, the total protein concentration at 400mg/kg bw showed a significant increase. Serum AST and ALT levels remained relatively stable across the experimental groups. The absence of marked elevation in AST and ALT levels suggests that the extract did not induce significant hepatocellular injury in the treated animals or indication of preserved hepatic functions after administration of extracts (Lala et al., 2026).

In spite of these higher values of ALP enzyme levels, there was still no statistical difference between the treated group and the control group. An increase in ALP activities is usually indicative of hepatobiliary dysfunction or cholestatic injury. As such, the absence of a statistical variation in the ALP activities may be an indication that the crude extract did not have an adverse effect on the biliary function

of the liver under the study conditions (Lala et al., 2026; Poo et al., 2024). Evaluation of total protein concentration showed a gradual dose-dependent increment. At 400mg, the increase observed was statistically significant ($p < 0.05$) when compared to the control groups. Serum total protein is known to be a common indicator of the synthetic capacity and nutritional status of hepatic cells. This increase may suggest enhanced protein synthesis or indicate improved liver function after administration of the extract (Lala et al., 2026; Moriles et al., 2026). Cumulatively, these findings from the biochemical assay show that the methanolic extract of *G. hirsutum* did not cause any significant hepatotoxic effect at the doses tested. Suggesting hepatic safety of the extract within the experimental duration.

The effect of the methanolic extract of *G hirsutum* on markers of renal health is shown in Figure 2. There was no significant difference ($p > 0.05$) observed owing to the administration of the crude extract on parameters like serum urea, sodium (Na^+), and potassium (K^+) concentrations relative to the control groups. However, the concentration of creatinine shows a marked increase in the groups treated with the plant extract when compared to the control group.

A significant elevation in serum creatinine concentration was observed between the treated groups and controls. This elevation in serum creatinine suggests a weakening of the capacity for renal filtration due to the administration of the extract. Serum creatinine is considered an important biomarker of glomerular filtration rate and serves as an indication of the functional integrity of the kidney (Mello et al., 2021). When serum creatinine levels are elevated, the condition is commonly associated with a reduction in renal clearance and nephrotoxic injury (Al-Naimi et al., 2019; Kim & Moon, 2012).

Similarly, evaluations of the serum electrolyte levels show stable sodium and potassium concentrations across all groups. Normal electrolyte balance, when maintained, serves as an indicator of preserved renal tubular functions and fluid electrolyte homeostasis in the animals administered with the extracts. Damaged or weakened renal function and nephrotoxic injury are usually a consequence of electrolyte disturbance, which is absent in this case (Mello et al., 2021).

There was a decreasing trend observed in the PCV, RBC, and HB when the control groups were compared to the treatment groups. This decrease, though non-statistically significant, would suggest a possible mild suppression of the erythropoietic process as well as a possible interference with the RBC integrity after administration of the extracts. In toxicological studies, the reduction in these erythropoietic indices is usually associated with conditions related to anemia, oxidative stress and in some cases, it may also suggest weakening of the erythropoietic production, and it may also suggest destruction of the red blood cells in circulation (Ladokun et al., 2015). Other studies involving medicinal plant extracts showing mild hematoxic effects at high doses have been reported. (Awe & Banjoko, 2013; Ladokun et al., 2015). In one of the treated groups (200mg/kg), an increase was observed in the WBC when compared to the control. While the 400mg/kg group showed a slight decrease when compared to the 200mg group. This observed increase in WBC count is often indicative of immune response stimulation or an activation of the defense mechanism in the treated animals. When exposed to Xenobiotics, physiological adaptations, stimulation of the immune system, and inflammatory response have all been associated with attendant Leukocytosis (Ladokun et al., 2015). Overall, these findings suggest that the methanolic leaf extracts of G hirsutum did not show any severe toxic effect on the hematological profile of the test animals. It is important to note that the dose-related reductions observed could suggest a mild alteration in the erythrocytic parameters, following prolonged administration of the plant extracts. Other studies have also shown mild changes in the haematological parameters without significant toxicity for sub-acute toxicity studies of medicinal plants (Kifayatullah et al., 2015).

Histological examination of the kidneys of animals treated with 200mg and 400mg of extract shows a dose-dependent effect of the extract on the renal structures after long-term administration (Figure 3). The control group showed that the renal structure was largely preserved. In the group dosed with 200mg/kg of the extract, there was mild degeneration of some proximal tubules in some sections. Overall, the renal structure was preserved at this dose, suggesting that the extract did not produce a significant toxic effect on the kidney after prolonged exposure. On the other hand, animals treated with 400mg/kg bw showed more alterations in their histopathology. The kidney section showed interstitial oedema, dilated lymphatic vessels, and distortion of the glomeruli. Dilation of the distal tubules was also observed. These abnormalities in the renal structure suggest stress and show that prolonged

exposure to higher doses of the extract may lead to distortion of the kidney structure and function. These findings show that the lower dose for the methanol extract of the leaf may have a comparative advantage over high doses in terms of safety. Meanwhile, prolonged administration at higher doses could induce renal damage. The kidney is considered vulnerable to toxic substances because it plays a vital role in filtration, excretion and processing metabolites and xenobiotics in the renal tubules. Renal injury can impair these functions, causing the accumulation of waste materials, leading to kidney dysfunction (Alarifi et al., 2012).

Microscopic observation of the effect Methanolic leaf extract of *Gossypium hirsutum* on the liver in long-term toxicity showed the significant difference between the liver sections of the control, rats treated with the methanol leaf extract of *Gossypium hirsutum* at doses of 200mg/kg, and rats treated with the methanol leaf extract of *Gossypium hirsutum* at the dose of 400mg/kg (Figure 4). The control group shows normal liver architecture with intact sinusoid channel (s) and hepatocytes (h). The histopathological effect at 400mg/kg of the extract as compared to the control showed some histopathological abnormalities such as slight degeneration from the normal architectural structure with Kupffer cells (AC), and necrosis of the hepatocytes (NH) and slight distortion of the normal architectural structure with sinusoid channel (S), and hepatocytes (H). However group treated with methanol leaf extract of *Gossypium hirsutum* at doses of 200mg/kg shows slight degeneration from the normal architectural structure with necrosis of the sinusoid channels (NC) and slight dilation of central vein (CV) coupled with heamorage and degeneration from the normal architectural structure with enlarged central vein (CV), blood congestion, and the sinusoid channels(S) (Boye et al., 2022)

CONCLUSION

The study therefore suggests that while *G. hirsutum* methanolic leaf extract may be relatively safe at lower doses and short-term exposure, caution should be exercised during prolonged use or administration at higher concentrations. Further studies involving larger sample sizes, chronic toxicity models, oxidative stress biomarkers, and molecular mechanisms are needed to establish the safety profile and therapeutic window of the plant extract.

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PATIENT AND PROVIDER PERSPECTIVES ON HEART FAILURE MANAGEMENT IN EMERGENCY DEPARTMENTS IN PUNJAB, PAKISTAN: A QUALITATIVE STUDY

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ABSTRACT

Objectives The study aimed to explore the experiences of persons living with heart failure residing in low resource settings of Pakistan and to identify the facilitators and barriers faced by healthcare providers in delivering care to persons living with heart failure in these settings of Pakistan. **Design** Qualitative exploration was undertaken to answer the study questions. **Setting** The study was conducted in a public-sector tertiary care hospital in Multan, Pakistan. **Participants** A total of 21 participants, patients (adult persons who were diagnosed with heart failure for more than 6 months) and healthcare providers (registered nurses and doctors with a minimum of one year of clinical experience in the management of heart failure) were recruited using a purposive sampling. **Results** Data analysis followed Braun and Clarke's six-phase framework. The qualitative analysis revealed three major themes: (1) System factors that influence the quality of care given to persons living with heart failure in public sector hospital (2) Staff factors indicate how healthcare providers are providing care to persons living with heart failure and the challenges they face during disease management and (3) Patient factors indicate substantial gaps in patient education, medication access, and post-discharge support within a public sector hospital. **Conclusion** This qualitative inquiry identified substantial gaps in patient education, medication access, follow-up continuity, and system capacity that hinder effective heart failure management within the public sector. The results underscore the need for comprehensive, patient-centered interventions including teleconsultation follow-ups, strengthened discharge processes, and enhanced caregiver engagement in transitional care of persons living with heart failure to support long-term disease manageme

FROM HOMO ECONOMICUS to HOMO EVOLUTIVUS: A DYNAMICAL SYSTEMS APPROACH to MICROECONOMIC DECISION-MAKING

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ABSTRACT

This paper develops a unified dynamical framework that reconceptualizes microeconomic decision-making through the lens of evolutionary adaptation rather than perfect rational optimization. Moving beyond the traditional *Homo Economicus* paradigm, we introduce *Homo Evolutivus*: an adaptive agent whose behavioral strategies evolve under competitive selection, imitation, and bounded rationality. The model integrates microeconomic utility theory with evolutionary game dynamics by treating consumption and strategic choice as population-level evolutionary processes governed by nonlinear differential equations. Using replicator and replicator–mutator dynamics, we analyze how heterogeneous decision-making strategies compete over time under varying payoff structures, social comparison effects, and resource constraints. The framework demonstrates that utility-maximizing behavior may emerge endogenously as an evolutionarily stable outcome rather than as an a priori assumption. We derive equilibrium conditions, investigate local and global stability properties through Jacobian and Lyapunov analysis, and identify bifurcation regions in which small parametric changes generate abrupt transitions in aggregate market behavior.The results reveal that decentralized adaptation can produce persistent disequilibrium, path dependence, and multiple stable consumption regimes, particularly under strong social interaction effects. By embedding microeconomic behavior within a dynamical systems framework, the paper provides a mathematically rigorous alternative to static rational-choice models and establishes new theoretical foundations for evolutionary microeconomics, adaptive consumer theory, and nonlinear market dynamics.

Keywords: Evolutionary Game Theory; Economic Theory; Microeconomic Dynamics; Replicator Dynamics; Adaptive Rationality

INTRODUCTION

The neoclassical conception of the economic agent—Homo Economicus—rests on the postulate of a perfectly rational decision-maker who possesses complete preferences, unlimited computational capacity, and full information, and who selects the alternative that maximizes a well-defined utility function. This idealization has been extraordinarily productive: it yields sharp comparative-static predictions, supports a coherent welfare theory, and lends itself to elegant equilibrium analysis. Yet its descriptive accuracy has been challenged repeatedly. Simon (1955) argued that real agents are boundedly rational, satisficing within cognitive and informational limits; Kahneman and Tversky (1979) documented systematic deviations from expected-utility maximization; and a large behavioral literature has since accumulated showing that choices are reference-dependent, socially conditioned, and frequently inconsistent with the axioms of rational choice.

A complementary line of defense, originating with Alchian (1950) and Friedman (1953), holds that even if individual agents are not literal optimizers, competitive selection may winnow out unprofitable behaviors so that surviving agents behave "as if" they optimized. This evolutionary defense of marginalism is suggestive, but it has rarely been made fully explicit as a dynamical proposition. If selection is the mechanism that disciplines behavior, then the appropriate object of analysis is not a static optimum but the trajectory of a population of competing strategies through time. Nelson and Winter (1982) made this insight central to the theory of the firm; the present paper develops its counterpart for microeconomic consumer behavior.

We propose replacing Homo Economicus with Homo Evolutivus: an adaptive agent whose behavioral rule is not chosen by introspective optimization but inherited, imitated, and revised under selective pressure. Rationality is not assumed; where it appears, it is an emergent property of the selection dynamics. Methodologically, we embed microeconomic decision-making within evolutionary game theory and the qualitative theory of nonlinear dynamical systems. The population of agents is partitioned into behavioral strategies whose frequencies evolve according to replicator and replicator–mutator equations (Taylor and Jonker, 1978; Hofbauer and Sigmund, 1998; Nowak, 2006). Payoffs are derived from a microeconomic utility function augmented with social-comparison effects, linking the demand-theoretic primitives of consumer theory to the fitness concept of evolutionary dynamics.

Three results organize the paper. First, utility-maximizing behavior arises endogenously as an evolutionarily stable strategy in the low-noise limit of the replicator–mutator dynamics, so that Homo Economicus is recovered as a special case of Homo Evolutivus rather than presupposed. Second, the qualitative theory of dynamical systems—Jacobian-based local analysis and Lyapunov-based global analysis—characterizes when adaptation converges to an equilibrium and when it does not. Third, when social comparison is sufficiently strong, the adaptive system undergoes a bifurcation that produces multiple stable consumption regimes, path dependence, and abrupt aggregate transitions, none of which can occur in the static rational-choice benchmark. The remainder of the paper formalizes these claims.

FROM HOMO ECONOMICUS to HOMO EVOLUTIVUS

It is useful to state precisely what is retained and what is relaxed in moving from the classical agent to the evolutionary one. We retain the microeconomic content of choice: agents derive utility from consumption, face prices and resource constraints, and respond to incentives. We relax three assumptions. First, optimization is replaced by adaptation: an agent does not compute a global maximum but adjusts behavior toward strategies that have recently performed well, whether through individual reinforcement learning or social imitation. Börgers and Sarin (1997) and Fudenberg and Levine (1998) establish that several such learning processes have the replicator equation as their deterministic limit, which gives the framework a behavioral microfoundation independent of any biological metaphor.

Second, the unit of analysis shifts from the individual to the population. Rather than tracking one agent's deliberation, we track the distribution of behavioral strategies across a continuum of agents. This population perspective is what makes selection meaningful: a strategy spreads not because it is reasoned to be best but because its current payoff exceeds the population average. Third, rationality becomes graded rather than binary. Persistent experimentation and imitation error—captured by a mutation term—mean that the population never fully converges to a single deterministic rule, so that bounded rationality is a structural feature of the model rather than a deviation to be explained away (Weibull, 1995; Sandholm, 2010).

This reframing has two payoffs. It dissolves the long-standing tension between the descriptive failure of perfect rationality and the predictive success of optimization-based economics, by showing the latter to be a limiting case of the former. And it widens the range of admissible aggregate phenomena: because the governing equations are nonlinear, the model can exhibit multiplicity, hysteresis, and tipping behavior that static optimization rules out by construction (Brock and Durlauf, 2001; Schelling, 1978).

THE MODEL

Population, Strategies, and the State Simplex

Consider a large population of agents, each of whom adopts one of n behavioral strategies indexed by $i \in \{1, \ldots, n\}$. A strategy is a complete decision rule—for concreteness, a consumption plan or a heuristic mapping economic circumstances to a chosen consumption level. Let x_i denote the share of agents currently using strategy i. The population state is the vector $x = (x_1, \ldots, x_n)$, which lies in the unit simplex

$$\Delta_{n-1} = \{\, x \in \mathbb{R}^n : x_i \geq 0, \textstyle\sum_i x_i = 1 \,\}. \qquad (1)$$

The interior of the simplex, where every strategy is present, is denoted $\operatorname{int} \Delta_{n-1}$. The vertices correspond to monomorphic populations in which a single strategy prevails. The state x summarizes the heterogeneity of the population and, as shown below, is the carrier of all aggregate dynamics.

Utility, Payoffs, and Social Comparison

Each strategy i prescribes a consumption level c_i of a representative good sold at price p. The instantaneous utility an agent obtains from following strategy i, when the population state is x, is taken to be

$$u_i(x) = ac_i - (b/2)c_i^2 - pc_i + \gamma c_i \bar{C}(x), \quad (2)$$

where $a > 0$ and $b > 0$ parameterize a standard quadratic (diminishing-returns) private benefit, pc_i is expenditure, and the final term is a *social-comparison* effect proportional to the population's mean consumption

$$\bar{C}(x) = \sum_j x_j c_j. \quad (3)$$

The coefficient γ measures the strength and sign of social interaction. When $\gamma > 0$, an agent's marginal utility of consumption rises with aggregate consumption—a bandwagon or "keeping-up-with-the-Joneses" effect; when $\gamma < 0$, the effect is positional or contrarian in the sense of Veblen (1899) and Leibenstein (1950). Because u_i depends on x through $\bar{C}$, payoffs are frequency-dependent: the value of a strategy is determined jointly by its own prescription and by what everyone else is doing. We identify the evolutionary payoff (fitness) of strategy i with this realized utility, $\pi_i(x) \equiv u_i(x)$. The population's average payoff is

$$\bar{\pi}(x) = \sum_j x_j \pi_j(x). \quad (4)$$

Replicator Dynamics

Selection and imitation are modeled by the replicator equation (Taylor and Jonker, 1978; Hofbauer, Schuster, and Sigmund, 1979). A strategy's share grows in proportion to the amount by which its payoff exceeds the population mean:

$$dx_i/dt = x_i [\pi_i(x) - \bar{\pi}(x)], \quad i = 1, \ldots, n. \quad (5)$$

Equation (5) preserves the simplex: the shares remain nonnegative and sum to one for all t. Successful strategies—those earning above-average payoff—expand, while below-average strategies contract, exactly as Alchian's (1950) selection argument requires. No agent maximizes anything; aggregate adjustment is driven entirely by relative performance. The nonlinearity of (5), arising both from the product $x_i\pi_i$ and from the frequency dependence of π_i, is the source of the rich dynamics analyzed below.

Bounded Rationality: Replicator–Mutator Dynamics

Pure replicator dynamics describe error-free imitation. To represent bounded rationality—experimentation, mistakes, and incomplete imitation—we augment (5) with a mutation process (Nowak and Sigmund, 2004; Nowak, 2006). Let Q_{ji} be the probability that an agent revising from strategy j ends up using strategy i. With a uniform error rate $\mu \in [0, 1]$,

$$Q_{ji} = (1 - \mu)\, \delta_{ji} + \mu/(n - 1)\, (1 - \delta_{ji}), \quad (6)$$

where δ_{ji} is the Kronecker delta. The replicator–mutator equation is then

$$dx_i/dt = \sum_j x_j \pi_j(x)\, Q_{ji} - x_i \bar{\pi}(x). \quad (7)$$

When $\mu = 0$ the matrix Q is the identity and (7) collapses to the replicator equation (5). For $\mu > 0$, mutation continually reinjects minority strategies, preventing complete convergence to a vertex and thereby encoding the persistence of bounded rationality at the population level. The parameter μ thus indexes the degree to which the population departs from the perfectly rational ideal.

EQUILIBRIUM and STABILITY ANALYSIS

Rest Points and the Evolutionary Folk Theorem

A state x^* is a rest point of (5) if $dx_i/dt = 0$ for all i. This holds either at a vertex (some $x_i^* = 0$) or at an interior state where every surviving strategy earns the same payoff, $\pi_i(x^*) = \bar{\pi}(x^*)$ for all i with $x_i^* > 0$. This payoff-equalization condition is the dynamical analogue of an interior Nash equilibrium. The evolutionary folk theorem (Hofbauer and Sigmund, 1998) makes the correspondence precise: every

Nash equilibrium of the underlying game is a rest point of the replicator dynamics; every *stable* rest point is a Nash equilibrium; and every *asymptotically stable* rest point is an evolutionarily stable strategy (ESS) in the sense of Maynard Smith and Price (1973). Equilibrium is therefore not imposed but selected: only those Nash configurations that are robust to the adaptive dynamics survive.

Local Stability: The Jacobian

Local stability of a rest point x^* is determined by the Jacobian of the vector field. Writing the right-hand side of (5) as $F_i(x)$, the Jacobian has entries

$$J_{ik} = \partial F_i/\partial x_k = \delta_{ik}\,[\pi_i - \bar{\pi}] + x_i\,[\partial \pi_i/\partial x_k - \partial \bar{\pi}/\partial x_k], \tag{8}$$

evaluated at x^* and restricted to the tangent space of the simplex (the hyperplane $\sum_i dx_i = 0$), since one coordinate is redundant. The rest point is locally asymptotically stable when every eigenvalue of the restricted Jacobian has negative real part, and unstable when some eigenvalue has positive real part. The first term in (8) reflects direct selection on the relative payoff of strategy i; the second term captures the feedback that arises because each strategy's payoff depends on the state through the social-comparison channel $\gamma\bar{C}$. It is precisely this feedback that can drive eigenvalues across the imaginary axis and thereby destabilize an interior equilibrium, as Section 5 demonstrates.

Global Stability: Lyapunov Methods

Local analysis is silent about basins of attraction and global convergence. For these we use Lyapunov's direct method. When x^* is an interior ESS, a standard Lyapunov candidate is the Kullback–Leibler divergence of the current state from the equilibrium,

$$H(x) = \sum_i x_i^* \ln(x_i^* / x_i), \tag{9}$$

defined on int Δ_{n-1}. The function H is nonnegative, vanishes only at x^*, and—when x^* is an ESS—satisfies $dH/dt = -\sum_i (x_i^* - x_i)\,\pi_i(x) \le 0$ along trajectories of (5), with equality only at x^*. By Lyapunov's theorem, x^* is then globally asymptotically stable on the interior: from any initial heterogeneous population the adaptive process converges to the evolutionarily stable configuration. Conversely, when no interior ESS exists, H fails to decrease monotonically, and the analysis below shows that the dynamics may instead select one of several boundary attractors depending on initial conditions.

The Endogenous Emergence of Utility Maximization

These results yield the paper's first substantive claim. Suppose one of the available strategies, call it the rational strategy r, prescribes the consumption level that maximizes private utility given prices, $c_r = \arg\max\,(ac - (b/2)c^2 - pc)$. In the low-noise limit $\mu \to 0$, the rest points of the replicator–mutator equation (7) converge to those of the replicator equation (5), and the rational strategy is an asymptotically stable rest point whenever it is a strict best reply to the prevailing state—that is, whenever it is an ESS. Homo Economicus is thus recovered as the $\mu \to 0$ limit of Homo Evolutivus: optimization is the behavior that selection favors when experimentation is negligible and the optimum is robust. For $\mu > 0$, however, the stationary distribution remains dispersed around c_r, so that observed behavior is "as if" optimizing only approximately, with a residual heterogeneity that grows with the noise level. The classical agent is therefore not abolished but located—as a boundary case within a larger adaptive family.

SOCIAL INTERACTION, BIFURCATIONS, and MULTIPLE REGIMES

The Two-Strategy Reduction

The qualitatively novel behavior of the model is most transparent in the two-strategy case, which admits a complete analytical treatment. Let strategy H prescribe a high consumption level c_H and strategy L a low level c_L, with $\Delta c \equiv c_H - c_L > 0$. Let x be the share of H-types, so that $1 - x$ use L and $\bar{C}(x) = c_L + x\,\Delta c$. Substituting into (5) and simplifying, the dynamics reduce to a single scalar ordinary differential equation,

$$dx/dt = x(1-x)[\pi_H - \pi_L] = x(1-x)\,\Delta c\,[K + s\,x], \tag{10}$$

where we have collected the state-independent payoff gap into $K = (a - p) - (b/2)(c_H + c_L) + \gamma c_L$ and defined the *social-interaction strength* $s \equiv \gamma\,\Delta c$. The factor $x(1 - x) \ge 0$ confines motion to the interval

[0, 1]; the sign of dx/dt is governed entirely by the affine term $K + sx$. The parameter s cleanly isolates the social channel: it is positive precisely when conformist comparison reinforces high consumption.

Equilibria and the Transcritical Bifurcation

Equation (10) has two boundary rest points, $x = 0$ (a population of low consumers) and $x = 1$ (a population of high consumers), and a possible interior rest point

$$x^* = -K / s, \quad \text{valid when } 0 < -K / s < 1. \tag{11}$$

Linearizing (10) gives the local stability conditions. The low-consumption state $x = 0$ is stable if $K < 0$; the high-consumption state $x = 1$ is stable if $K + s > 0$; and the interior point x^*, when it exists, is always unstable and acts as a separatrix between the two boundary attractors. Holding $K < 0$ fixed and increasing the social-interaction strength s from zero, the system passes through a transcritical bifurcation at the threshold

$$s^* = -K = (b/2)(c_H + c_L) - (a - p) - \gamma c_L, \tag{12}$$

at which the interior equilibrium enters the unit interval through the vertex $x = 1$ and exchanges stability with it. Figure 1 plots the equilibrium correspondence as a function of s. For $s < s^*$, the system is monostable: every population converges to the low-consumption regime. For $s > s^*$, the system is bistable: the low- and high-consumption regimes are both locally stable, separated by the unstable interior branch $x^* = -K/s$.

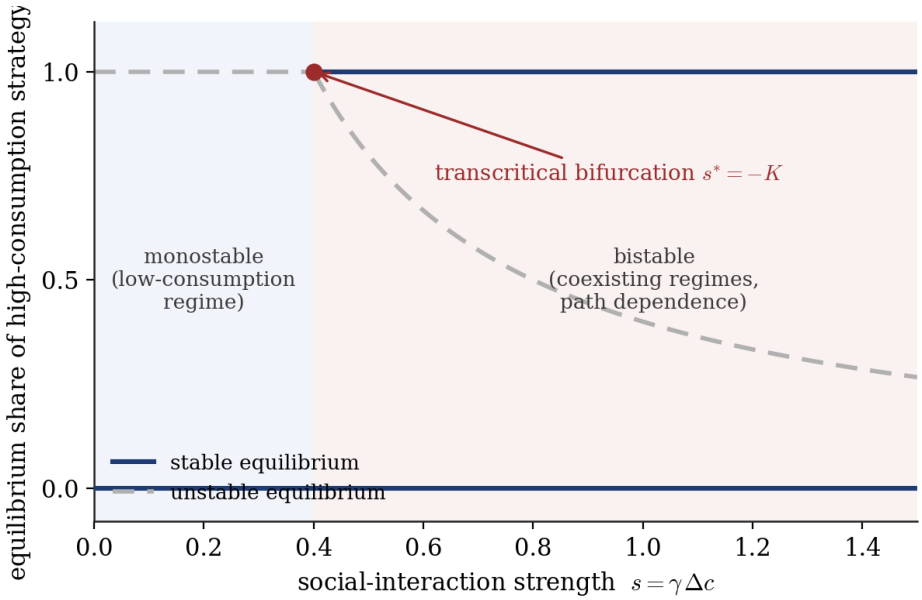


Figure 1.

Equilibrium share of the high-consumption strategy as a function of the social-interaction strength s = γΔc, holding the intrinsic payoff gap fixed at K < 0. Solid curves denote locally stable equilibria; dashed curves denote unstable equilibria. At the transcritical threshold s* = −K the system transitions from a monostable low-consumption regime to a bistable regime in which two stable consumption regimes coexist.

Figure 2 displays the growth-rate function dx/dt for three values of s. Below threshold the function is negative on (0, 1), so all trajectories flow to $x = 0$. At threshold the high-consumption vertex becomes non-hyperbolic. Above threshold a new interior zero appears with positive slope—an unstable equilibrium—while both vertices are now sinks. The same information is summarized in Table 1.

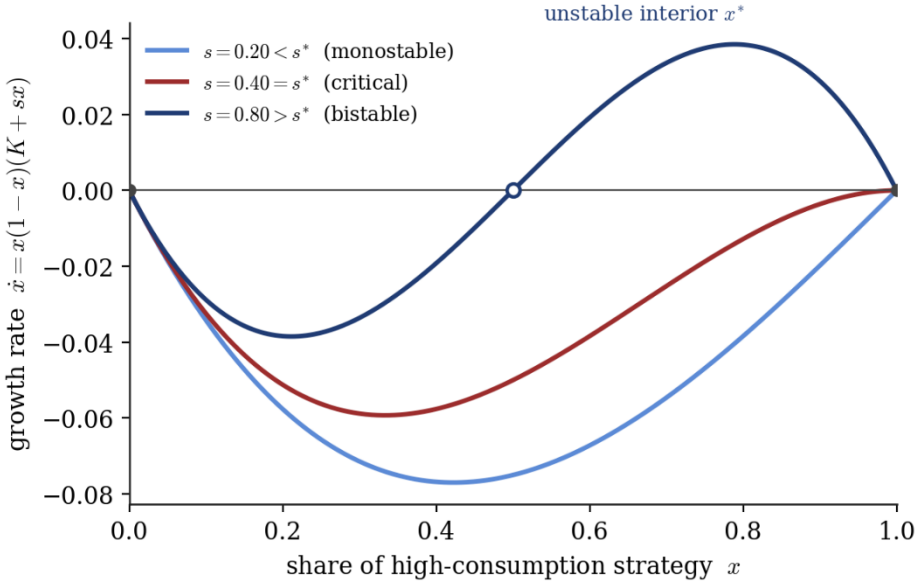


Figure 2. Growth rate dx/dt = x(1−x)(K + sx) of the reduced replicator dynamics for three values of the social-interaction strength s, with K = −0.4.

Filled circles mark stable vertices; the open circle marks the unstable interior equilibrium that emerges in the bistable regime.

Table 1. Existence and Local Stability of Equilibria of the Reduced Dynamics (10)

Regime	**x = 0**	**x = 1**	***x****	**Outcome**
$s < s^*$	stable	unstable	absent	Monostable; low-consumption regime
$s = s^*$	stable	non-hyperbolic	at vertex	Critical (transcritical bifurcation)
$s > s^*$	stable	stable	unstable	Bistable; path-dependent regimes

Note. Conditions assume K < 0 and Δc > 0. The threshold is s* = −K; the interior equilibrium is x* = −K/s.

5.3. Multiple Regimes and Path Dependence

The bistable regime is the framework's sharpest departure from static rational-choice theory. With identical preferences, prices, and resource constraints, the population may settle into either a high- or a low-consumption equilibrium; which one is realized depends entirely on the initial distribution of strategies relative to the separatrix $x^* = -K/s$. Figure 3 traces trajectories from a range of initial states under a strong social-interaction strength: populations starting above the separatrix are drawn to universal high consumption, those starting below to universal low consumption, even though no fundamental differs across them. Outcomes are therefore *path-dependent* and *history-dependent*, a form of hysteresis that the unique-equilibrium benchmark cannot generate.

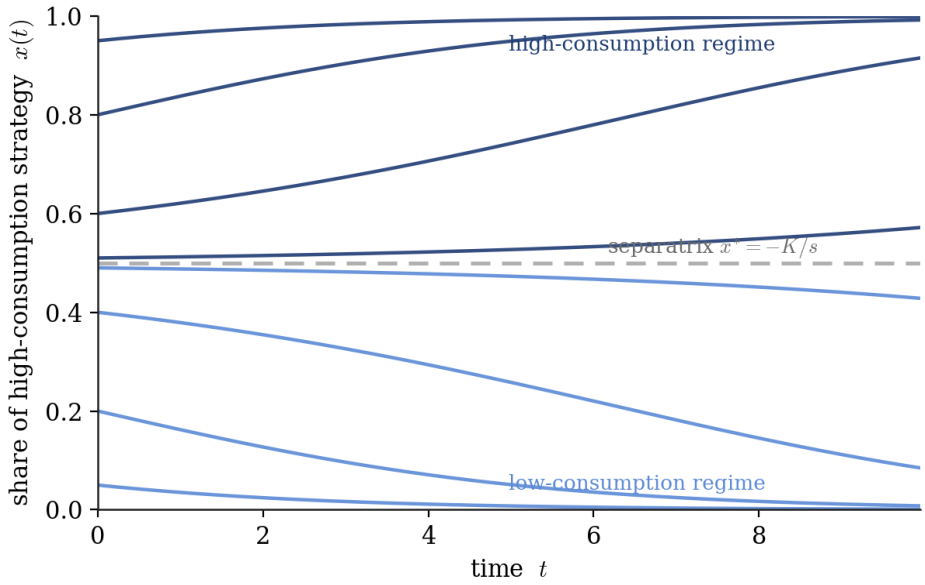


Figure 3. Trajectories of the reduced replicator dynamics in the bistable regime (s = 0.8, K = −0.4) from several initial conditions.

The dashed line is the unstable separatrix x* = −K/s. Initial states above it converge to the high-consumption regime; those below converge to the low-consumption regime, illustrating path dependence under strong social comparison.

Two further implications follow. First, because the threshold (12) depends on the price p and on the comparison coefficient γ, a gradual change in a fundamental—a slow price decline or an intensification of social comparison through, say, increased media exposure—can push the system across s^* and trigger an abrupt, discontinuous jump in aggregate consumption: a tipping point in the sense of Schelling (1978). Second, near the bifurcation the system exhibits critical slowing down, so that recovery from shocks becomes sluggish and the aggregate state can remain in persistent disequilibrium for long intervals. Both phenomena are routinely observed in consumption booms, fashion cascades, and social epidemics, and both are precluded by construction in the optimizing benchmark. The mechanism here is structurally akin to the multiplicity that Brock and Durlauf (2001) derive from discrete choice with social interactions, but it arises dynamically, as a property of the adaptive trajectory rather than of a static equilibrium-selection criterion.

DISCUSSION

The analysis supports three broad conclusions. First, rationality and adaptation are not competing hypotheses but nested ones. Utility maximization survives in the framework as the low-noise, robust-optimum limit of an evolutionary process; it is neither assumed away nor enthroned as a universal law. This nesting offers a principled reconciliation of the descriptive critique of Homo Economicus with the analytical successes of optimization-based economics, and it makes the degree of rationality an estimable parameter—the mutation rate—rather than a maintained assumption.

Second, embedding microeconomic choice in a dynamical system enlarges the set of explainable phenomena. Because the governing equations are nonlinear and frequency-dependent, the model accommodates multiple equilibria, path dependence, hysteresis, and tipping behavior—features that are increasingly documented empirically in consumption and diffusion data but that lie outside the reach of static, unique-equilibrium models. The bifurcation result in particular reframes certain macro-level regularities, such as consumption regimes and fashion cascades, as emergent consequences of decentralized adaptation under social comparison rather than as anomalies.

Third, the framework reorients normative analysis. If the realized equilibrium is selected by history rather than uniquely determined by fundamentals, then policy has a role not only in changing incentives

at the margin but in steering the system across basins of attraction—shifting the separatrix, dampening destabilizing social feedback, or exploiting critical slowing down to time interventions. Welfare statements must then be conditioned on the attained regime, and small, well-timed interventions near a bifurcation may have disproportionate and lasting effects.

Several limitations qualify these claims and mark directions for further work. The model is deterministic and mean-field; a finite population introduces demographic noise whose interaction with the bifurcation merits a stochastic treatment via the diffusion approximation. The payoff specification is quadratic with a linear comparison term, chosen for analytical transparency; richer, nonlinear comparison structures could generate limit cycles or chaotic consumption dynamics under the same selection mechanism. Finally, the strategy set is fixed; allowing innovation to introduce new strategies endogenously would connect the framework to the open-ended evolutionary dynamics of Nelson and Winter (1982) and to models of economic novelty. Empirically, the central testable prediction—a discontinuous, history-dependent shift in aggregate consumption as social-interaction strength crosses a threshold—invites estimation on panel data exhibiting candidate tipping behavior.

CONCLUSION

This paper has developed a dynamical-systems reconstruction of microeconomic decision-making built around Homo Evolutivus, an adaptive agent whose behavior is shaped by selection, imitation, and bounded rationality rather than by assumed optimization. By identifying evolutionary payoffs with a socially augmented utility function and letting strategy frequencies evolve under replicator and replicator–mutator dynamics, the framework derives utility maximization as an emergent, evolutionarily stable outcome in the low-noise limit, characterizes convergence through Jacobian and Lyapunov analysis, and shows that strong social comparison induces a transcritical bifurcation producing multiple stable consumption regimes, path dependence, and abrupt aggregate transitions. These results establish a mathematically rigorous alternative to static rational-choice models and lay foundations for an evolutionary microeconomics in which equilibrium is an achievement of adaptive dynamics rather than a premise. The reconceptualization trades the certainty of a unique optimum for the realism of a contingent, history-laden process—an exchange that, the analysis suggests, brings microeconomic theory closer to the behavior it seeks to explain.

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EGZERSİZE BAĞLI HİPOALJEZİ VE AĞRI MODÜLASYONU: FİZYOTERAPİ PERSPEKTİFİNDEN BİR DERLEME

EXERCISE-INDUCED HYPOALGESIA AND PAIN MODULATION: A REVIEW FROM A PHYSIOTHERAPY PERSPECTIVE

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ABSTRACT

Exercise-induced hypoalgesia refers to the temporary reduction in pain sensitivity that occurs during or after physical exercise. This phenomenon suggests that exercise may influence the body's endogenous pain control systems. The high prevalence of chronic pain and the certain limitations of pharmacological treatments make exercise an important option in pain management. This study addresses the fundamental mechanisms underlying exercise-induced hypoalgesia, the effects of different exercise modalities on pain, and its clinical relevance from a physiotherapy perspective. The endogenous opioid system, the endocannabinoid system, and descending inhibitory pain pathways are thought to contribute to the reduction in pain observed after exercise. In addition, individuals' pain beliefs, fear of movement, pain catastrophizing, and expectations regarding exercise may also influence this response. Aerobic exercise, resistance exercise, and isometric exercise are among the most frequently investigated exercise modalities in this context; however, their hypoalgesic effect sizes may differ. Reductions in pain sensitivity after exercise may be more pronounced in healthy individuals. However, this response may not occur consistently in individuals with chronic pain and may even lead to increased pain in some cases. Therefore, exercise type, intensity, and duration should be planned individually, taking into account the individual's pain condition and exercise tolerance. This study aims to discuss these mechanisms and their clinical implications from a physiotherapy perspective.

Keywords: Exercise-induced hypoalgesia, pain modulation, chronic pain.

ÖZET

Egzersize bağlı hipoaljezi , egzersiz sırasında ya da egzersiz sonrasında ağrı duyarlılığının geçici olarak azalmasıdır. Bu durum, egzersizin vücuttaki doğal ağrı kontrol sistemlerini etkileyebildiğini gösterebilmektedir. Kronik ağrının yaygın görülmesi ve ilaç tedavilerinin bazı sınırlılıklar taşıması, egzersizi ağrı yönetiminde önemli bir seçenek haline getirmektedir. Bu çalışmada, egzersize bağlı hipoaljezinin temel mekanizmaları ile farklı egzersiz türlerinin ağrı üzerindeki etkileri ve fizyoterapi açısından klinik önemi ele alınacaktır. Egzersiz sonrası ortaya çıkan ağrı azalmasında endojen opioid sistem, endokannabinoid sistem ve inen inhibitör ağrı yollarının etkili olduğu düşünülmektedir. Bunun yanında kişinin ağrıya bakışı, hareketten korkması, ağrıyı felaketleştirmesi ve egzersize yönelik beklentileri de bu yanıtı etkileyebilir. Aerobik egzersizler, direnç egzersizleri ve izometrik egzersizler bu konuda en sık incelenen egzersiz türleri olmakla birlikte, bu modalitelerin hipoaljezik etki büyüklükleri birbirinden farklılık göstermektedir. Sağlıklı bireylerde egzersiz sonrası ağrı duyarlılığında azalma daha belirgin olabilir. Ancak kronik ağrılı bireylerde bu yanıt her zaman aynı şekilde görülmeyebilir ve bazı kişilerde ağrı artışına yol açabilir. Bu nedenle egzersiz türü, şiddeti ve süresi; kişinin ağrı durumu ve egzersiz toleransı ile birlikte değerlendirilerek bireysel olarak planlanmalıdır. Çalışmamız, söz konusu mekanizmalar ve klinik yansımaları fizyoterapi perspektifinden ele almayı amaçlamaktadır.

Anahtar Kelimeler: Egzersize bağlı hipoaljezi, ağrı modülasyonu, kronik ağrı.

GİRİŞ

Ağrı, Uluslararası Ağrı Çalışmaları Derneği (IASP) tarafından 2020 yılında yeniden tanımlanmıştır. Buna göre ağrı, gerçek ya da olası doku hasarıyla ilişkili olan veya buna benzeyen hoş olmayan duyusal ve duygusal bir deneyimdir. Revize tanıma eşlik eden notlar bu konuda iki önemli hususa dikkat çekmektedir. Birincisi, ağrı biyolojik, psikolojik ve sosyal etmenlerden değişen derecelerde etkilenen kişisel bir deneyimdir. İkincisi ise ağrı ile nosisepsiyon birbirinden farklı fenomenlerdir. Tanıma eklenen "gerçek ya da olası doku hasarıyla ilişkili olana benzeyen" ifadesi, ağrının yalnızca doku hasarıyla sınırlandırılmaması gerektiğini ortaya koymaktadır. Bu sayede nöropatik ve nosiplastik ağrı gibi durumlarda klinik olarak belirgin bir doku hasarı saptanmasa bile bireylerin ağrı bildirebileceği kabul edilmektedir (Stevens, 2021; Jordan ve ark., 2021).

Ağrının anlaşılmasında biyopsikososyal model önemli bir çerçeve sunmaktadır. Bu modele göre ağrı deneyimi, biyolojik, psikolojik ve sosyal faktörlerin karmaşık etkileşimiyle şekillenmektedir (Kovačević ve ark., 2024; Gatchel ve ark., 2007). Bu nedenle ağrıyı yalnızca nosiseptif uyarıların sonucu olarak görmek yetersizdir. Aynı doku hasarı ya da aynı klinik durum, farklı bireylerde farklı ağrı deneyimlerine yol açabilir. Bireyin ağrıya yüklediği anlam, korku ve kaçınma davranışları, psikolojik stres ile sosyal çevre koşulları ağrının şiddetini ve baş etme biçimini etkileyebilmektedir (Gatchel ve ark., 2007). Bu durum, özellikle kronik ağrının değerlendirilmesinde yalnızca fiziksel bulgulara odaklanmanın yetersiz kalabileceğini göstermektedir.

Kronik ağrı, genel olarak normal iyileşme süresini aşan, üç ila altı aydan uzun süren ya da tekrarlayan ağrı olarak tanımlanmaktadır. Akut ağrı çoğu zaman koruyucu ve uyarıcı bir işleve sahiptir. Ancak kronik ağrı ise bu fizyolojik işlevin ötesine geçerek başlı başına bir sağlık sorunu haline gelebilir. Dünya Sağlık Örgütü'nün Hastalıkların Uluslararası Sınıflandırmasının 11. revizyonunda (ICD-11) kronik ağrının daha sistematik biçimde ele alınması da bu değişen yaklaşımı desteklemektedir. Bu sınıflamada kronik ağrı, etiyoloji ve altta yatan patofiziyolojik mekanizmalar temel alınarak yedi ana grup altında değerlendirilmektedir (Treede ve ark., 2015). Kronik ağrı, yalnızca bireysel düzeyde değil, toplum sağlığı açısından da önemli bir sorundur. Küresel hastalık yükü verileri, 1990–2019 yılları arasında kronik ağrıyla ilişkili prevalans ve engellilikle geçirilen yıllar yükünde anlamlı bir artış olduğunu göstermektedir (Zhu ve ark., 2025). Güncel epidemiyolojik veriler, kronik ağrının yetişkin nüfusta yaygın görüldüğünü ortaya koymaktadır. 2023 yılı verilerine göre ABD'li yetişkinlerin %24,3'ünde kronik ağrı, %8,5'inde ise yaşam veya iş aktivitelerini sık kısıtlayan yüksek etkili kronik ağrı bildirilmiştir (Lucas ve Sohi, 2024).

Kronik ağrının bireyin yaşam kalitesi üzerindeki etkisi çok yönlüdür. Kronik ağrılı bireylerde fiziksel işlevsellik, mesleki yaşam, aile ilişkileri, sosyal katılım, uyku düzeni ve duygu durum olumsuz etkilenebilmektedir. Bu etkiler birbirinden bağımsız değildir. Örneğin ağrı nedeniyle fiziksel aktivitenin azalması kişinin iş yaşamını, sosyal ilişkilerini ve psikolojik iyilik halini zorlaştırabilir. Benzer şekilde hastaların ifadelerine göre uyku kalitesinin bozulması ağrıyla başa çıkmayı güçleştirmekte; depresyon ve ağrı arasındaki çift yönlü ilişki ise bu süreci kısır bir döngüye dönüştürebilmektedir (Hadi ve ark., 2019). Bu nedenle kronik ağrının yönetiminde yalnızca ağrı şiddetinin azaltılması değil, bireyin işlevselliğinin, katılımının ve yaşam kalitesinin korunması da temel hedefler arasında yer almalıdır.

Bu çok yönlü tablo, kronik ağrı yönetiminde farmakolojik yaklaşımların yeterliliğini de sorgulatmaktadır. Nitekim bu yaklaşımın bazı sınırlılıkları bulunmaktadır. Özellikle uzun süreli opioid kullanımında yan etkiler, tolerans gelişimi, bağımlılık, yoksunluk, kötüye kullanım ve doz artırma gereksinimi gibi sorunlar ortaya çıkabilmektedir (Brush, 2012). Bu bağlamda fiziksel aktivite ve egzersiz, kronik ağrı yönetiminde giderek daha fazla yer bulan non-farmakolojik yaklaşımlar arasında öne çıkmaktadır. Geçmişte kronik ağrılı bireylere daha çok istirahat önerilirdi. Ancak güncel yaklaşımlar, uygun şekilde planlanmış hareketin ve egzersizin desteklenmesi yönündedir. Egzersiz; ağrı şiddetini azaltma, fiziksel fonksiyonu geliştirme ve yaşam kalitesini destekleme potansiyeline sahip olmakla birlikte mevcut kanıtlar, bu etkilerin her çalışmada aynı düzeyde gerçekleşmediğini ve kanıt kalitesinin düşük olduğunu göstermektedir (Geneen ve ark., 2017).

Bu çerçevede egzersiz uygulamaları, bireyin mevcut sağlık durumu ve fiziksel kapasitesi gözetilmeksizin uygulanan standart bir protokol olarak değil, kişiye özgü biçimde planlanmalıdır.

Egzersizin ağrı üzerindeki etkisini anlamlandırabilmek için ise egzersize bağlı hipoaljezi kavramının ve bu yanıtı şekillendiren mekanizmaların incelenmesi gerekmektedir. Bu doğrultuda mevcut çalışma; egzersize bağlı hipoaljezinin fizyolojik temellerini, farklı egzersiz modalitelerinin ağrı modülasyonu üzerindeki etkilerini ve psikososyal faktörlerin bu yanıttaki rolünü fizyoterapi perspektifinden ele almayı amaçlamaktadır.

EGZERSİZE BAĞLI HİPOALJEZİNİN AĞRI MODÜLASYONUNDAKİ ROLÜ

Egzersize bağlı hipoaljezi (EIH), egzersiz seansı sırasında veya sonrasında ağrı duyarlılığının geçici olarak azalması şeklinde tanımlanmaktadır. Bu yanıt; basınç ağrı eşiğinde artış, ağrı toleransında yükselme ve ağrılı uyaranlara verilen yoğunluk derecelendirmelerinde azalma gibi çeşitli yöntemlerle değerlendirilebilmektedir. EIH yanıtının süresi genellikle sınırlı olmakla birlikte egzersiz sonrası birkaç dakikadan otuz dakikaya kadar değişen bir aralıkta gözlemlenebilmektedir (Vaegter ve Jones, 2020). EIH yanıtı bireylerde egzersiz türüne bağlı olarak değişkenlik gösterebilir. Yapılan bir çalışmada, sağlıklı bireylerde aerobik egzersizin deneysel ağrı üzerinde büyük bir hipoaljezik etki oluşturduğu, dinamik direnç egzersizinin küçük bir hipoaljezik etki sağladığı, ancak izometrik egzersizin anlamlı bir etki göstermediği ortaya konmuştur. Buna karşılık, kronik kas-iskelet ağrısı olan bireylerde EIH yanıtının daha değişken olduğu ve sıklıkla bozulmuş bir biçimde ortaya çıktığı bildirilmektedir (Wewege ve Jones, 2021).

EIH'nin altında yatan mekanizmalar arasında en sık incelenen sistemlerden biri endojen opioid sistemdir. Kas kasılması sırasında iskelet kasındaki mekanosensitif afferent liflerin (A-delta ve C lifleri) deşarjı artmakta ve bu süreç endojen opioid sistemini aktive edebilmektedir. Egzersiz sonrasında dolaşımdaki beta-endorfin düzeylerinde gözlemlenen artışın, periferik afferent nöronların uyarılması yoluyla spinal ve supraspinal inhibitör mekanizmaları harekete geçirerek ağrı modülasyonuna katkıda bulunduğu düşünülmektedir. Bununla birlikte, opioid antagonistleriyle gerçekleştirilen çalışmalardan elde edilen bulgular henüz netlik kazanmamış olup opioid blokajının EIH yanıtını bazı koşullarda etkilediği, bazılarında ise herhangi bir değişikliğe yol açmadığı görülmektedir (Koltyn ve ark., 2014).

Opioid sisteme alternatif olarak öne sürülen bir diğer mekanizma, endokannabinoid sistemin egzersiz sonrası ağrı modülasyonundaki rolüdür. Endokannabinoid sistem; kannabinoid reseptörleri (CB1 ve CB2), bu reseptörlerin endojen ligandları (anandamid [AEA] ve 2-araşidonoilgliserol [2-AG]) ile bunların sentez ve yıkımından sorumlu enzimlerden oluşan, beyin ve omurilikteki ağrı işleme bölgelerinde yoğun olarak bulunan nöromödülatör bir sistemdir (Watkins, 2018). Egzersiz sonrasında dolaşımdaki endokannabinoid düzeylerinde anlamlı artışlar bildirilmiş olup, bazı endokannabinoidlerin egzersizden kaynaklanan analjezik etkilere aracılık edebileceği ileri sürülmektedir (Watkins, 2018).

Egzersizin ağrıyı modüle edebilmesinde merkezi sinir sistemindeki inen inhibitör ağrı yolları da kritik bir rol oynamaktadır. EIH'nin temel olarak periakuaduktal gri madde (PAG) kaynaklı ve rostral ventromedial medulla (RVM) ile lokus seruleus aracılığıyla spinal dorsal boynuza iletilen inen inhibitör yolların aktivasyonu üzerinden meydana geldiği düşünülmektedir. PAG ve RVM nöronları, hipotalamik, limbik ve otonomik merkezlerle bağlantılıdır. Bu durum egzersizin hem ağrı modülasyonunu hem de stres yanıtını aynı anatomik ağ üzerinden etkileyebileceğini göstermektedir (Gajic ve ark., 2026). Klinik veriler, kronik kas-iskelet sistemi ağrısı olan bireylerde inen inhibisyonun sıklıkla yetersiz olduğunu ve ağrılı uyaranlara karşı aşırı bir zamansal toplanma (temporal summation) yanıtı geliştiğini göstermektedir. Ayrıca yapılandırılmış egzersiz programının bu bozukluğu kısmen düzeltebileceği bildirilmektedir (Gajic ve ark., 2026). Bu nedenle, egzersizin inen inhibitör yolları harekete geçirmesi, EIH'nin merkezi sinir sistemi düzeyindeki temel mekanizmalarından biri olarak kabul edilmektedir.

EGZERSİZ TÜRLERİ VE FİZYOTERAPİ AÇISINDAN KLİNİK ÖNEMİ

EIH yanıtının büyüklüğü ve tutarlılığı, kullanılan egzersiz türüne, şiddetine ve süresine bağlı olarak önemli farklılıklar göstermektedir. Aerobik egzersizler bu konuda en sık incelenen egzersiz türü olup, özellikle egzersiz şiddetinin EIH yanıtının büyüklüğünü belirleyen kritik bir değişken olduğu bildirilmektedir. Sağlıklı genç yetişkinlerde yapılan bir çalışmada, 5 dakikalık ısınma periyodunun ardından kalp atım hızı rezervinin %70'inde 20 dakika süren bisiklet egzersizinden oluşan şiddetli aerobik egzersiz protokolünün basınç ağrı eşiğinde anlamlı bir artış sağladığı, ancak eşik üstü basınç

ağrı algısını değiştirmediği ortaya konmuştur. Buna karşın orta şiddetli aerobik egzersiz (%50–55 kalp atım hızı rezervi) basınç ağrı eşiği üzerinde anlamlı bir etki göstermemiştir. Öte yandan her iki egzersiz şiddetinin de devamlı ve tekrarlı ısı ağrı uyaranlarına verilen yanıtları azaltabildiği görülmüştür. Bu bulgu, söz konusu etkinin tüm ağrı modalitelerine eşit ölçüde genellenmediğine ve ağrı indüksiyon tekniğinin belirleyici bir rol oynadığına işaret etmektedir. Bulgular, EIH'de bir doz-yanıt ilişkisinin varlığına güçlü biçimde işaret etmektedir (Naugle ve ark., 2014). Nitekim literatürdeki diğer kanıtlar da bu yöndeki veriler ile paralel sonuçlar ortaya koymuştur. Sağlıklı bireylerde aerobik egzersizin EIH oluşturduğu, yüksek şiddetli egzersizin en büyük etkiyi sağladığı, bunu orta şiddetli egzersizin takip ettiği, düşük şiddetli egzersizin ise anlamlı bir etki göstermediği bildirilmiştir. Egzersiz süresi açısından değerlendirildiğinde ise yalnızca orta süreli egzersizin (20–40 dakika) anlamlı düzeyde hipoaljezik etki oluşturduğu; kısa (≤20 dakika) ve uzun süreli (>40 dakika) egzersizlerin ise bu etkiyi ortaya koymadığı bildirilmiştir (Tomschi ve ark., 2024).

Direnç egzersizleri açısından bulgular daha az tutarlıdır. Sağlıklı katılımcılarda gerçekleştirilen randomize kontrollü bir çalışmada, diz ekstansiyon egzersizinin yüksek şiddette (1 tekrar maksimumunun %75'i) ya da düşük şiddette (%30'u) uygulanmasının kuadriseps ve trapezius üzerindeki basınç ağrı eşiğinde anlamlı bir farklılık oluşturmadığı bildirilmiştir. Koşullu ağrı modülasyonunun da her iki egzersiz şiddetinden sonra anlamlı biçimde değişmediği saptanmıştır (Wilson ve ark., 2024). Bu bulgular, dinamik direnç egzersizlerinde EIH'yi tetikleyen optimal egzersiz dozunun henüz yeterince tanımlanmadığına işaret etmektedir. Öte yandan EIH yanıtının farklı egzersiz türleri arasında benzer büyüklükte olabileceği, ancak bireyler arasında ve hatta aynı bireyde farklı günlerde tutarsızlık gösterebileceği belirtilmektedir. Bazı kişiler egzersiz sonrası tutarlı şekilde hipoaljezi gösterirken, bazılarında hiperaljezi gözlenebilmekte, bazı kişilerin yanıtı ise günden güne değişebilmektedir (Vaegter ve Jones, 2020).

Kronik ağrı popülasyonlarında EIH yanıtı; ağrı duyarlılığının azalması, değişmemesi ya da artması şeklinde belirgin bir değişkenlik sergileyebilmektedir. Bu durumun, merkezi ağrı işlemleme mekanizmalarındaki değişiklikler ve endojen ağrı inhibisyonundaki yetersizlikle ilişkili olabileceği düşünülmekle birlikte, altta yatan mekanizmalar henüz tam olarak aydınlatılamamıştır. Öte yandan, ağrılı bir kas grubu ile egzersiz yapıldığında EIH yanıtının bozulabildiği; buna karşın aynı bireyde ağrısız bir bölgenin egzersize dahil edilmesi durumunda hipoaljezik yanıtın korunabildiği gösterilmiştir. Bu bulgu, klinik uygulamada ağrılı olmayan kas gruplarının egzersize dahil edilmesinin, egzersize bağlı ağrı alevlenmelerini önlemeye yönelik bir strateji olarak değerlendirilebileceğine işaret etmektedir (Rice ve ark., 2019). EIH yanıtındaki bu bozulmanın altında yatan mekanizmalardan biri olarak santral sensitizasyon kavramı öne çıkmaktadır. Santral sensitizasyon, merkezi sinir sisteminde nöral sinyal iletiminin artması sonucu ağrıya karşı duyarlılığın yükselmesi olarak tanımlanmakta ve fibromiyalji, osteoartrit, romatoid artrit ile kronik bel ağrısı gibi fizyoterapi pratiğinde sık karşılaşılan durumlarda gözlemlenmektedir. Aynı tanı grubu içinde santral sensitizasyonun görülme sıklığı ve şiddeti bireyden bireye belirgin biçimde farklılık göstermektedir. Bu nedenle santral sensitizasyonun varlığı ve derecesinin bireysel olarak değerlendirilmesi, egzersize verilecek ağrı yanıtının öngörülmesinde ve tedavi planlamasında belirleyici bir rol oynayabilir (Nijs ve ark., 2021).

SONUÇ

Ağrı yönetiminde egzersizin değeri, yalnızca ağrıyı azaltan bir uygulama olmasından değil, ağrı modülasyon sistemlerini harekete geçirebilen bir tedavi aracı olmasından kaynaklanmaktadır. Egzersize bağlı hipoaljezi bu etkiyi göstermekle birlikte, her bireyde aynı biçimde ortaya çıkmaz. Egzersiz sonrası ağrının azalması, seçilen yüklenmenin o birey için uygun olabileceğini düşündürür. Buna karşılık egzersiz sonrası ağrı artışı, hastanın egzersize uygun olmadığı anlamına gelmez. Çoğu zaman egzersizin şiddetinin, süresinin, seçilen kas grubunun veya ilerleme hızının yeniden düzenlenmesi gerektiğini gösterir. Bu nedenle ağrı alevlenmesi, tedaviyi bırakma nedeni olarak değil, programı yeniden ayarlama işareti olarak değerlendirilmelidir. Bu çalışmadan çıkarılabilecek önemli bir klinik sonuç, sağlıklı bireylerde gözlenen egzersize bağlı hipoaljezik yanıtların ağrılı bireylere doğrudan aktarılmaması gerektiğidir. Ağrılı bireylerde sinir sisteminin duyarlılığı, önceki ağrı deneyimleri, hareket korkusu ve egzersize yönelik beklentileri bu yanıtı değiştirebilir. Bu farklılık, egzersiz reçetesinin yalnızca tanıya

ya da egzersiz türüne göre değil, bireyin verdiği gerçek yanıta göre düzenlenmesi gerektiğini göstermektedir.

Fizyoterapistin rolü bu noktada yalnızca egzersiz seçmek değil, hastanın egzersize verdiği ağrı yanıtını okuyabilmektir. Egzersiz sonrası ağrının süresi, şiddeti, yayılımı, toparlanma zamanı ve hastanın hareket sırasında hissettiği güven düzenli olarak izlenmelidir. Ağrılı bölgeyle başlanan egzersiz ağrıyı artırıyorsa daha iyi tolere edilen bölgelerden başlanmalıdır. Yüksek şiddetli egzersiz tehdit oluşturuyorsa daha düşük şiddetle ilerlemek; hareket korkusu belirginse egzersizi ağrı eğitimiyle desteklemek daha uygun bir yaklaşım olabilir. Dolayısıyla ağrı yönetiminde etkili egzersiz en yoğun ya da en popüler olan değildir. Etkili egzersiz; bireyin ağrı sistemini aşırı uyarmadan güvenli hareket deneyimini artıran, toleransı zamanla geliştiren ve gerektiğinde yeniden düzenlenebilen egzersizdir. Egzersize bağlı hipoaljezinin anlaşılması, fizyoterapiste bu süreci daha bilinçli yönetme imkânı sağlar. Bu nedenle ağrılı bireylerde egzersiz tedavisinin başarısı, egzersizin uygulanmasından çok kime, ne zaman, hangi dozda ve nasıl bir ilerleme planıyla verildiğine bağlıdır.

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FINITE ELEMENT ANALYSIS-BASED INVESTIGATION OF THE MECHANICAL BEHAVIOR OF VORONOI-STRUCTURED CRANIAL IMPLANTS WITH DIFFERENT PORE SIZES

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ABSTRACT

The development of cranial implants that anatomically fit skull defects is extremely important for the protection of brain tissue, the restoration of the integrity of the skull and the improvement of the aesthetic appearance. The use of additive manufacturing technologies and the increased use of reverse engineering tools in biomedical applications have resulted in the investigation of different design approaches for patient-specific implant development. In this sense, porous structures have emerged as an important design alternative to enhance the mechanical behavior and the biomechanical compatibility of cranial implants.

The objective of this study was to evaluate the mechanical performance of Voronoi-based porous cranial implant shell models with different rib heights under the loading condition of 700 N using finite element analysis. Thus, five distinct Voronoi configurations were developed, with rib heights of 0.5, 1.0, 1.5, and 2.0 mm assigned to each implant model. The mechanical behaviour of the implant-skull system was studied. The optimal configuration was identified using a TOPSIS based multi-criteria decision-making approach and ANOVA contribution analysis was carried out to quantify the effect of Voronoi type and rib height on the mechanical response.

The findings indicated that the increase in rib height substantially reduced the implant's Von-Mises stress, total deformation, and maximum principal stress within the skull. The force exerted on the cranium increased with greater rib height, suggesting a necessary balance between implant stiffness and biomechanical load distribution. The ANOVA results indicated that rib height was the predominant design parameter, contributing to roughly 91.6% of the variation in Von-Mises stress, 84.6% of the total deformation, 58.4% of the highest primary stress in the skull, and 87.1% of the force transmission. The findings indicate that rib height significantly affects the mechanical performance of porous cranial implants more than the selection of Voronoi type, and that a multi-criteria optimization strategy offers a systematic method for choosing well-balanced implant designs.

Keywords: Cranial implant, Voronoi structure, porous implant, finite element analysis, rib height, TOPSIS, ANOVA, biomechanical optimization

POLİTİK KIRILMALAR VE TİYATRO İLİŞKİSİ: AVUSTRALYA FEDERASYONU VE TÜRKİYE CUMHURİYETİ ARASINDA KARŞILAŞTIRMA[1]

POLITICAL FRACTURES AND THEIR RELATIONSHIP WITH THEATRE: A COMPARISON BETWEEN THE AUSTRALIAN FEDERATION AND THE REPUBLIC OF TURKIYE[2]

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ÖZET

Avustralya, 1901 yılında Avustralya federasyonuna dönüşene kadar her birinin ayrı politik stratejileri olan ve birbirinden bağımsız altı eyalet sistemine sahip olduğu bilinir (New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania). Bugünkü Türkiye ise 1923 yılında Türkiye Cumhuriyeti'nin kuruluşu ile Osmanlı İmparatorluğu tarihini sona erdirmiştir. Bu politik kırılma noktaları her iki coğrafya için oldukça önemli değişimlere ve tüm yaşam alanlarına yansımasına neden olmuştur.

Tiyatro sanatı üretildiği coğrafyanın politik dinamiklerinden doğrudan etkilenen alanlardan biridir. Tarihsel olarak birbirine yakın zamanlarda ve coğrafi olarak birbirinden oldukça uzak olan iki ülkenin politik değişimleri tiyatro yaşamını da etkiler ve öncelikle ulusal bir tiyatro yaratma çabalarıyla dikkati çeker. Dönüşüm tarihlerinde Avustralya tiyatrosu ihraç oyunlarla tiyatro yaşamını aktif tutmaya çalışır. Türkiye ise geleneksel tiyatro türlerinden çerçeve sahneli ve metinli tiyatro modeline geçiş sağlamıştır. Bu dönüşüm sürecinin Devlet desteği ve özel girişimlerle verdiği mücadele önemlidir.

Bu araştırmanın amacı, coğrafi olarak birbirinden oldukça uzak olan iki ülkenin politik kırılma noktalarından sonra tiyatro yaşamının nasıl etkilendiğini tespit etmek ve karşılaştırmaktır. Hem Avustralya hem Türkiye tiyatro tarihi incelenerek dünyanın her yerinde tiyatronun politik etkileşimlerini görünür kılmak hedeflenmiştir. Böylece kurumsal ve sanatsal açıdan üretime ve uygulamaya ilişkin etkileşimlerin karşılaştırılması sağlanacaktır.

Anahtar kelimeler: Türk tiyatrosu, Avustralya tiyatrosu, Oyun yazarlığı, Avustralya Federasyonu, Türkiye Cumhuriyeti

ABSTRACT

Australian political history was characterised by a system of six independent states, each with its own distinct political strategies, until the formation of the Commonwealth of Australia in 1901. Meanwhile, in Turkiye, the history of the Ottoman Empire came to an end with the establishment of the Republic of Turkiye in 1923. These political turning points led to significant changes in both regions, with repercussions felt across all aspects of life.

The art of theatre is one of the artistic fields directly influenced by the political dynamics of the region in which it is produced, from scriptwriting and performance production right through to the staging of a play. The political transformations of these two countries, which, historically, occurred at roughly the

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same time yet are geographically quite distant, first and foremost draw attention through their efforts to create a national theatre. During this periods, Australian theatre sought to maintain an active theatre scene through imported plays. On the other hand, Turkiye, transitioned from traditional theatre forms to a model of staged and with play texted theatre. The struggle to achieve this transformation, supported by both state funding and private initiatives, is significant.

The aim of this research is to identify and compare how the theatrical life of these two geographically distant countries was affected by their respective political turning points. By examining the theatrical histories of both Australia and Turkiye, the study aims to highlight the interactions between theatre and politics. This will enable a comparison of the interactions relating to production and practice from both institutional and artistic perspectives.

Keywords: Turkish theatre, Australian theatre, Playwriting, Commonwealth of Australia, Republic of Turkiye

GİRİŞ

Bugün dünya üzerinde varlık sürdüren ülkeler tarihi çeşitli politik kırılma anlarını yaşamıştır. Bir ülkenin politik dinamikleri toplumsal yaşamın tüm alanlarını, sanatı, gelenekleri vb. daha birçok alanı etkiler. Bu etkilerin tiyatro sanatı ile ilişkisi yadsınamaz. Öyle ki tarih boyunca tiyatro iktidarla, politik olanla sürekli etkileşim yaratmıştır. Orta çağ dönemi dahi tiyatro etkinliklerinin kilise tarafından en kısıtlı olduğu dönem olarak bilinir ancak sonunda Mericle ve Morality oyunları ile dönemin politik tavrı ile tiyatro bir araya gelmiştir (Brocket, 1995). Tiyatro tarihinin benzer örnekleri gözetildiğinde günümüze dek çeşitli zamanlarda ve hemen her coğrafyada bu etkileşimi görmek mümkündür. Bu bağlamda birbirinden oldukça uzak ancak rejim değişiklikleri birbirine yakın tarihlerde gerçekleşen Avustralya ve Türkiye politik kırılmalar ve tiyatro etkileşimin örnekleri arasında değerlendirilebilir.

Avustralya coğrafi olarak Avrupa, Asya, Amerika gibi pek çok kıta için uzak mesafe sayılabilecek bir kıta ülkesidir. Avustralya'yı ilginç yapan hem oldukça genç hem de oldukça eski bir tarihe sahip olmasıdır. 2015 yılında yapılan bir araştırma MÖ 47000 yılına ait kaya sığınakları keşfetmiştir ve bilinen tüm zamanlarında kıta yerlileri olan Aborijinler bu toprakların geleneksel sahipleridir. Ancak tarih 1787 yılını gösterdiğinde İngiltere kralı III. George tarafından yola çıkarılan 11 gemilik filonun Avustralya'ya ulaşması ile kıta için yeni bir tarih yazılmaya başlamıştır. Meyrick (2024) bu tarihten sonraki 113 yılı İngiliz kolonisi olarak ifade eder. Zamanla farklı ülkelerden göç edenler de olmuştur ancak hepsi de İngiliz yönetimine tabi kalmıştır.

Avustralya birbirinden bağımsız altı eyalet sistemine (New South Wales, Tasmania, Western Australia, South Australia, Victoria, Queensland) sahipken 1891 yılı itibariyle başlayan Avustralya federasyonu girişimi ancak on yıllık tartışmalı bir dönem sonrasında kabul edilmiştir. Bu süreçte eyaletlerin politik ve ekonomik olarak zarar görmemeyi öncelemeleri dikkat çekicidir. 1 Ocak 1901 tarihinden itibaren İngiliz kolonilerinden oluşan altı eyalet birleşmiş ve Avustralya federasyonu oluşmuştur. Beş ay sonra da ilk federal parlamento büyük bir coşkuyla Melbourne'da açılmıştır. Böylece Avustralya bağımsız bir ulus olmuştur (Meyrick, 2022). Ancak burada bir yanılgıya düşmemek gerekir çünkü Avustralya 1901 yılında kurulmuş bir ülke değildir, bu tarih Avustralya Federasyonu'nun kuruluş yılıdır. Eyaletlerin çoğunun kuruluşu ilk filonun ulaşmasından sonra başlamıştır. Aslında bugün bilinen Avustralya'nın İngiliz sömürgesinin kaçınılmaz bir sonucu olarak ifade edilmesi bir yandan da İlk Milletler'in tarihine haksızlık olabilir ya da onları bilinen Avustralya var olana kadar bu toprakları işgal etmiş imasını yaratabilir. Dolayısıyla 1901 yılı Avustralya ulusunun başlangıç tarihi sayılacaksa bunun nedeninin zaten önceden bir ulusun var olmuş olmasıdır (Brooklyn vd., 2022).

Avustralya'nın uluslararası devletler topluluğu içinde ne zaman bağımsız bir kimlik kazandığı sorusuna yanıt vermek zordur ama 1901'deki Federasyon'un kurulmasından çok sonra gerçekleşmiştir. Aslında ilk liderler Avustralya'nın bağımsız bir dış politikaya sahip olacağı düşüncesini reddetmiştir. Bağımsızlık bir hükümetin diğer hükümetlerin dayatmalarından bağımsız olarak kendi kararlarını alma yeteneği olarak ifade edildiğinde Avustralya için 1901 erken bir tarih sayılır. 1933 Montevideo Sözleşmesi'nin 1. maddesinde devlet olmanın dört kriteri özetlenmiştir; kalıcı nüfus, tanımlanmış bir

toprak, bir hükümet ve diğer devletlerle ilişkiler kurma ve uluslararası antlaşmalar yapma kapasitesi. Ancak Avustralya Federasyon'un kurulmasıyla son kriteri yerine getirmiş sayılmaz. Aksine dış ve savunma politikası bir süre daha Britanya İmparatorluğu tarafından kontrol edilmeye devam etmiştir. Bu nedenle I. Dünya Savaşı'nda Britanya'nın savaş ilanı Avustralya da dahil olmak üzere tüm İmparatorluğun savaşta olduğu anlamına gelmiştir. Avustralya ancak bu savaş sonrasında uluslararası bir kimlik kazanmaya başlamış ve bağımsızlığı kademeleri bir sürece dayanmıştır (Brooklyn vd., 2022).

Avustralya'nın federasyona geçiş sürecinde Osmanlı İmparatorluğu tarihinin son zamanlarındadır. İmparatorluğun görkemli günleri geride kalmış, fethedilen pek çok toprak kaybedilmiştir. 19. yy.ın sonlarında Tanzimat Fermanı ile meşru hale gelen Batılılaşma hareketi, hilafet ile yönetilen imparatorluğun bürokratik bir batı politikasını benimsemesini kolaylaştırmamış bu nedenle yönetim ve toplumsal yaşamın beklentilerini tam olarak karşılayamamıştır. Devamında Meşrutiyetin ilanı durumu düzeltmek için yeterli olamamış, I. Dünya Savaşı ve iç çatışmalar gibi art arda yaşana kaos ortamı imparatorluğun sonunu getiren dinamikler arasında yer almıştır. Gerek iç gerekse dış ilişkileri stratejik bir yönetimle sürdürecek ciddi bir değişimin gerektiği bu aşamada demokratik Türkiye Cumhuriyeti 1923 yılında kurulmuştur.

Her iki ülke için yönetsel ve toplumsal yaşamı doğrudan etkileyen bu politik kırılma noktaları birbirinden farklı ancak değişimin etkileri yönüyle benzer unsurlar taşımaktadır. Avustralya müzakereler ve referandumlar sonrası yeni bir anayasal düzlemde değişim gerçekleşmiştir. Bu durumu belki de yatay bir değişim olarak tanımlamak mümkündür çünkü ayrı eyaletler tek bir anayasa çerçevesinde ve kendi stratejilerini koruyarak birleşmiştir. Oysa Türkiye monarşiden demokrasiye radikal bir rejim değişikliği ile yeni bir yönetim modeline geçiş yapmıştır. Bu nedenle askeri-siyasi-hukuki bir devrim niteliğindedir. Politik değişimler birbirinden farklıdır ancak değişim her iki ülke için de birtakım etkileri beraberinde getirmiştir.

AVUSTRALYA FEDERASYONU SONRASINDA TİYATRO YAŞAMINDAKİ DEĞİŞİMLER

Federasyon sonrası Avustralya tiyatrosunun en büyük tartışma konularından biri ulusal tiyatro var etme girişimleridir. Ancak burada bir soru ortaya çıkar, Avustralyalı kimdir? Kolonileşmeden önce var olan İlk Milletler mi Avustralyalıdır, yeni Avustralyalılar mı? Ulusal tiyatro Avustralyalılar tarafından gerçekleştirilen tiyatro mudur? Öyle ise Avustralyalı kimdir dediğimiz ilk soruya geri dönmek gerekir ve bir açmaz oluşur. Bu sorunun yanıtı federasyon sonrası açıklanmış ve gerçek Avustralyalılar, Avustralya'da doğmuş beyazlardır denmiştir ancak bu yanıt İlk Milletler'i ve sanatını geçersiz sayar bu nedenle çeşitli camialar tarafından kabul görmemiştir. O halde kolonileşmeye kadar var olan performanslar mı ulusal sanat sayılmalıdır yoksa Avrupa-Amerika etkisinde yeni Avustralyalıların performansı mı ulusal kabul edilmelidir? Göç politikası ve kozmopolit bir Avustralya gözetildiğinde 1900'lerden bu yana göç eden beyaz Avrupalılar, Amerikalılar ya da Asyalı göçmenler düşünüldüğünde Avustralya tiyatrosu nasıl tanımlanabilir? Konu ulusal tiyatro olduğunda sorular artabilir ve buna benzer soruların varlığı tiyatroda sömürgeci ya da Avustralyalı gibi ifadelerin neden tartışıldığına açıklık getirir (Kelly, 1996; Meyrick, 2022, 2024).

Tiyatro hakkında bu tür tartışmalar beraberinde kendini arzu ettiği biçimde temsil edemeyen bir sanat alanını çağrıştırır. Avustralya Aborijinler, beyaz Avustralyalılar ya da sömürgeciler ve Asyalılar çerçevesinde pek çok teatral faaliyete sahiptir ama bunların özgürlüğü ve özgünlüğünün meşru kılınması için uzun bir süreç gerekmiştir. Örneğin ilk koloniler ulaştıktan sonra Aborijin performansları hem beyaz sömürgecilerin isteği üzerine hem de Aborijinlerin varlıklarını temsil etme biçimi olarak duyumsanıp kendi istekleriyle sergiledikleri performanslar olmuştur. Çünkü performans sadece bir gösteri olmaktan öte bir aidiyet ve sahiplik durumlarını da temsil etmektedir (Casey, 2018). Ancak meselenin kökeninde ırkçılık yer aldığında ve İlk Milletlerin sahip olduğu ve sunduğu tüm deneyimler yok sayıldığında performansın algısı değişmeye başlar. (Başlangıçta Aborijinler için söz konusu olan ırkçılık göçlerin artması ve çeşitlenmesi nedeniyle başka etnik kökenlere yönelik örnekler de barındırmaktadır). Bu durumda tiyatronun karşılaştığı en büyük sorunlardan biri de sansür ve otosansür kaçınılmaz bir şekilde konuya dahil olur (Gilbert, 2003). Gerek oyun kişilerinin yaratımı gerekse oyun konuları yerli, beyaz ya da Asyalı oluşlarına göre oyunu etkilemekte; bu durum Avustralya içindeki multikültürel yapıyı, eleştiriyi, sansürü ve tüm bunlara koşut transvestism ve çeşitliliği beraberinde

getirmiştir. Kısacası bu tartışmalar oyun yazarlarının yaratım sürecini doğrudan etkileyen ve belki de problemlerle yüzleşilen ilk riskli alanı da yaratmış olur.

Avustralya tiyatrosu için belki de ilk dönüm noktası federasyondan önce, 1874 yılında yaşanmıştır. Amerikalı tiyatro oyuncusu James Cassius Williamson'ın Avustralya'ya gelerek Melbourne'de *Struck Oil (Petrol Çıkarıldı*) oyununu sahnelemiş ve oldukça fazla bilet satışlarına erişmiştir. Williamson *The Firm* adlı bir tiyatro şirketi kurarak İngiliz sanatçılar W.S. Gilbert ve Arthur Sullivan operetlerinin eser haklarını satın almış, adeta bir tiyatro imparatorluğu kurmuştur. Sanatın ticarileşmesi ve tabi tutulduğu vergiler düşünüldüğünde bu durum önemlidir. Williamson 1913 yılında hayatını kaybetmiş olmasına rağmen The Firm hakimiyeti onlarca yıl devam etmiştir. Yıldız oyuncuların Avustralya'ya gelmesini sağladığı ya da Avustralya içi turne tiyatrosunu arttırdığını da belirtmek gerekir. Federasyonun kabulü ile eyaletler arası seyahatin kolaylaşması da popülerliğini yükselten gerekçelerinden biri sayılabilir. Ancak Williamson'ın başarısı sanatsal olmaktan öte ticari bir başarı olarak kabul edilebilir çünkü müzikli gösteriler ve kendinin de bir komedi oyuncusu olmasından kaynaklanan komik eserler sergilemesi seyirciyi çekmiştir ama İbsen ya da Strindberg gibi Batının değerli sanatçılarının eserlerini ya da Avustralya'nın özgün eserlerini sahnelenmekten kaçınmıştır (Meyrick, 2022; 2024). Bu noktada Avustralya tiyatrosunun federasyon öncesi ve sonrası dönemde bir sömürge tiyatrosu olarak tanımlanması da kaçınılmaz görülür. Öyle ki gerek ulusal oyun var etme çabası gerekse ticari oyunların her zaman federasyonla karşılaştırılması doğru değildir. Avustralya tiyatrosu yaklaşık elli yıllık bir süre boyunca sömürge tiyatrosu kapsamında ele alınabilir ve bu sürecin sona ermesi neredeyse 1930'ları bulmaktadır (Kelly, 1996).

Williamson'ın büyük etkisi yanında 1908 yılında kurulan *Adelaide Repertory Th*eatre, 1911'de kurulan *Melbourne Repertory Company* ve 1922'de kurulan *Pioneer Players* önemlidir ve nitelikli tiyatro eserlerini sahnelemek üzere The Firm'e bir tepki olarak kurulmuşlardır. 1920'lerde Avustralya tiyatro sahnelerinin de oldukça görkemli bir hale geldiğini ve bu sahnelerde gerek Williamson'ın dünya yıldızlarını turne tiyatrosu ile Avustralya'ya getirmesi gerek diğer toplulukların politik tiyatro gösterileri ya da özgün Avustralya oyunlarının sahnelenmesi gibi seçeneklerinin arttığını söylemek mümkündür (Meyrick, 2024).

Federasyon sonrası Williamson etkisinin sona erdiği 1976 yılına kadar diğer tiyatro kuruluşları için rekabetçi ortam oldukça sert geçmiştir denilebilir. Bu süre içerisinde ilk devlet destekli tiyatro kuruluşu 1952 yılında Melbourne'da kurulan *Melbourne Theatre Company* olmuştur. Bugünkü adı *Sydney Theatre Company* olan *Old Tote Theatre Company* ise 1963 yılında kurulmuştur. Devamında 1970'te *Royal Queensland Theatre Company* ve 1972'de *State Theatre Company South Australia* kurulmuştur. Bu topluluklar hem federal hükümet hem de bağlı olduğu eyalet tarafından fonlanan oldukça görkemli kuruluşlar arasındadır. Tarihler 1973'ü gösterdiğinde Danimarkalı mimar Jorn Utzon tarafından tasarlanan Sydney Opera Binası'nın Avustralya'nın hem sanatsal hem de ikonik mimari yapısı olarak açılışı gösterimler ve izleyici deneyimi açısından oldukça kıymetlidir. 1960'lar farklı türlerde gösterimler yapan özel tiyatro topluluklarının kuruluşuyla da dikkat çekicidir. 1968 tarihli Perth'te açılan Hole in the Wall Company, 1970 yılında Sydney'de açılan Nimrod Theatre, 1970'de Melborne'da açılan Australian Performing Group ya da diğer adıyla Pram Factory, 1974 yılında Brisbane'daki Popular Theatre Troupe ve 1976'da Adeliade'da Troupe dikkat çekenler arasındadır. 1958'de ilk tiyatro okulu olan National Institute for Drama Art da Avustralya tiyatrosu açısından önemli girişimlerdir (Meyrick, 2024).

1970'lere gelindiğinde Phillip (1973) tiyatro sanatının toplumun ortak ve anlamlı bir deneyim yaşadığı bir sanat olduğunu vurgulamıştır. Bu ortaklığın ithal oyunlar yerine kendi konularından ve kendi sanatçıları tarafınsan temsil edilmesinin önemini dile getirmiştir. Aynı dönemde Edward Gough Whitlam başbakanlığı ile Avustralyalı oyunların sahnelerde sayıca arttığını ve 1960'larda %14 olan yerli oyun oranının 1980'lerde %43 oranına ulaştığı görülmüştür (Meyrick, 2024). Bu artış oyun yazarlarının motivasyonu açısından önemli olmakla birlikte yanıtı netlik kazanmamış soruları çağırır. Avustralyalı oyun yazarı ifadesinin Avustralya'da doğan yazarlar olarak tanımlandığı koşullar gözetildiğinde halen yerli oyunların yaratıcılarının varlığı ve kimliği açıklık kazanamamıştır.

Avustralya tiyatrosunun federasyon sonrası dikkat çeken etkileri Williamson gibi zaten öncesinde var olan etkenlerin hız kazandığı ve yükseldiği hem de uzun vadede nitelikli tiyatro kuruluşları ve özel

tiyatro etkinlikleri bağlamında değerlendirilebilir. Kritik dönüm noktalarının yer aldığı yaklaşık 1980'lere dek çok sayıda oyun sahnelenmiş ve göç unsurunun etkisiyle Avustralya tiyatrosu giderek multikültürel bir tiyatro anlayışına dönüşmeye başlamıştır.

AVUSTRALYA FEDERASYONU SONRASINDA SAHNELENEN OYUNLARDAN ÖRNEKLER

Avustralyalı bir tiyatro yaratma düşüncesini hayata geçirmek kolay olmamıştır. Dönemin seyirci profili, oyunlara gösterdiği reaksiyonlar, rekabet ortamı ve yasal çerçeveler gözetildiğinde oyun yazarlarının hem kendini temsil etmesi hem de nitelikli eserler üretmesi için zaman ve güçlü bir mücadele ruhu gerekmiştir.

Federasyondan kısa süre sonra 1912'de sahnelenen iki komedi dönemin tiyatro yaşamı konusunda fikir vericidir. Bunlardan biri Steele Rudd tarafından kaleme alına *On Our Selection* 1928'e kadar turne yapan ve neredeyse Avustralya nüfusunun dörtte biri tarafından izlenen bir kırsal yaşam komedisidir. Devlet arazilerinin küçük çiftçilere tahsis edilmesi sonrasında kırsalda çorak bir araziyi işlemeye çalışan Rudd ailesinin hikayesidir. Verimsiz araziyi işleme güçlükleri, felaketler, varlıklı toprak sahipleri ile yaşanan sorunlar ve finalde tüm zorlukların üstesinden gelen ve politikaya atılan bir aileyi anlatır (Rudd, 1973; Meyrick, 2022). Bir diğer oyun ise hiciv diliyle dikkati çeken *The Time Is Not Yet Ripe*'tir. Louis Esson tarafından yazılan oyun ancak birkaç hafta sahnelenebilmiş ve seyircileri profesyonellerden oluşmuştur. Oyun politik bir eleştiri içerir ama aynı zamanda kadın hakları savunuculuğu yapan kadın oyun kişisiyle de dikkat çekicidir. Bir baba, kızı ve nişanlısının politik rakip olduğu süreç hikayenin omurgasını oluşturur. Böylece politikanın toplumsal beklentileri nasıl manipüle ettiği eleştirel bir dille ifade edilmiştir (Esson, 2012). Bu iki oyun şu sebeple önemlidir; bir oyunun çok izlenmesi ve gişe başarısı sağlaması geleceğin tiyatro yaşamını şekillendirme için yeterli bir kriter değildir. Esson'ın oyunu Avustralya'nın ve hatta dünya politik süreçlerinin toplumsal bir yansıması olarak değerlendirilebilir.

Her ne kadar Avustralyalı oyun yazarları The Firm nedeniyle uzunca bir süre ticari oyunların gölgesinde kalmış olsalar da mevcut tabloyu gözlemleyerek neleri yapıp yapmayacaklarını da keşfetmişlerdir (Meyrick, 2022). Federasyon sonrası prodüksiyon kadar oyunların içerikleri de zenginleşmeye başlamıştır. Örneğin Katherine Susannah Prichar tarafından 1927'de kaleme alınan *Brumby Innes* beyaz bir adamın biri beyaz, ikisi Aborijin, üç kadın üzerindeki çekici ama bir o kadar da olumsuz duyguları üzerine örülüdür. Bir Aborijin töreni sırasında Brumby adlı bir erkeğin zorbalık ve tecavüz gibi olumsuzluklarıyla başlayan oyun eleştirel bir nitelik taşıdığı için de önemlidir. Çünkü Brumby'nin zorbalıkları karşısında hem Aborijin kadınları hem de beyaz kadını temsil eden oyun kişisinin çaresizliği benzerlik gösterir. Sadece kadınlar üzerinde değil Aborijinlere karşı vahşeti ve ırkçı tavrın eleştirisi açısından da değerli olan bu oyun Brumby üzerinden tarihsel gerçeklik eleştirisi de yapmaktadır. Bu oyunu özgün yapan diğer özelliği ise yerli oyun kişilerini canlandıran kişilerin *Ngaala-Warngga* adlı bir Aborijin dili kullanmasıdır (Prichard, 1974; Casey, 2007).

Aynı dönemde yazılan *Gallipoli Bill* de tarihsel gerçeklikten hareketle kaleme alınan bir metindir. Arthur Adams'ın oyunu daha sonra düzenlenerek sinema için de bir çıkış noktası olmuştur. Anzak askerlerinin Gelibolu'daki savaş sırasında yaşadıkları iç sıkıntılarını ve savaşın arka planında askerlerin kendi aralarındaki iletişimi işleyen metin 1915 yılının etkilerini dile getirmiştir. Bu örnekler hem ulusal repertuvar oluşturma açısından kıymetlidir hem de tarihe ışık tutması ve nitelikli oyun yazarlığı örnekleri olarak değerlendirilebilir (Meyrick, 2002).

1944 tarihli Douglas Stewart (1963) tarafından kaleme alınan *Ned Kelly* de Avustralya tiyatrosunun önemli metinlerinden biridir. Oyunun baş kişisi olan Kelly bir haydut olarak görülür ama sömürge kültürüne karşı verdiği mücadele ile onurlu bir duruş sergiler. Bir çete hikayesi etrafında şekillenen oyun dış aksiyonuyla değil başından sonuna gelişen ahlaki tavırla dikkati çeker. Yine kırsal oyunlardan biri olarak değerlendirilebilir ve bu oyunun en önemli unsuru kişileştirme yoluyla sorulan sorulardır. Kelly'nin mücadelesi sonunda suç kavramının ve yasalarla belirli adalet anlayışının her zaman doğru ve işler olup olmadığını sorgulaması dönemin tiyatro anlayışı ve geleceğe bıraktığı miras açısından oldukça önemlidir.

Oyun konuları kadar oyun kişileri de Avustralya'ya özgü olmaya başlamıştır. *Brumby Innes* örneği toplumsal cinsiyet eşitsizliğini öne çıkaran kişileştirme unsurları taşır. Bunun nedenlerinden biri kişileştirmede Avustralyalı erkelerin yüceltilmesi olabilir. Bu alışıldık kişileştirme tarzına ek olarak bir başka unsur dikkati çeker ki bu da motivasyon olarak zayıf olan Avustralyalı erkeklerin iç dünyasındaki umutsuzluk ve kalp kırıklıklarıyla yüzleşmesinin kişileştirmenin bir parçası olmasıdır (Meyrick, 2022).

Farklı tür içeriklerden oluşan yukarıdaki örnekler Avustralya tiyatrosunun federasyon sonrası süreçte Avustralya'ya özgü konuları işleme çabasının göstergesidir. Bu süreç hem iç politik dinamiklerin yerleşmeye çalıştığı hem de I. Dünya savaşı gibi dış dinamiklerin etkilerinin yaşadığı bir dönemdir. Her ne kadar ulusal tiyatronun ne olduğu tartışılsa da oyunların dili Avustralyalı, konular coğrafyaya özgü ve tarihsel gerçeklikle ilintilidir. Konular genel olarak kırsal yaşamdan ama konuşma dili gündelik ve gerçekçi hatta kimi oyunlarda yerli dillerin diyalog örgüsünde yer alması önemlidir. Böylece ulusal bir repertuvar oluşturulmaya başlanmıştır ama bu tür oyunlara eşlik eden Avrupalı ve Amerikalı gösterimler, müzikli vodviller de seyirci tarafından oldukça talep görmektedir.

Avustralya repertuvarı derken Kelly (1996) önemli bir noktaya dikkat çeker ve bu Avustralya oyunlarının yazar odaklı Avustralyalı sayılmasıdır. Avustralyalılık üzerine yukarıdaki tartışmalara ek olarak oyunların konularını oluşturan içerik, kişileştirme unsurları ve hikaye ile bu kişilerin birlikteliği de ayrıca önemlidir. Çünkü Avustralya denildiğinde zihinlerde oluşan anlam, izleyenlerin kim olduğu, kültürel hakimiyetleri ve yorumları üzerinde de durulmalıdır. Örneğin yabancı kökenli bir oyun yerel bir probleme, amaca dikkat çekecekse bu oyundan yararlanılabilir. Bununla birlikte yerel bir yazar tarafından tamamen yabancı bir içerik taşıyan oyunlar da yazılabilir. Bir turne tiyatrosunun ırk, inanç, toplumsal cinsiyet eşitsizliği gibi ciddi konularda seyirciyle bağ kurması da Avustralya tiyatrosu için bir çeşitlilik ve zenginlik barındırabilir. Bu nedenlerle yazarın kim olduğu, konunun ne olduğu kadar gösterimin seyirci ile etkileşimi bağlamında da bir nitelik değerlendirmesi yapılabilir. Sadece Avustralyalılık göstergesi için yerel ve milliyetçi unsurlara odaklanmak, daha dar bir çerçevede kalmaya ve küresel tiyatro kültürüne ne ölçüde dahil olunduğunun belirsizleşmesine neden olabilir. Çünkü bir oyunun öznesini beyaz bir erkekle kurgulamak, onu bir yerli ve üstün özelliklerle bezemek aynı zamanda İlk Milletler'in nasıl yerlerinden edildiğini de meşru kılmakla paraleldir. Yine Avustralya'da doğanların sonradan gelen göçmenleri alt etmeleri gibi izleyenlerin dikkatini çekecek konular ya da bu yüceltme sırasında toplumsal cinsiyet eşitliliğinin göz ardı edilmesi oyunların Avustralyalı ama bir o kadar da ticari olduğunu düşündürmektedir. İşte bu nedenle basına da yansıyan ve adeta bir çağrı niteliğinde tartışmalar dikkat çekicidir. Tiyatro camiasının Avustralyalı yazarları popüler ve ticari beklentilerle oyunlar yazmaktan uzaklaşmasını ve gerçekçi, kendi coğrafyasına ve burada yaşayanlara özgü oyunlarla, Esson'ın da oldukça istekli olduğu bir tür halk tiyatrosu düşüncesine yönelmeleri konusunda söylemleri yer almaktadır (Newey vd., 2003). Bu tür tartışmalar göstermektedir ki Avustralya tiyatrosu kendine özgü olmakla birlikte uluslararası platformlarda da varlık gösterebilecek bir güçte ve biçimde inşa edildiğinde ulusal tiyatro tartışmaları anlam kazanabilir.

TÜRKİYE CUMHURİYETİ SONRASINDA TİYATRO YAŞAMINDAKİ DEĞİŞİMLER

Türkiye Cumhuriyeti'nin ilanı ile yönetimde radikal bir değişim olmuş ve bürokrasi, eğitim, sanat, ordu gibi yönetimsel ve toplumsal tüm alanların işleyişine yansımıştır. Cumhuriyet sonrası tiyatro da bu reformlardan etkilenmiştir. Rejim değişikliğinin ilk etkisinin Türk kadının sahneye çıkması olduğu söylenebilir. Osmanlı imparatorluğu döneminde seyirci olması dahi hoş karşılanmayan kadınlar, Atatürk'ün 1923 yılı temmuz ayında Bedia Muvahhit ile bir araya gelmesi sonucu sahneye çıkmaya başlamıştır. Daha önce kadın rollerinde erkek oyuncuların kılık değiştirmesi ya da gayri müslim kadınlar tarafından temsil edildiği düşünüldüğünde bu anlamda İslam inancının hakim olduğu toplumlarda da bir ilk gerçekleşmiştir. İdeolojik etkisi yanı sıra oyun yazarlarının kadın oyun kişilerini yaratımı için de bir konfor alanı yaratmıştır (And, 1983; Tuncay, 2011).

Cumhuriyet Türkiye'sinin yeni ve savaşlardan çıkmış yoksul bir ülke olarak politik bir tutum geliştirmesi ve dünya düzenine uyum sağlaması gerekiyordu. Bu noktada Batının emperyalist yanı eleştiriliyor ama uygarlığın deneyimlerinden de beslenmek gerekiyordu (Akıncı, 2003). Bu amaçla gerek tiyatronun kurumsal yapılanmasında gerekse oyunların yazılması ve sahnelenmesinde modern Batı uygarlığının deneyimlerinden yararlanılmıştır. Yeni düzenin de sanata destek sağlaması bu sürecin

olabildiğince verimli gelişmesini hedeflemiştir. Böylece Cumhuriyet'in ilanından sonra yaklaşık 30-40 yıl içinde kurumsal ve sanatsal üretim bağlamda zorlu ama epey yol alınmıştır.

Cumhuriyetin ilk yıllarında tiyatro etkinlikleri daha çok Meşrutiyet döneminde var olan toplulukların etkinlikleriyle devam etmiştir ancak bu topluluklar tutarlı bir gelişim göstermezler. Bu dönem tiyatro topluluklarının sık sık dağıldığı ve farklı isimlerle birleştiği görülmektedir. *Benliyan Operet Kumpanyası*, *İstanbul Operet Heyeti*, *İstanbul Şehir Opereti* gibi topluluklar örnek verilebilir. Topluluklar İstanbul'un eğlence ve sanatsal etkinliklerin en yoğun sürdürüldüğü kent olduğundan etkinliklerini daha çok bu çevrede gerçekleştir aynı zamanda İzmir Ankara gibi diğer büyük kentlere ya da Anadolu'ya turneye giderlerdi. Repertuvarları genelde hafif içerikte, müzikli oyunlardan ve operetlerden oluşmaktadır. Bunun yanı sıra batının Shakespeare, Strindberg, Ibsen, Moliere gibi büyük yazarların oyunları ve yerli yazarların oyunları da sahneleniyordu. Ayrıca geleneksel tiyatronun yansımaları olan tuluat tiyatrosunun da gösterileri devam etmektedir. Kavuklu Hamdi gibi Ortaoyunu ustalarıyla çalışmış olan *Naşit*, *Şark Tiyatrosu* adı altında etkinliklerini sürdüren Kel Hasan ve kendi adıyla topluluk kuran *İsmail Dümbüllü* tuluat tiyatrosu geleneğini sürdürenler arasındadır. Aslında tüm bu etkinlikler cumhuriyetin ilanından önce de gerçekleşmekteydi ve bu dönemde yeni politik ortamın olumlu atmosferinin yansımaları hissedilmekteydi. Bu topluluklar 1950'lerden sonra *Muammer Karaca Tiyatrosu*, *Dormen Tiyatrosu*, *Kenter Tiyatrosu* gibi daha uzun soluklu ve profesyonel işlerle seyirci karşısına çıkacak topluluklar için de bir başlangıç niteliğindeydi (And, 1983; Şener, 1999).

1914 yılında kurulan *Darülbedayi* esasen tiyatro insanı eğitme amacıyla kurulmuş bir kurumdu ancak beklentiyi karşılayamamış, ödenekli bir tiyatro topluluğu gibi işlev görmeye başlamıştı. Cumhuriyetin ilk yıllarında da devam eden Darülbedayi'de oyunların Batıdan esinlenerek sahnelendiğini bazen de uyarlamalar yapıldığını söylemek mümkündür. Bu nedenle halkın ilgisini çekecek vodvil tarzı oyunlara sıklıkla karşılaşılır. Burada etkinliklerin devam etmesinin önemli olduğu kadar eserlerin genelde zayıf nitelikte olması, hazırlıkların önemsenmemesi ya da derme çatma salonlarda oyunların temsil edilmesi gibi olumsuzluklar da yer almaktadır (Şener, 1999). Cumhuriyetin ilk yıllarında da bocalama dönemi devam eden Darülbedayi 1926-27 sezonunda birçok ülkede tiyatro görgüsünü geliştirmiş Muhsin Ertuğrul'un baş yönetmen olarak atanmasıyla toparlanmaya ve nitelikli oyunlar sahnelemeye başlamıştır. Tiyatro disiplini, bilgi ve deneyimleriyle Muhsin Ertuğrul Cumhuriyet dönemi Türk tiyatrosunda iz bırakan bir isim olmuştur. Muhsin Ertuğrul'un önemle üzerinde durduğu konuların başında yerli oyunlar ve oyun yazarlığının gelişmesi yer almaktadır. Türk tiyatrosunun sağlam temeller üzerinde kurulması ve gelişmesi için salt öykünme yazarlığı değil, kendi kültürümüzün kişiliğini yansıtmasını öngörmüştür. Bununla birlikte yüzeysel Batılılaşmaya karşı çıkmıştır. Kimi çevreler tarafından tiyatronun tek adamı olma ve onun işini devralacak nesiller yetiştirmeyişi nedeniyle eleştirilse de Ertuğrul'un katkıları ve başarıları yadsınamaz. Darülbedayi 1934 yılında *Şehir Tiyatroları* adını alarak devlet tarafından fonlanan kurumsal bir tiyatro olarak çalışmalarını sürdürmüştür. Her sezon yerli yazarların oyunlarının sahnelenme sayısı giderek artmış, uyarlamalar azalmıştır. Böylece oyun yazarları için de bir motivasyon sağlamıştır (And, 1983; Nutku, 2015).

Anadolu'nun tiyatro tarihi çok eski olmasına rağmen hem metinsiz performanslar hem de kurumsal yapının yerleşmesi Cumhuriyet sonrası gerçekleşmiştir. Osmanlı İmparatorluğu döneminde sürekliliği sağlanamayan birkaç girişim bu dönemde düzenli bir işleyiş kazanmıştır. Darülbedayi'nin nitelikli oyunlar sahnelemesi ve 1934'te *Şehir Tiyatroları*na dönüşmesi, 1932'de *Halkevleri*'nin ve 1940'ta *Köy Enstitüleri*'nin kuruluşu bu kurumsal etkileşimlerin birer basamağıdır. Halkevleri ve Köy Enstitüleri eğitim odağında yapılanmalar olsa da dönemin tiyatro etkinlikleri ve seyirci ile etkileşim yaratma noktasında önemlidir. 1936 yılında Carl Ebert'in davet edilmesiyle *Devlet Konservatuvarı*'nın kuruluşu ile tiyatro eğitiminin devlet eliyle nitelik kazanması ve devamında 1949'da *Devlet Tiyatroları*na dönüşümü halen varlığını güçlü bir şekilde sürdüren zemini oluşturmaktadır. Böylece hem Batının büyük oyunlarının hem de yerli yazarların oyunlarının sahnelenmesi için kurumsal alanlar zenginleşmiştir. İlerleyen zamanlarda Ankara Üniversitesi ile tiyatro eğitimi üniversite düzeyinde eğitimin bir parçası olmuştur. Tüm bunlar Avrupa uygarlıklarından esinlenilen etkiler arasındadır. Çünkü yeni kurulan devletin aydın ve modern bir toplum yetiştirme gayesi tarih boyunca var olan tiyatronun bu amaçlar için yararlanılmasıyla birleşmiştir (Konur 2001; Şener, 1999). Bu girişimlerin pek çoğu tek partili dönemde başlamış olup çok partili döneme geçildikten sonra 1950'li yıllarda Halkevleri ve Köy Enstitüleri kapatılmıştır. Yani Türkiye'nin tiyatro etkinlikleri hem radikal rejim değişikliğinden

hem de iç politik dinamiklerinden her zaman doğrudan etkilenmiştir. Özdemir Nutku (2008) bu hareketliliği cumhuriyetin ilk yıllarında yaşanan bir bocalama döneminin yerini bilinçlenmeye bıraktığı şeklinde açıklar. Nitelikli tiyatro insanı yetiştirmek ve gösteriler sahnelemek için, tiyatronun benimsenmesi için oldukça çaba sarf edilmiş, çeşitli girişimlerde bulunulmuştur. Ancak bu ilgi zamanla azalmış ve kurumsal yapıya da yansıyan bir gevşemeye neden olmuştur. Tiyatro iniş çıkışlarla, parlak dönemleri ve sorunlarıyla halen tartışmalar devam etmektedir.

Türk tiyatrosunda oyunlar cumhuriyetten önce de sonrasında da kategorize edilmiş, birbirine benzer gruplandırmalar yapılmıştır. Trajik oyunlar, melodramlar, müzikli oyunlar gibi sınıflandırmalar yapılsa da yerli yazarların artık konuya odaklandığı bilinir (And,1983). Cumhuriyetin ilanından sonraki yaklaşık 15 yıllık sürede yazılan oyunlarla ilerleyen dönemlerde yazılan oyunlar arasında içerik ve oyun dili bağlamında farklılıklar dikkati çeker. Çünkü bu ilk dönem politik olduğu kadar toplumsal yaşantının da değiştiği dönemdir. Bu nedenle oyunların karakter, olay dizisi, diyalog örgüsü gibi dramatik unsurlar açısından aksadığı ve sözlü anlatıma odaklanan oyunlar bulunmaktadır (Şener, 1971). Bu sınıflandırmada Şener'in (1993) ülkücü oyunlar olarak da bahsettiği inkılap temsilleri sayılabilir. İnkılap temsilleri edebi açıdan zayıf, her farklı oyun adeta aynı yazar tarafından yazılmış gibi görünür. Temel amacı yeni reformları, cumhuriyetin devrimlerini topluma anlatmak, önceki dönemin aksaklıklarını görünür kılmaktır. Günlük yaşamdan içerikleriyle de dikkati çeken bu oyunların eleştirel bir yanı teatral işlevi olmuştur. Sanatı güdümleme olarak değerlendirilen bu tavır tiyatronun yönetimin hizmetine girmesi olarak değerlendirilebilir. Yönetimin de isteğiyle yazılan bu oyunlar için zorlu savaş ve sansür dönemlerini yaşayan kimi oyun yazarlarının büyük bir isteklilikle gönüllü olduğu bilinir. Yaşar Nabi tarafından kaleme alınan *İnkılap Çocukları*, Hayri Muhitttin'in *Gazi Mustafa Kemal*'i ve Faruk Nafiz Çamlıbeli'in *Akın*'ı inkılap temsillerinin örnekleri arasındadır (Boyacıoğlu,1992).

1945 yılı itibariyle tek partili cumhuriyet dönemi çok partili döneme geçiş yapmıştır. Bu değişim politik kulvarlar kadar toplumsal yaşamda ve sanatta da etkili olmuştur. Bir yanda ekonomik sorunlar diğer yanda kırsal bölgelerde yaşayan halkın da kendini değerli hissetme ihtiyacı partili olma isteğini tetiklemiş, böylece bir gruba dahil olarak kendini güvende hissedeceği bir ortamda duyumsamasına kapı açmıştır. Çok sesliliğin toplumsal gelişim açısından kıymetli olduğu görüşüne koşut Türkiye'nin geçirdiği politik, ekonomik, askeri ve kültürel yıpranma süreçleri gözetildiğinde bu geçişin niteliği tartışmaya açıktır. Türk tiyatrosunun kaçınılmaz ekonomik problemleri ve özel tiyatroların oyun sahnelemek için özverili tutkuları, oyun yazarlarının sansür ve oto sansür sorunlarıyla mücadele etmeleri genel sorunlar arasındadır. Ancak 1960'lı yıllar politik eleştirel, köy yaşamı, aile içi dinamikler, ekonomik problemler, kimlik arayışı gibi pek çok konu çeşitliliğini yansıtan oyunların teatral bir üslupla üretildiği ve Türk tiyatrosunun altın çağı denilen döneme kadar oyunların içeriği ve dramatik yapısı eleştiriye açıktır (Belkıs, 2003, 2010). Nitelikli oyunları tenzih ederek günümüzde de aynı tartışmaların geçerliliğini kabul etmek gerekir.

TÜRKİYE CUMHURİYETİ SONRASINDA SAHNELENEN OYUNLARDAN ÖRNEKLER

Böyle bir politik ortamda üretilen oyunlardan birkaç örnek cumhuriyetle birlikte var olan tiyatro etkinliklerini anlamak açısından yerinde olacaktır. Bu oyunlardan biri Meşrutiyet dönemi yazarlarından olan Müsahipzade Celal'in 1929 yılında yazdığı *Bir Kavuk Devrildi*'dir. Osmanlı imparatorluğu'nun son dönemlerine eleştirel bir üslupla yaklaşan metin bürokrasinin yozlaşması ve liyakatsizliğin eleştirisi üzerine kurulu bir komedidir. Birbirine açık iki gençten hareketle gelişen olaylar akıcı bir oyun diline sahiptir. Kavuk, yanlış işleyen bürokrasinin simgesi gibi oyun sonunda devrilir. Hem yanlış işleyişin yıkılması hem de aşıkların bir araya gelmesiyle oyun mutlu sonla biter (Musahipzade Celal, 1936).

Bir diğer örnek inkılap temsilleri arasında yer alan Faruk Nafiz Çamlıbel'in 1932 tarihli *Akın* oyunudur. Türk tiyatrosunun tarihi olaylar, söylencelerden hareketle üretilmiş birçok oyunundan biri olan *Akın* Türklerin göçebe tarihinden bir kurguyu içerir. Yazılış amacı da Türklüğü övmek olan oyunda İslamiyet öncesi dönemde İstemi Han liderliğinde yaşayan topluluğun baş edemediği bir kıtlık döneminde ya göç etmeleri ya da gelenekler gereği hükümdarın kendinin tanrılara kurban edilmesine izin vermesi gerekecektir. İstemi Han'ın yerine geçmek isteyen rakipleri ve planları oyunun gelişimine katkı sağlamaktadır. Bu çerçevede adil bir yönetici olan hakanın sevenlerinin ve ailesinin desteğiyle onu ortadan kaldırmaya yönelik planlar suya düşer ve göç kararı verilir (Çamlıbel, 2012).

Hüseyin Rahmi Gürpınar'ın 1933 yılında yazdığı *Kadın Erkekleşince* adlı oyunu hem toplumsal cinsiyet eşitsizliği hem de dönemin içinde bulunduğu toplumsal çatışmayı yansıtması açısından önemlidir. Geleneksel bir ailenin oğluyla evlenen genç kız çalışma yaşamında var olmak istediği ve ailenin öngördüğü ahlak kurallarının dışında davrandığı için kabul edilmemiş ve genç çift anne tarafından dışlanmıştır. Zamanla bir çocuk sahibi olan çift, ikisi de çalıştığı için çocuğa sırayla bakmayı planlar ancak içinde bulundukları bunalımlar büyük bir felaket getirecek küçük bebeğin kaybıyla oyun sona erecektir (Gürpınar, 1974). Geleneksel yaşamın modernizmle karşı karşıya kalması, oyun kişilerinin anlayışsızlıkları bu geçiş döneminin toplumsal yansımalarını gösterirken kadının çalışma yaşamında var olma tutkusunun çocuğunun ölümüne neden olacak olayları tetiklemesi biçiminde verilmesi feminist eleştirel yaklaşımların odaklandığı oyunlardan biri haline getirmiştir.

Dönemin ahlak anlayışı üzerine bir başka eleştirel oyun Cevat Fehmi Başkut tarafından l 948'de kaleme alına *Paydos*'tur. Ekonomik sorunlarla baş edemeyen kırsal bölge insanının haksız zenginleşme arzusuyla ahlaki değerlerini yok saymaları oyunun temel konusudur. Türk tiyatrosuna çok sayıda oyun kazandırmış olan Başkut, erdemli bir köy öğretmeninin ekonomik yetersizlikler karşısında ailesinin ve çevresindekilerin baskılarıyla bakkallığa soyunması ve insanların gerçek yüzüyle yüzleşmesini konu eder (Başkut, 1976). Türkiye her ne kadar II. Dünya savaşına katılmadıysa da dönemin kaosundan etkilenmiştir. Hem kuruluşundan bu yana verdiği mücadele hem de giderek yoksullaşma ve ekonominin el değiştirmesi gibi sorunlar toplumu adeta ahlak ve insanlık sınavına tutmuştur. Ancak pek çok oyunda erdemli davranışların istismar kurbanı olan oyun kişilerince felakete sürüklendiği örnekler toplumsal yaşamın yozlaşmasını gözler önüne serer.

Son olarak Turgut Özakman tarafından 1957'de yazılan *Duvarların Ötesi* suç ve suçlu kavramlarını sorgulatan içeriği ile dikkati çeker. Hapishaneden kaçan dört mahkum ve rehin aldıkları öğretmen kadın çerçevesinde gelişen oyun bir yandan mahkumların yaşamdan kopmuş tavırları, kabalıkları ve cehaletleriyle öte yandan öğretmen tarafından anlaşılmanın yeniden ortaya çıkardığı insani yanlarıyla gelişir. Öfke, acıma, bağ kurma gibi duygularla yaratılan çelişki polisler tarafından kuşatılan mahkumların kurtuluş şansı olmayışına olan inançları ve trajik sonlarıyla biter (Özakman, 2000). Türk tiyatrosunun uzunca bir süre karakterlerin psikolojik boyutunu yaratmadaki eleştirel bakışı kıran metinlerden biri olan duvarların ötesi insanın yokluk ve cehalet kurbanı olabildiğini, yaşama tutunmak için olumlu ilişkilerin kıymetini ve bazen de hataların geri dönüşü olmayan yollara sürüklediğini gösteren metinlerden biridir.

Daha çok Tanzimat ve Meşrutiyet oyunlarında zaman zaman düzyazı gibi akıcı bir diyalog örgüsüne sahip olamayışı sorunu Cumhuriyet sonrası ilk yıllarda aşılmaya başlanmıştır. Genel olarak gündelik ve akıcı bir oyun dili dikkati çeker. Elbette tiyatronun aynı zamanda öğreticiliğinden yararlanmak için idealize edilmiş konuşma kalıplarıyla karşılaşmak da mümkündür. Genel olarak oyun dilinin Türk toplumuna uygun bir akış yakaladığını söylemek mümkündür.

Oyunlar biçim olarak batı tarzında sahne ve perdelerle ayrılmış yazılı bir metin anlayışı artık benimsenmiştir. Buna koşut konuların seçiminde yerel olmaya özen gösterilmiş, ülkenin içinde bulunduğu politik ortam, aile ve mahalle yaşamı gibi gündelik yaşamın yansımaları, geleneksel yaşantıların değişim karşısındaki direnci gibi coğrafyanın hissettiği konular işlenmeye başlanmıştır. Özellikle çok partili döneme geçildikten sonra politik sansüre maruz kalmamak adına oyunların içeriğinin geçmiş tarihlerden, halk masallarından, efsanelerden oluşturulduğu görülür. Genel olarak köyden kente toplumun tüm katmanlarının oyunların konusunu oluşturduğu görülür. Ancak kişileştirme konusu uzun süre tartışılmış ve psikolojik boyutu yetersiz bulunmuş, zamanla bu alanda da ustalaşmış eserler artmaya başlamıştır (Şener, 1999). Her ne kadar konusu Türkiye ile özdeşleşmiş, oyun kişileri konuyla uyumlu kişileştirme unsurları barındırmış metinler üretilmişse de ulusal tiyatro yaratma tartışmaları 1970'lerde dahi tartışılan konulardan olmuştur. Türk tiyatrosunu ulusal bir tiyatro olarak temsil etmek için gereksinimleri bilinmekte, çözümler önerilmekte ancak uluslararası platformlarda kendine özgü bir belirginlik gösteremeyişi uzunca bir süre tartışmaları sürdürmüştür.

SONUÇ

Avustralya ve Türkiye arasında politik kırılma anlarının tiyatro etkileşiminin incelendiği bu araştırmada ilk değinilmesi gereken nokta rejim değişikliğindeki farklılıklardır. Avustralya yerli halka sahip olan bir

kıta ülkesi iken İngiltere sömürgesinde altı bağımsız eyalete dönüşmüştür. Devamında diğer ülkelerden de göç almış ve sonunda eyaletler birleşmesiyle Avustralya Federasyonu kurulmuştur. Bu süreç yerli halkın aleyhine işlemiş, onlarla birlikte çok kültürlü bir kıta ülkesi olarak yeni bir anayasal düzenleme ile ülke olarak meşru kimliğini duyurmuştur. Türkiye ise çoklukla Anadolu toprakları üzerinde kurulu, Osmanlı İmparatorluğu yönetiminin kötüye gitmesi ve savaşlar sonrasında aynı coğrafyada aynı toplumla radikal bir rejim değişikliğine gitmiş, hilafetten demokratik cumhuriyete geçmiştir. Her iki coğrafyanın halkları bu değişimden etkilenirken Avustralya yerli halkları dönüşüm sırasında zarar görmüş, Türkiye'de ise tüm halk birlikte mücadele etmiş ve yeni dönemi birlikte karşılamıştır. İlerleyen takvim Avustralya'yı bağımsız ve dünyanın dört bir yanından göç alan, ekonomik olarak güçlü bir devlete dönüştürürken Türkiye iç politik dinamiklerden de çokça etkilenen ve uzunca bir süre yoksullukla mücadele eden bir ekonomik gelişim sergilemiştir. Dolayısıyla bu etkenler her iki ülkenin tiyatro yaşamını etkilemiştir.

Her iki ülkenin ulusal tiyatro yaratma çalışmaları kayda değer önem taşır. Avustralya bu konuyu İlk Milletler, yeni Avustralyalılar ve Asyalılar üzerinden tartışır, Avustralyalılık kavramı öne çıkar. Türkiye'de aynı konu Ortaoyunu gibi geleneksel türlerden beslenmek ya da Batı tarzı tiyatroyu benimsemek arasında gelişir.

Avustralya tiyatrosu için kadın sorunu, toplumsal cinsiyet konularının oyunlara dahil edilmesi noktasındadır ve buradaki gelişim tıpkı Aborijinlerin oyunlara dahil edilmesiyle neredeyse paralel gelişmiştir. Bu süreç kendi coğrafyası için geç, Türkiye ile kıyaslandığında daha erken bir gelişim sayılabilir. Çünkü Müslüman Türk kadının sahneye çıkması ancak cumhuriyet ile başlayabilmiş, toplumsal cinsiyet konularının işlenmesi daha çok geleneksel ve modern çatışmaları altında gelişim göstermeye başlamıştır.

Özel tiyatro toplulukları her iki ülke için de politik değişimlerden önce ve sonra aktif bir şekilde etkinliklerini sürdürmeye çabalar. Avustralyalı topluluklar Williamson ve ticari yaptırımlarla uğraşırken Türkiye'deki toplulukların ekonomik problemleri ve süreklilik sorunları öne çıkar. Ancak kurumsallaşma sürecine bakıldığında Avustralya'da ilk devlet fonuyla varlık gösteren resmi kurum 1952 yılında hayata geçmişken Türkiye'de cumhuriyetin kuruluşu sırasında var olan kurumsal tiyatrosu devam eder. 1934 yılında isim değişikliğine gidilir ve 1949 yılında da Devlet Tiyatroları kurulur. Kısacası Avustralya kurumsal tiyatrosunu federasyonun kuruluşundan yaklaşık elli yıl sonra sağlamıştır. Türkiye'de ise cumhuriyetin ilanından yaklaşık 25 yıl sonra kent ve kırsalda çok sayıda kurumsal yapılanmaya erişildiği söylenebilir.

Meyrick (2022) Avustralya tiyatrosunun gelişimini diğer ülkelerle karşılaştırıldığında kısmi, kırılgan ve tereddütlü olarak değerlendirir. Türk tiyatrosu için de aynı sözleri etmek mümkündür. Çünkü Avustralya tiyatrosu federasyon sonrası dönemde klasik Batı tarzı bir gelişim göstermiş, oyunların konuları, kişileştirmesi ve diyalog örgüsünün kendine özgü olması hedeflenmiştir. Aynı durum Türk tiyatrosunda da görülür. Cumhuriyet sonrası tiyatro Batı'daki gelişmelerden etkilenerek gelişmiş yine dramatik unsurlarının yerel olmasına özen gösterilmiştir. Bu bağlamda her iki ülkenin gelişimi ve eserlerden örnekler arasında birbiri ile benzerlik kurmak mümkündür. Ama buna koşut her iki ülke de uzunca süre ulusal tiyatro yaratma çabalarıyla gündemde kalmıştır.

Araştırma sırasında her iki ülkenin rejim değişikliğinden sonraki yaklaşık 30 yıllık sürede kaleme alınan oyunlarından örnekler verilmiştir. Bu örnekler irdelendiğinde suç ve suçlu kavramlarının tartışılması noktasında ve ahlaki olanın ne olduğu sorusuna yanıtlar arayan Ned Kelly ve Duvarların Ötesi oyunları aslında benzerlik kurulabilir. Yine tarihsel gerçeklik bağlamında Gallipoi Bill ve Akın oyunları arasında bağ kurmak mümkündür. Gallipoi Bill Anzak askerlerinin Çanakkale'de savaşa dahil olmaşarını ve iç dünyalarını, Akın ise Türklük olgusunu yüceltme amacıyla yazılan tarihsel oyunlardan biridir. Akın İnkılap Temsilleri denilen ve yönetimin isteği üzerine toplumda coşkulu duygular yaratmak üzere kaleme alınmıştır ancak Avustralya tiyatrosu da gerek savaş döneminde gerekse Britanya'ya sadakatini hissettirme noktasında tiyatrodan yararlanmıştır. Dolayısıyla tiyatro hem iktidar eleştirisiyle hem de iktidara hizmetiyle anılan bir sanat durumundadır.

Brumbery Innes barbar bir beyaz erkek ve kadınlarla olan ilişkisini irdelerken aynı zamanda yeni Avustralyalılar ve yerli halklar arasındaki çatışmayı da gözler önüne serer. Hem sömürge düzeni hem

de toplumsal cinsiyet eşitsizliği eleştirilir ve ilk feminist oyunlardan biri olarak örnek verilebilir. Kadın Erkekleşince oyununa bakıldığında ise eski ve yeni yani geleneksel ve modern arasındaki çatışma öne çıkarılır ve aslında ne gelenek ne de çağdaşlık övülür. Aşırıya kaçan her ideolojinin kendi durumu içerisinde felaket getireceği anlaşılır. Ancak bu oyun kadının ekonomik özgürlüğünü elde etmek amacıyla toplumda kendini gerçekleştiren bir birey olma arzusunu çocuğunun ölümü gibi bir finalle cezalandırmaktadır. Böylece yazarın kadınların bu tür girişimlerde ısrarcı olmaması gerektiğine dair bir görüş savunduğu düşünülebilir. Bu bağlamda Brumby Innes ilk feminist örneklerden sayılırken Kadın Erkekleşince antifeminist bir üslup barındırmaktadır.

On Our Selection ile benzer oyunlar daha çok 1960'lardan sonra Türk tiyatrosunda görülür ancak hem bu oyunla hem de The Time Is Not Ripe politik eleştirel içeriği ile Bir Kavuk Devrildi ve Paydos oyunlarıyla karşılaştırılabilir. Bir Kavuk Devrildi de iki Avustralya oyunu gibi komedi yoluyla eleştirisini gerçekleştirir. Özellikle The Time İs Not Ripe ile karşılaştırıldığında politik gücü elde tutma arzusunun insanları nasıl dönüştürdüğünü vurgulaması bağlamında benzerlik dikkati çeker. Paydos'taki var olma çabasıyla On Our Selection'daki var olma çabası arasında da ilişki kurmak mümkündür. Her iki oyun da yokluktan çıkış arama için çaba sarf eden kişilerle gelişir ancak Paydos acı gerçeği görünür kılarken On Our Selection mizahi bir bakış açısıyla sisteme dahil olma sürecini gösterir.

Bu karşılaştırmalar sonunda her iki ülkenin de kendine özgü teatral bir üslup yakaladığı ama yine her ikisinin de uluslararası platformlarda özgün bir temsil alanında parlamadığı görülür. Oysa dramatik unsurları kurallarıyla yerine getiren bu metinlerde ulusal, özel bir dokunuş beklenmiştir. Avustralya'da bu beklenti yazarın Avustralyalı olması ile nispeten çözülse de pek çokları halen Avustralyalı olmanın nasıl olduğu sorusunun ikna edici bir yanıtı olmadığını belirtir. Türk tiyatrosu ise zaten yazarları hep aynı coğrafyanın sanatçısı olduğundan tartışmalarını daha çok doğaçlama, tiplemeler ve güldürü üzerine kurulu geleneksel türlere dönülmesi gerektiği, Ortaoyunu gibi geleneksel türlerden esinlenerek özgünlüğün yakalanabileceğini savunmuştur. Günümüzde de her iki ülkede oyunlar çağın gereklerine uyum sağlayan biçim ve içerikte, sahneleme teknikleriyle oldukça başarılı gösterimler ortaya koyabilmektedir.

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THE BIOGRAPHER'S BURDEN: SUBJUGATION OF THE FEMALE SUBJECT IN CAROL SHIELDS' *MARY SWANN*

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ABSTRACT

This article examines the inner conflicts and struggles of a male biographer during the process of writing the lives of the well-known literary figures in Carol Shields' *Mary Swann*. As a prominent biographer, Morton Jimroy delves into the lives of deceased male literary figures, yet these efforts mostly result in emotional exhaustion and disappointment. By collecting the very few remaining fragments, he specifically chooses to narrate the life of Mary Swann, an obscure female poet who became famous several years after her tragic death. However, as his biographical work progresses, he develops an ambivalent love and hate relationship with his subject, reducing Mary Swann first to an object and then an abject status by discrediting and misinterpreting her authenticity and subjectivity. The biographer becomes increasingly frustrated and challenged by the enigmatic female poet's elusive territory, biographical greyness, and creativity. He nurtures a sense of distaste and hostility, underpinned by a subtle misogyny. This study posits that the biographer's frustrations stem from his drive to attain hegemony and profound crisis of masculine authority over the text; consequently, he seeks to reclaim dominance over the dead female poet through fabricating a life narrative. Subsequently, the study reveals how his subtle misogyny and narrative skill attempt to discredit Swann's subjectivity by means of subjugation and manipulation of biographical truth.

Keywords: Carol Shields, Mary Swann, Masculine Authority, Subjugation, Biography Writing.

THE EFFECT OF PERCEPTIONS TOWARD AUGMENTED REALITY ON PURCHASE INTENTION IN PAKISTAN: THE MEDIATING ROLE OF CONSUMER ATTITUDE

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ABSTRACT

This study aims to investigate the effect of consumers perceptions of augmented reality (AR) on purchase intention in Pakistan, using consumer attitude as a mediating variable. In terms of online shopping, augmented reality has arisen as an interactive technology that allows consumers to have an immersive view of the product and provides information inside a real-world environment, enhancing the online shopping experience and assisting with product evaluation before making a purchase decision. This study, which is based on the Technology Acceptance Model (TAM), is concerned with two mainly perceptual factors: Perceived usefulness (PU) and Perceived ease of use (PEOU). Perceived usefulness refers to consumers belief that buying experience can be improved by augmented reality, while perceived ease of use shows their perception that augmented reality is simple and easy to use. The study views consumer attitude toward augmented reality as a mediating psychological process through which these perceptions influences purchasing decision of consumers. Data collection and analysis were done through data from 389 customers residing in Pakistan and involved in online shopping. Online survey methodology was used to collect data, which were later analyzed via SPSS (Statistical Package for the Social Sciences) and Smart PLS-SEM (Partial Least Squares Structural Equation Modeling). SPSS was utilized in conducting descriptive analysis and demographics, Smart PLS-SEM served the purpose of examining the measurement model and structural model. Reliability and validity of the measurement model were tested by calculating factor loadings, Cronbach's alpha, composite reliability, average variance extracted, and discriminant validity, respectively. Moreover, the structural model was analyzed in order to examine direct impacts of perceived usefulness, perceived ease of use, consumer attitude and purchase intention, and mediation role of consumer attitude. A statistically significant indirect effect was observed, indicating that consumer attitude mediates the relationship between perceived usefulness and purchase intention. This study makes contribution to emerging literature on AR technologies and its impact on consumer decision making process through addressing consumer perception of AR. The findings are useful for marketing managers in online business and companies, as the results of the study show the influence of consumer perception toward AR on their attitudes and purchase decisions.

Keywords: Augmented Reality, TAM Model, Consumer Attitude, Purchase Intention, Online Shopping.

EXPLAINABLE ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE HYDROGEN STORAGE MATERIALS

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ABSTRACT

Hydrogen is one of the most promising clean energy carriers to fulfill the global sustainability targets. Nonetheless, the design of effective, safe, high-Scapacity hydrogen storage materials remains a significant challenge for scientists owing to the complex interplay of the structural, thermodynamic, and electronic features of materials. Conventional experimental and computational strategies are often expensive and tedious, creating an obstacle for a large exploration of possible candidate materials. Specifically, this study aims at the application of Explainable Artificial Intelligence (XAI) for predictive modeling and design of sustainable hydrogen storage materials. Various machine learning models are implemented to examine and assess key material descriptors that affect hydrogen storage performance indicators like storage capacity, stability, and adsorption energy. Apart from being very effective for predicting hydrogen interactions, the proposed framework is interpretable to extract the most significant physical and chemical characteristics influencing hydrogen interaction mechanisms.

The method combines materials informatics, feature engineering, and explainable machine learning methods to enhance scientific insight and transparency. The framework's ability to marry predictive accuracy and model interpretability facilitates better-informed decision-making when investigating next-generation hydrogen storage materials.

The method also facilitates experimentation cost-savings by further optimizing the candidate materials for validation. These findings illustrate that explainable AI can markedly speed up materials discovery, while preserving trust, robustness and scientific interpretability.

This proposed work demonstrates the promise of synergizing artificial intelligence with materials science in promoting sustainable energy technologies and in formulating data-driven frameworks for hydrogen energy systems.

Keywords: Explainable Artificial Intelligence, Hydrogen Storage Materials, Machine Learning, Materials Informatics, Sustainable Energy, Predictive Modeling.

REHABILITATION FOR ADOLESCENT IDIOPATHIC SCOLIOSIS DURING GROWTH

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ABSTRACT

Adolescent Idiopathic Scoliosis (AIS) affects 2-3% of the general population and requires effective intervention strategies to prevent progression. This retrospective study evaluated the effectiveness of Physiotherapeutic Scoliosis Specific Exercises-Schroth (PSSE-Schroth) compared to general or no exercises in 30 adolescents with AIS. Participants were divided into two groups: PSSE group (n=15) receiving scoliosis-specific exercises, and control group (n=15) receiving non-specific or no exercises. Inclusion criteria included Cobb angle 15-25°, Risser 0-2, and Angle of Trunk Rotation (ATR) >5°. Outcome measures included Cobb Angle and ATR stability, defined as <5° change and <2-3° change respectively, assessed over a 16-month follow-up period. Paired t-test ($p < 0.05$) and Cohen's d effect size calculations were performed. Results demonstrated that the PSSE-Schroth group showed significant stabilization with mean Cobb angle improvement ($t=1.88$, $p=0.081$, $d=0.485$) and ATR reduction ($t=3.06$, $p=0.009$, $d=0.789$). In contrast, the control group exhibited worsening with Cobb angle progression ($t=5.52$, $p<0.001$, $d=1.424$) and ATR deterioration ($t=-6.58$, $p<0.001$, $d=-1.698$). PSSE-Schroth proved to be a safe, non-invasive, and effective approach for stabilizing AIS curves between 15-25°, supporting its integration into clinical practice for AIS management.

Keywords: Physiotherapy,Adolescent Idiopathic Scoliosis,Physiotherapeutic Scoliosis Specific Exercises,Growth

INTRODUCTION

Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional spinal deformity that affects 2-3% of the general population, predominantly during the adolescent growth spurt. The condition presents significant challenges in clinical management, requiring early detection and appropriate intervention to prevent progression. Current treatment options include observation, physiotherapy, and bracing, depending on the severity of the curve and skeletal maturity of the patient.

Physiotherapeutic Scoliosis Specific Exercises-Schroth (PSSE-Schroth) represents an advanced, evidence-based approach for three-dimensional correction and spinal stability in AIS patients. This method focuses on postural correction, breathing techniques, and muscle strengthening tailored to the specific curve pattern. The Schroth method classifies scoliosis curves into distinct types (3C, 4C, N3N4, SL/STL) with positive and negative variations, allowing for individualized treatment protocols.

Despite the growing body of literature supporting the effectiveness of scoliosis-specific exercises, there remains a need for comparative studies evaluating their effectiveness against general exercises or observation. This study aims to evaluate the effectiveness of PSSE-Schroth in preventing progression and maintaining stability in adolescents with mild to moderate idiopathic scoliosis curves.

MATERIALS AND METHODS

Study Design and Participants

This retrospective study analyzed data from a prospective database including 30 adolescents diagnosed with AIS. Participants were divided into two groups:

PSSE group (n=15): Received scoliosis-specific exercises based on the Schroth method

Control group (n=15): Received non-specific exercises or no structured exercise intervention (Table 1)

Inclusion Criteria

Patients were included if they met the following criteria:

Cobb angle between 15° and 25°

Risser sign 0-2 (indicating skeletal immaturity)

Angle of Trunk Rotation (ATR) > 5°

Age range: 12-14 years

Outcome Measures

Primary outcome measures included:

Cobb Angle: Measured on standing posteroanterior radiographs. Stability was defined as <5° change from baseline.

Angle of Trunk Rotation (ATR): Assessed using scoliometer during forward bending test in both standing and seated positions. Stability was defined as <2-3° change.

Clinical assessments were performed at baseline and after a 16-month follow-up period. Digital photography and radiographic imaging were utilized for documentation and measurement purposes.

Statistical Analysis

Data were analyzed using paired t-tests to compare pre- and post-intervention measurements within each group. Statistical significance was set at $p < 0.05$. Effect sizes were calculated using Cohen's d, where values of 0.2, 0.5, and 0.8 represent small, medium, and large effects respectively.

Hypothesis

$$t = \Sigma d / \sqrt{[(n\Sigma d^2 - (\Sigma d)^2) / (n-1)]} \quad (1)$$

Where d is the difference between paired scores, Σd is the sum of differences, and n is the number of pairs.

$$d = (M_1 - M_2) / SD_{poole_d} \quad (2)$$

Where M_1 and M_2 are the means of the two groups and SD_{poole_d} is the pooled standard deviation.

The study hypothesized that PSSE-Schroth would demonstrate significant improvement compared to general exercises in:

Preventing progression of AIS

Maintaining spinal stability

Tables and Figures

Table 1. Demographic Characteristics and Clinical Outcomes Comparison between PSSE and Control Groups

Measure	Group	Sex (F/M)	Age (F/M)	Statistic	p-value	Effect Size
Cobb angle	PSSE	F:80%, M:20%	F:13, M:12.7	1.88	0.081	0.485
Cobb angle	Control	F:66.7%, M:33.3%	F:13.2, M:13.4	-5.52	<0.001	-1.424
ATR	PSSE	F:80%, M:20%	F:13, M:12.7	3.06	0.009	0.789
ATR	Control	F:66.7%, M:33.3%	F:13.2, M:13.4	-6.58	<0.001	-1.698

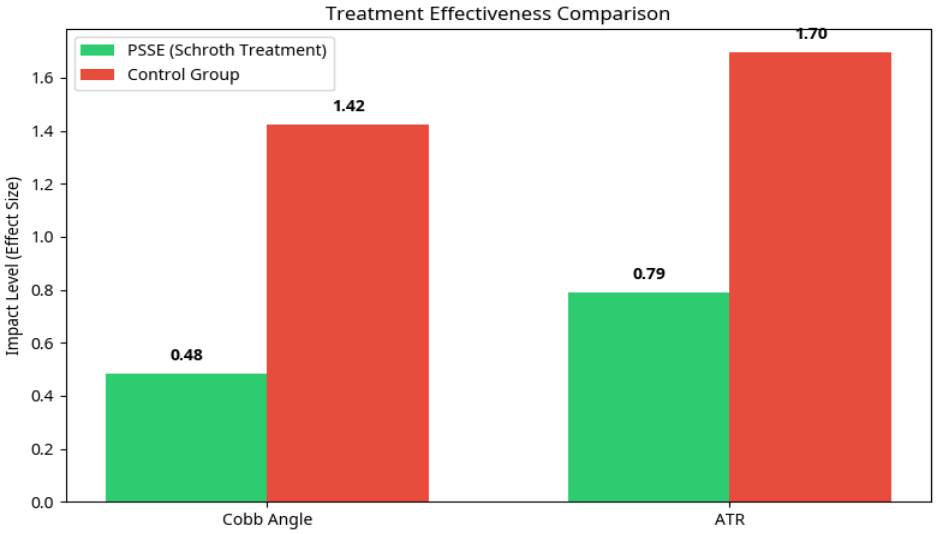


Figure 1. Higher bars mean a bigger change. Green shows positive impact for the treatment group, while Red shows the impact of the condition worsening in the control group.

RESULTS

The study found distinct paths for both groups over the 16-month period. The PSSE-Schroth group showed a mean Cobb angle stabilization ($t=1.88$, $p=0.081$, $d=0.485$) and a significant reduction in ATR ($t=3.06$, $p=0.009$, $d=0.789$), indicating improved trunk symmetry. Conversely, the control group experienced significant deterioration: the mean Cobb angle progressed significantly ($t=5.52$, $p<0.001$, $d=1.424$) and the ATR values worsened ($t=-6.58$, $p<0.001$, $d=-1.698$). Clinical cases within the PSSE group documented instances where Cobb angles reduced from 21.0° to 14.6°, confirming the potential for correction when specific exercises are applied correctly during growth.(Figure 1)

DISCUSSION

This study provides compelling evidence supporting the effectiveness of Physiotherapeutic Scoliosis Specific Exercises (PSSE-Schroth) in stabilizing mild to moderate Adolescent Idiopathic Scoliosis (AIS) curves during the critical growth period. The significant differences observed between the PSSE

and control groups highlight the limitations of general or non-specific exercises in managing progressive spinal deformities.
The PSSE-Schroth group demonstrated statistically significant improvement in the Angle of Trunk Rotation (ATR) ($p=0.009$) and a clear trend toward stabilization in the Cobb angle ($p=0.081$). These results indicate that the intervention successfully prevented curve progression, which is the primary goal of conservative treatment in AIS. The medium-to-large effect sizes (Cohen's $d = 0.485$-0.789) suggest that these benefits are clinically meaningful for patients.
In sharp contrast, the control group showed significant worsening in both Cobb angle and ATR ($p<0.001$), with very large effect sizes (Cohen's $d = 1.424$-1.698). This underscores the natural history of curve progression in skeletal immature patients (Risser 0-2) when no specific intervention is applied. The three-dimensional nature of the Schroth method—addressing rotational components and sagittal plane alignment—likely contributes to its superior effectiveness over traditional physical therapy.

Strengths:

- Use of validated outcome measures (Cobb angle and ATR) ensures reliability.
- The evidence-based approach aligns with current international SOSORT guidelines.

Limitations:

- The small sample size (n=30) limits broad generalizability.
- The 16-month follow-up period, while significant, does not capture long-term results until skeletal maturity

CONCLUSION

In conclusion, PSSE-Schroth is an effective, safe, and non-invasive approach for managing adolescents with idiopathic scoliosis presenting with Cobb angles between 15° and 25°. The intervention successfully stabilized spinal curves and significantly improved trunk rotation compared to a control group, which exhibited marked progression over the same period.
These findings support the integration of PSSE-Schroth into standard clinical practice as a primary conservative treatment for mild to moderate AIS. By specifically targeting the three-dimensional deformity of the spine, the Schroth method offers a proactive way to maintain stability and improve clinical outcomes during the high-risk adolescent growth spurt. Future research with larger cohorts and longer follow-up is recommended to further validate these findings.

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GALENIC COMPOUNDING PRACTICES IN ALBANIAN COMMUNITY PHARMACIES: A CROSS-SECTIONAL SURVEY

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ABSTRACT

Galenic compounding plays an important role in personalized therapy, enabling pharmacists to prepare pharmaceutical forms tailored to the specific needs of patients, particularly in pediatrics and in cases where industrially manufactured medicines are unavailable on the market (orphan drugs). Despite its pharmaceutical and clinical significance, galenic compounding remains limited in Albania. This study aimed to evaluate galenic compounding practices in community pharmacies in Albania and to identify the professional and regulatory factors influencing their implementation.

A descriptive cross-sectional study was conducted using a structured questionnaire consisting of open- and closed-ended questions, administered through direct interviews with pharmacists from randomly selected community pharmacies across seventeen cities in Albania. A total of 295 community pharmacies participated in this study. Data were analyzed using descriptive statistical methods and presented as percentages.

Of the 295 pharmacies interviewed, only 11.5% reported performing galenic preparations. The highest relative frequency was observed in Tirana and Gjirokastër (20%), followed by Fier (14%) and Durrës, Vlorë, and Korçë (13%). Only 28% of pharmacies performing galenic preparations based them on physician prescriptions. Approximately 17% of pharmacies referred to the Albanian Pharmaceutical Formulary of 1973. Pediatric preparations constituted the most frequent category of galenic preparations (88.2%). Capsules and syrups represented only 8.8% of the pharmaceutical forms prepared, while ophthalmic preparations were prepared by only 11.8% of pharmacies. Only five pharmacies in Tirana performed 10–20 galenic preparations per day, whereas most pharmacies carried out 5–7 preparations daily.

The results indicate that galenic compounding remains underdeveloped in Albanian community pharmacies despite its important role in personalized therapy. The limited use of magistral preparations appears to be associated with the absence of an updated National Pharmacopoeia, insufficient regulatory guidance, and lack of standardization of laboratory practices. Strengthening the regulatory framework and increasing pharmacists' professional training could improve the quality, safety, and accessibility of galenic preparations in Albania.

Keywords: Galenic compounding, personalized therapy, community pharmacy, magistral preparations, pharmaceutical regulation, Albania.

1. INTRODUCTION

Historically, the galenic preparation of drugs has represented a cornerstone of pharmaceutical practice, much more than a simple technical procedure: it has been the expression of the pharmacist's professional competence and commitment to meeting the specific needs of each individual patient. Pharmaceutical compounding is defined as the process of mixing, combining, or altering substances to create a medication tailored to the specific therapeutic requirements of an individual patient (Pegues, 2006).

In the European Union, the preparation of galenic drugs is regulated by Directive 2001/83/EC, which clearly distinguishes between two categories of pharmaceutical preparations: the officinal formula, prepared according to the specifications of a pharmacopoeia of the countries belonging to the European Union and intended for all patients served by the pharmacy, and the magistral formula, prepared in response to a medical prescription issued for a specific patient (van der Schors et al., 2021).

Compounded preparations occupy a meaningful place in patient-centred healthcare, offering the possibility of truly personalised pharmacotherapy. By allowing pharmacists and physicians to adjust dosages, adapt pharmaceutical dosage forms, and combine active substances, compounding addresses the gaps left by commercially available products — gaps that, for many patients, would otherwise go unfilled. This is particularly evident in the care of paediatric and geriatric populations, where the diversity of individual needs makes standardised, one-size-fits-all solutions inherently insufficient.

Before industrially manufactured medicines became widely available, compounding was not an exception but the rule — the everyday craft of the pharmacist. Yet the twentieth century brought profound transformation. The rapid rise of the pharmaceutical industry reshaped the profession, and by the 1970s, compounded preparations accounted for less than 1% of all prescriptions (McPherson et al., 2006). What had once been central to pharmacy practice became, for many, a forgotten art. Nevertheless, compounding has endured, and continues to serve as an indispensable pillar of pharmaceutical care wherever commercially available products fall short of meeting patients' needs.

In Albania, this dimension of pharmacy practice remains comparatively underdeveloped. Although community pharmacies are accessible across the country, compounding services are offered by only a limited number of them, and dedicated compounding facilities are far from consistently available. More fundamentally, Albania has yet to establish a comprehensive regulatory framework specifically designed for pharmaceutical compounding. Existing regulations address the manufacture, storage, and distribution of medicines in broader terms, but detailed standards and operational guidelines for compounding within pharmacy settings remain largely absent.

The lack of an updated national pharmacopoeia, combined with the absence of standardised compounding procedures, places additional strain on pharmacists who wish to engage in this practice. Over time, these structural constraints have contributed to a gradual shift in the community pharmacist's role — away from the preparation of individualised medicines and towards pharmaceutical care and medication therapy management more broadly. While this evolution reflects wider trends in the profession, it also risks marginalising a service that holds genuine therapeutic value for those patients whose needs cannot be met by the medicines that line pharmacy shelves.

Because reliable data on pharmaceutical compounding in Albania remain scarce, there is a pressing need for research that can illuminate the current reality of practice and give voice to the challenges that pharmacists encounter in this field. Evidence of this kind could lay the groundwork for the development of national standards and help restore and strengthen the pharmacist's professional role in delivering care that is, at its heart, centred on the individual.

It is within this context that the present study was undertaken. Its aim was to assess the prevalence of pharmaceutical compounding practices among community pharmacies in Albania and to identify the factors that shape — and at times constrain — the provision of these services.

2. MATERIALS AND METHODS

A descriptive survey with face-to-face structured interviews was conducted with randomly chosen community pharmacists in seventeen cities of Albania. The research was done from May 2020 to May 2021.

A list of all licensed community pharmacies (n = 922) was collected from the Compulsory Health Care Insurance Fund (FSDKSH), and a random sample of community pharmacies was selected and invited to participate in the study (FSDKSH, 2021). The sample was chosen to represent around 35% of licensed pharmacies (n = 322). Other types of pharmacies were not included, such as chain pharmacies, hospitals, and clinics.

Participation was voluntary, and all respondents provided verbal consent before the interview. No personal or identifiable information was collected.

We contacted the directors of the various pharmacies in person, via e-mail, and by phone to explain our project and the goal of the research, and we received good responses from most of them. Each pharmacy manager or pharmacy director was asked for permission to conduct the personal interview. Only 27 pharmacy directors decided not to join the survey. Therefore, 295 community pharmacies consented to take part and answer the questionnaire in total.

The questionnaire included eleven questions, some closed-ended and others open-ended. The questionnaire was intended as a registration tool to determine if compounding services were offered and to collect data on total and compounded prescription volumes.

The question, "Does your pharmacy provide compounding services?" included check boxes for yes and no answers. Those respondents who reported providing compounding services were asked to specify whether they prepared officinal formulations, magistral formulations, or both. The number of compounded drugs delivered in a typical month and during a whole year. The origin of methods utilized for compounding was asked in all situations. The survey also collected information on the categories of active ingredients most frequently used, whether narcotic preparations were compounded, and the dosage forms most commonly prepared.

Results were expressed as frequencies and percentages. No inferential statistical tests were performed because the study was descriptive in nature. Data were entered into Microsoft Excel and subsequently analyzed using descriptive statistical methods.

3. RESULTS

3.1 Distribution of surveyed pharmacies

A total of 295 pharmacies located throughout Albania participated in the survey and were distributed as follows:

Table 1. Distribution of Surveyed Pharmacies Across Albanian Cities

City	Number of Pharmacies	City	Number of Pharmacies
Gjirokaster	10	Lezha	13
Berati	17	Lushnje	20
Korçe	20	Pogradeci	15
Durres	30	Puka	02
Elbasan	14	Saranda	10
Fieri	14	Shkoder	24
Kavaja	07	Tirana	60
Kruja	09	Vlora	20
Lac	10	Total	295

Table 1 presents the geographical distribution of the 295 pharmacies included in the survey across 17 Albanian cities. The largest number of pharmacies was surveyed in Tirana (n = 60), followed by Durrës (n = 30) and Shkodër (n = 24). Intermediate numbers of pharmacies were recorded in Korçë, Lushnjë and Vlorë (n = 20 each), while the smallest sample was obtained in Pukë (n = 2). The surveyed

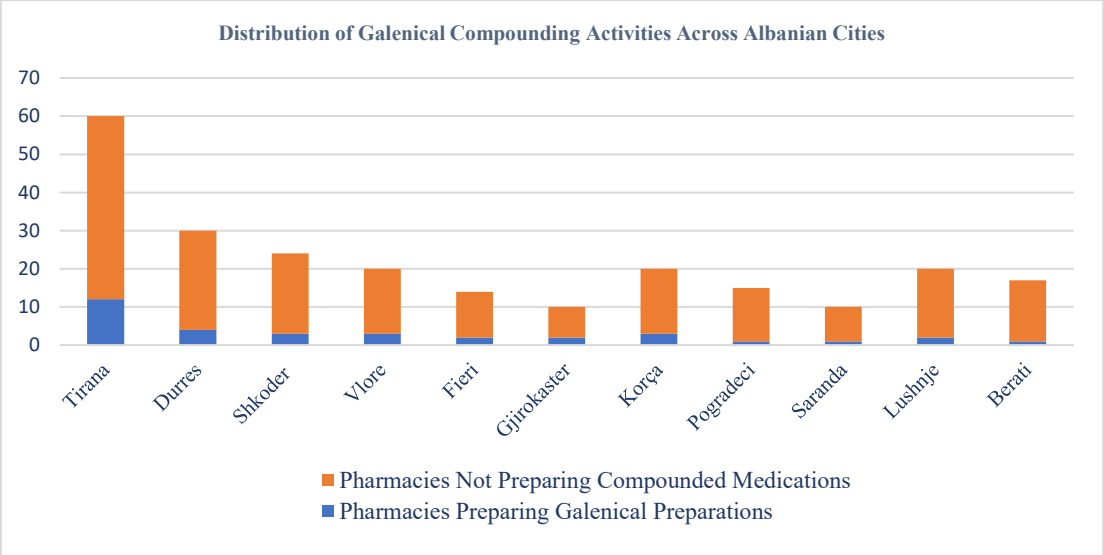
pharmacies were broadly distributed throughout the country, providing a representative overview of galenical compounding practices in different regions of Albania.

3.2 Galenical compounding activities

As shown in Figure 1, galenical compounding activities were unevenly distributed among Albanian cities. The highest proportion of pharmacies preparing galenical formulations was observed in Tirana and Gjirokastër (20%), followed by Fier (14.3%), Durrës (13.3%), Korçë (15.0%) and Vlorë (15.0%). Despite these differences, pharmacies not involved in galenical preparation represented the majority in every city surveyed, indicating that pharmaceutical compounding remains a relatively uncommon practice in Albania.

Among the 55 pharmacies surveyed in Lezhë, Kavajë, Krujë, Pukë, Laç and Elbasan, none reported preparing galenical formulations. These results indicate that pharmaceutical compounding activities are currently absent in these cities, in contrast to other Albanian regions where galenical preparations are still performed, although to a limited extent.

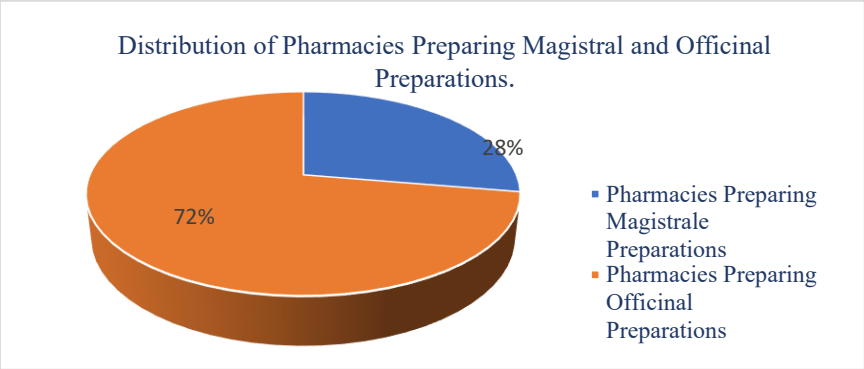
Figure 1. Distribution of galenic compounding activities across Albanian cities



3.3 Magistral and officinal preparations

Figure 2 highlights the limited tendency of doctors to prescribe magistral formulations. In contrast, pharmacists appear to be more actively involved in the preparation of officinal formulations, which account for 72% of all galenical preparations. Of the 34 pharmacies that reported preparing galenical formulations, only about 9 prepared magistral prescriptions. This represents approximately 3% of the total 295 pharmacies included in the survey, indicating the limited use of magistral compounding in Albania.

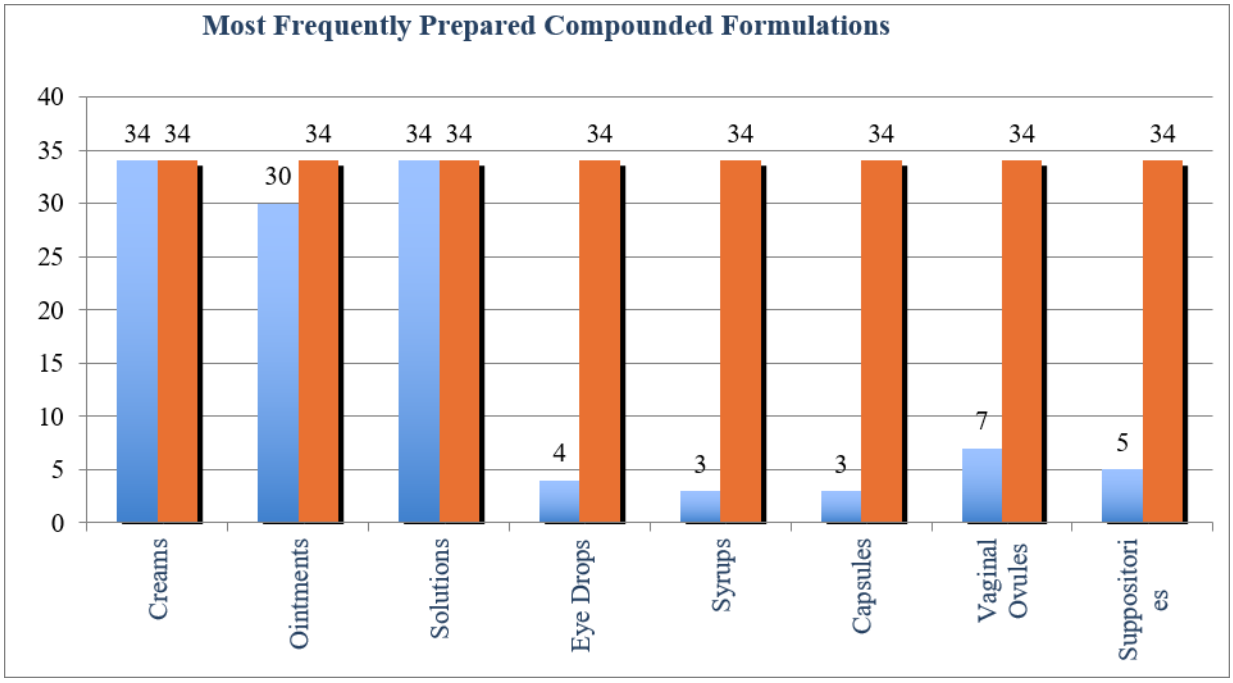
Figure 2. Distribution of Magistral and Officinal Galenical Preparations in Pharmacies



3.4 Most frequently prepared formulations and the active ingredients

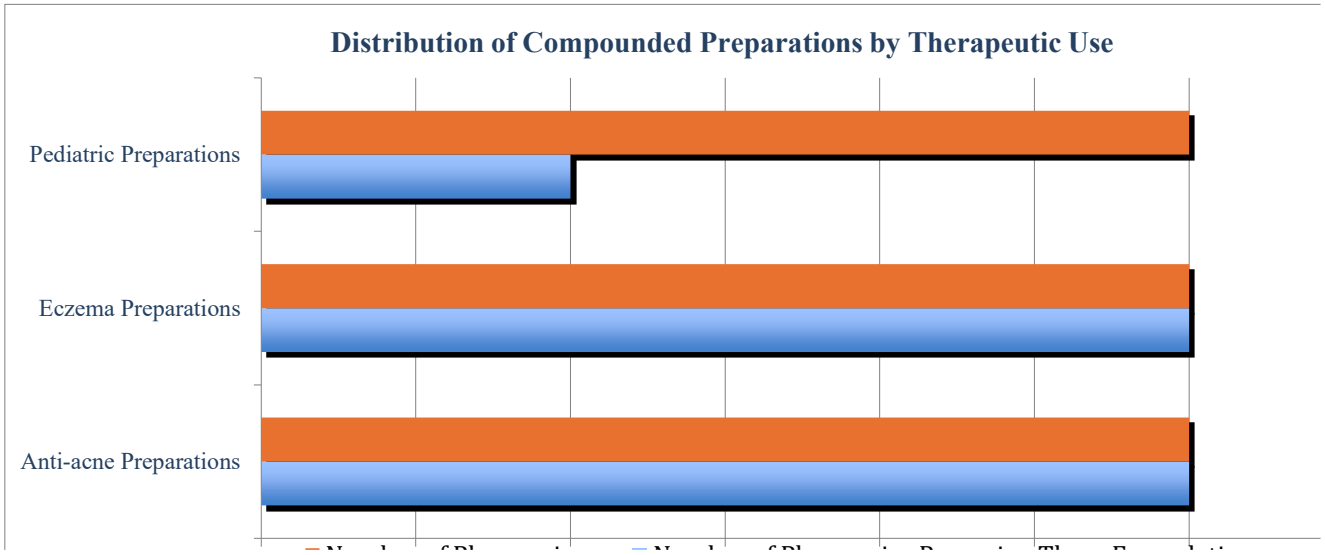
As shown in Figure 3, all pharmacies involved in galenical compounding primarily prepared topical formulations, such as creams and ointments, mainly intended for the treatment of acne and eczema. Oral dosage forms were considerably less common, with only 3 pharmacies (8.8%) reporting the preparation of capsules, while none of the surveyed pharmacies prepared tablets. Syrups were also prepared by only 3 pharmacies (8.8%). Vaginal ovules and suppositories were prepared by 7 (20.6%) and 5 (14.7%) pharmacies, respectively. Finally, ophthalmic preparations (eye drops) were reported by only 4 pharmacies (11.8%) out of the 34 pharmacies engaged in galenical compounding. These findings indicate that pharmaceutical compounding activities in Albania are predominantly focused on topical formulations, whereas oral and specialized dosage forms remain relatively uncommon.

Figure 3: Most frequently prepared compounded formulations in Albanian community pharmacies



The most frequently used active ingredients in compounded preparations were antifungal agents, salicylic acid, and corticosteroids. Antibiotics and anti-inflammatory agents were used less frequently. Among the antifungal agents, econazole, fluconazole, and ketoconazole were the most commonly reported compounds, while clobetasol and betamethasone were the predominant corticosteroids.

Figure 4: Distribution of compounded preparations by therapeutic use



As shown in figure 4, dermatological preparations intended for acne and eczema were the most frequently compounded products, being reported by all pharmacies engaged in galenical compounding. Pediatric formulations were also highly prevalent (88.2%), highlighting the importance of compounding in providing individualized therapies for children.

3.5Pharmacopoeias and reference standards

3.6 Given the wide variety of dosage forms prepared by Albanian pharmacies, it was also important to investigate the reference standards used during the compounding process. Although the European Pharmacopoeia (Ph. Eur.) does not provide specific pharmaceutical formulations for the preparation of officinal compounded medicines, it represents the principal reference for quality standards, monographs, and analytical methods. Since Albania does not have a national pharmacopoeia, pharmacists rely mainly on international sources, including the European Pharmacopoeia (Ph. Eur.), the Italian Official Pharmacopoeia (FUI), and the British Pharmacopoeia (BP). All 34 surveyed pharmacies reported using the European Pharmacopoeia as their primary reference source, while 50% also consulted the Italian Official Pharmacopoeia, which includes officinal formulations, and 17.6% the British Pharmacopoeia. In addition, approximately 17% of pharmacies reported consulting the Albanian Pharmaceutical Formulary of 1973 as an additional reference source. These findings demonstrate the strong reliance of Albanian pharmacists on internationally recognised pharmacopoeial standards for the preparation of galenical formulations.

3.6 Production volume and raw material sources

As shown in Table 2, the production volume of magistral preparations varied considerably among pharmacies. Two pharmacies reported preparing between 100 and 150 magistral formulations per month (1,200–1,800 annually), whereas the majority prepared between 20 and 40 formulations per month. These production data refer to the 13 pharmacies that reported preparing magistral formulations on a regular basis. The remaining pharmacies prepared fewer than three magistral formulations per month, indicating only occasional compounding activity. Overall, these findings indicate that only a limited number of pharmacies maintain a high level of magistral compounding activity.

Table 2. Monthly and annual production of magistral preparations in surveyed pharmacies

Number of pharmacies	Compounded per month	Compounded per year
2 pharmacies	100-150	1200-1800
3 pharmacies	50-80	600-1000
6 pharmacies	20-40	250-500
2 pharmacies	5-10	50-150

In addition, the limited availability of pharmaceutical-grade raw materials within the country forces many pharmacies to obtain active pharmaceutical ingredients and excipients from abroad. Overall, 64% of pharmacies relied on foreign suppliers, mainly from Greece (42%) and Italy (22%), whereas only 36% sourced these materials from Albania. These findings highlight the strong dependence of Albanian compounding pharmacies on both international pharmacopoeial standards and foreign suppliers of pharmaceutical raw materials.

4. DISCUSSION

The present study provides one of the first overviews of galenic compounding practices in Albanian community pharmacies. The results show that galenic compounding activities remain limited, as only 11.5% of the surveyed pharmacies reported that they produce galenic preparations. This result suggests that personalized pharmaceutical compounding currently represents a specialized activity and not a routine practice in Albanian community pharmacies.

The low frequency of galenic preparations observed in this study is in line with the international trend described by McPherson et al. (2006), who reported a significant decline in pharmacy-prepared preparations following the development of the pharmaceutical industry and the increased availability of industrially produced drugs. However, despite this decline, galenic preparations continue to play an important role in individualized therapy, especially when suitable commercial alternatives are lacking.

The predominance of officinal over magistral preparations observed in our study is in line with the findings of Buurma et al. (2003), who reported that standardized preparations are more frequently prepared than personalized formulations for individual patients in community pharmacies. In Albania, only about 3% of all pharmacies surveyed prepared magistral preparations, suggesting a limited demand for personalized prescriptions and a relatively low frequency of their prescription by physicians.

Topical pharmaceutical forms, especially creams and ointments, were found to be the most prepared preparations. Similar findings were also reported by Treadway et al. (2007), who identified dermatological preparations as among the most common formulations prepared in community pharmacies. The predominance of topical preparations can be explained by the apparent lower technical complexity of their preparation and the continuing clinical demand for the treatment of dermatological diseases.

According to van der Schors et al. (2021), pharmaceutical preparation in the pharmacy remains an important component of pharmaceutical care, especially in cases where individualized therapy is required. However, our study shows that several obstacles continue to limit the development of this activity in Albania. These include the lack of an up-to-date National Pharmacopoeia, the lack of clear regulatory guidelines, and the dependence on foreign suppliers for pharmaceutical-grade raw materials. Finally, as also highlighted by Brown (2008), galenic preparations constitute a valuable tool for personalized medicine. These findings suggest that strengthening compounding infrastructure and professional support could help preserve and expand this important pharmaceutical service in Albania.

Study Limitations: this study has some limitations. The findings were based on self-reported information provided by pharmacists and were not verified through direct observation of compounding activities. In addition, hospital pharmacies and pharmacy chains were not included in the survey. Nevertheless, the large sample size and broad geographical coverage provide a valuable overview of

galenical compounding practices in Albania. Improving the professional training of pharmacists, modernizing galenic laboratories, and establishing clear national standards can contribute to the expansion and safe development of galenic preparation practices in Albania.

5. CONCLUSION

As highlighted throughout this study, galenical compounding represents a distinctive professional activity of pharmacists and plays an important role in ensuring access to personalized medicines. Despite the growth of the pharmaceutical industry and the widespread availability of industrially manufactured medicines, compounded preparations remain essential for providing orphan medicines, individualized dosages, specific combinations of active ingredients, pediatric formulations, and customized therapies tailored to patients' needs.

The findings of this survey demonstrate that galenical compounding remains a limited practice in Albanian community pharmacies. Although Albania has a large number of pharmacies, only 11.5% of the surveyed pharmacies reported preparing galenical formulations, while magistral preparations were prepared by only about 3% of all pharmacies included in the study. These results indicate that the traditional practice of pharmaceutical compounding is currently underdeveloped in Albania.

Several factors may contribute to this situation, including the absence of an updated Albanian Pharmacopoeia, the lack of detailed regulations and professional guidelines governing pharmacy compounding, and the limited availability of standardized laboratory facilities. These shortcomings may discourage pharmacists from investing in and developing compounding services.

6. RECOMMENDATIONS

Based on the findings of this study, several measures could contribute to the development of galenical compounding in Albania. The adoption of an updated national pharmacopoeia and the implementation of specific regulations governing pharmacy compounding would provide a clearer professional and regulatory framework for pharmacists. In addition, the establishment of adequately equipped compounding laboratories, together with continuous professional training programs, could improve the quality, safety, and standardization of compounded medicines. Finally, greater collaboration between regulatory authorities, academic institutions, and professional organizations may facilitate the integration of European standards into Albanian pharmaceutical practice.

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FROM OBSTACLE TO OPPORTUNITY: THE ROLE OF CONFLICT IN FOREIGN LANGUAGE LEARNING

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ABSTRACT

Conflict is typically viewed as a negative force that hinders progress and causes disruption. However, in the context of foreign language education, conflict can be a valuable tool for promoting learning and growth. This abstract highlights the benefits of conflict in foreign language education, arguing that it can motivate students to engage with different perspectives and ideas, ultimately leading to a deeper understanding of the language and culture being studied.

The paper explores the idea of conflict in foreign language education, outlining the various forms it can take and the impact it can have on learning. It also discusses strategies for handling and resolving conflict in the classroom, emphasizing the importance of creating a supportive and open environment where students feel comfortable expressing their views and engaging in productive dialogue.

Central to the paper's argument is the idea that conflict can be a catalyst for learning, driving students to critically examine their assumptions and engage with new perspectives. By encouraging students to explore different viewpoints and ideas, teachers can help foster a deeper understanding of the language and culture being studied, as well as promote critical thinking and intellectual curiosity.

At the same time, the paper acknowledges that conflict can also be disruptive and detrimental to the learning process if not properly managed. As such, it emphasizes the role that teachers play in creating an environment that supports diversity and promotes open communication, allowing students to express themselves freely and engage in constructive dialogue.

Overall, the paper aims to persuade educators to view conflict not as an obstacle to progress in foreign language education, but rather as a valuable tool for promoting learning and growth. By embracing conflict and cultivating a classroom environment that supports open dialogue and diverse perspectives, teachers can help their students develop the skills and knowledge necessary to succeed in level education.

Keywords: Conflict in Education, Foreign Language Learning, Critical Thinking, Classroom Interaction, Intercultural Communication

INTEGRATED ASSESSMENT OF EMBODIED CARBON AND COASTAL WATER VARIABILITY UNDER POST-EARTHQUAKE URBAN RECONSTRUCTION

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ABSTRACT

Post-earthquake reconstruction can generate substantial environmental pressures through intensive material consumption and accelerated urban development. This study presents an integrated assessment of embodied carbon emissions and coastal environmental variability associated with the reconstruction process following the 2019 earthquake in Durrës, Albania.

A probabilistic life cycle assessment (LCA) was applied to estimate embodied carbon emissions from representative reinforced concrete buildings constructed under the national reconstruction programme. Coastal environmental conditions were evaluated using physicochemical water quality indicators, including turbidity, dissolved oxygen, pH, salinity, and temperature. An Integrated Environmental Pressure Index (IEPI) was developed to combine carbon-related impacts and coastal environmental variability within a single assessment framework.

The results indicate an average embodied carbon intensity of 0.325 t CO_2-eq/m^3, with cement production representing the dominant emission source. Coastal monitoring revealed pronounced spatial heterogeneity, particularly for turbidity (CV = 119%) and dissolved oxygen (CV = 27%). The calculated IEPI value of 0.632 suggests a high level of cumulative environmental pressure within the study area.

The results highlight the importance of evaluating reconstruction-related emissions together with coastal environmental conditions. The proposed framework offers a practical approach for integrating carbon assessment and environmental monitoring into reconstruction planning in rapidly developing coastal cities.

Keywords: Probabilistic life cycle assessment, Embodied carbon, Coastal urbanization, Water quality variability, Reconstruction impacts, Environmental pressure assessment

INTRODUCTION

Coastal cities are among the most dynamic and environmentally sensitive environments, where urban development continuously interacts with natural coastal processes (Beatley 2014; Neumann et al. 2015). Rapid urbanization has increased pressure on coastal ecosystems through land-use change, shoreline modification, infrastructure expansion, and increased surface runoff (Neumann et al. 2015; Seto et al. 2012; Islam and Tanaka 2004). These processes may alter coastal environmental conditions and affect water quality through sediment disturbance and the transport of suspended materials (Islam and Tanaka 2004; Cloern 2001).

Post-disaster reconstruction can create an additional source of environmental pressure, particularly in coastal urban areas where construction activities are concentrated within short time periods (Fardis 2009). Following major seismic events, reconstruction programmes require large quantities of construction materials, especially reinforced concrete, due to its structural performance and widespread use in seismic design (Habert et al. 2020; Monteiro et al. 2017). The extensive use of cement-based materials may substantially increase embodied carbon emissions associated with reconstruction activities (Habert et al. 2020; Sefa et al. 2026). Following the earthquake of 26 November 2019 (Mw 6.4), extensive reconstruction activities were implemented in Durrës, Albania (Sefa et al. 2026). The

programme involved the repeated construction of reinforced concrete buildings under relatively standardized design conditions. Cement production is recognized as one of the largest contributors to greenhouse gas emissions within the construction sector and may account for more than 80% of embodied carbon associated with reinforced concrete structures (Habert et al. 2020). Previous life-cycle assessment studies have shown that the environmental significance of reconstruction programmes increases considerably when building-level emissions are extrapolated to large-scale developments (Monteiro et al. 2017).

At the same time, urbanization around the Gulf of Durrës has increased pressure on nearshore marine environments (Bakalli et al. 2025; Sefa et al. 2026). Construction activities and land-based inputs may influence coastal systems through sediment mobilisation, increased turbidity, and localized changes in physicochemical water conditions (Islam and Tanaka 2004; Bakalli et al. 2025). However, environmental responses are often spatially heterogeneous and are controlled by multiple interacting physical and anthropogenic factors (Bakalli et al. 2025).

Most previous studies have examined these environmental dimensions separately. Life-cycle assessment research has primarily focused on carbon emissions associated with construction materials and buildings (Habert et al. 2020; Monteiro et al. 2017), whereas coastal environmental studies have mainly investigated water quality and physicochemical variability (Islam and Tanaka 2004; Bakalli et al. 2025). Integrated assessments that simultaneously evaluate reconstruction-related carbon emissions and coastal environmental responses remain limited, particularly in post-disaster coastal cities.

To address this limitation, the present study integrates embodied carbon assessment and coastal environmental variability within a single analytical framework. The methodology combines probabilistic life-cycle assessment of embodied carbon with quantitative analysis of coastal water variability. The objective is to examine how reconstruction-driven urban development may contribute to cumulative environmental pressures and to support more sustainable planning approaches in rapidly transforming coastal cities.

STUDY AREA

The study was conducted in Durrës, a major coastal city located along the central Adriatic coastline of Albania. Durrës is one of the country's most important urban and economic centres, hosting the largest seaport in Albania and supporting intensive residential, industrial, transport, and tourism activities (INSTAT 2024).

Table 6. Characteristics of the study area

Parameter	Description
Location	Durres, Albania
Coast type	Adriatic coastal zone
Reconstruction context	Post-earthquake (2019)
Dominant building system	Reinforced concrete
Main environmental pressures	Urbanization, construction activities, runoff
Coastal characteristics	Semi-enclosed coastal system

The Gulf of Durrës forms a semi-enclosed coastal environment where hydrodynamic conditions influence the transport and distribution of suspended materials and other land-based inputs. Such environments are generally sensitive to urban runoff, sediment disturbance, and anthropogenic pressures (Islam and Tanaka 2004; Cloern 2001). Over recent decades, the city has experienced continuous urban expansion driven by population growth, infrastructure development, and tourism-related investments.

These processes have increased pressure on nearshore coastal ecosystems and contributed to changes in water quality conditions in several sectors of the Gulf (Bakalli et al. 2025).

Durrës was among the areas most affected by the earthquake of 26 November 2019 (Mw 6.4) (Sefa et al. 2026). The post-earthquake reconstruction programme involved the construction of a large number of reinforced concrete buildings using standardized structural solutions and substantial quantities of cement-based materials (Sefa et al. 2026). The scale of reconstruction created conditions associated with increased material consumption and additional embodied carbon emissions.

The combination of intensive reconstruction activities and existing urbanization pressures makes Durrës a suitable case study for evaluating interactions between construction-related emissions and coastal environmental variability. The study area, therefore, provides an opportunity to investigate cumulative environmental pressures within a rapidly developing coastal urban system.

METHODOLOGY

Integrated methodological framework

This study adopts an integrated assessment framework to evaluate environmental pressures associated with post-earthquake reconstruction in a coastal urban environment. The framework combines embodied carbon assessment of reconstruction activities with the analysis of coastal water quality variability, allowing both environmental dimensions to be evaluated within a common analytical structure. Similar integrated approaches have been increasingly recommended for assessing cumulative environmental impacts in rapidly urbanizing coastal regions (Seto et al., 2012; Neumann et al., 2015).

Two complementary datasets were used in the analysis. The embodied carbon dataset was derived from a previous life cycle assessment of reinforced concrete buildings constructed under the post-earthquake reconstruction programme in Durrës (Sefa et al., 2026). That study provided detailed structural inventories, material quantities, and embodied carbon estimates for representative reconstruction typologies. The present research uses these results as the construction-related component of the integrated environmental assessment.

The coastal environmental dataset was developed from field measurements conducted by the authors at multiple sampling locations within the Gulf of Durrës. The monitoring programme included temperature, pH, dissolved oxygen, turbidity, conductivity, and salinity, which are commonly used indicators of environmental quality and anthropogenic disturbance in coastal ecosystems (APHA, 2017; Cloern, 2001; Islam and Tanaka, 2004). The interpretation of the obtained results was supported by recent investigations carried out in the same coastal area (Bakalli et al., 2025).

Table 7. Structural and environmental datasets used in the study

Dataset	Source	Variables	Purpose
Reconstruction dataset	Structural documentation	Concrete volume, material quantities	Embodied carbon assessment
Coastal monitoring dataset	Field measurements	Temperature, pH, DO, turbidity, salinity	Water variability analysis

The assessment was conducted in four sequential stages. First, structural and environmental datasets were compiled and prepared for analysis. Second, a probabilistic life cycle assessment (LCA) was used to evaluate embodied carbon emissions associated with reinforced concrete construction following ISO 14040 and ISO 14044 standards (ISO, 2006a; ISO, 2006b). Third, spatial variability of coastal environmental conditions was quantified using descriptive statistics and coefficients of variation, which are widely applied to evaluate environmental heterogeneity in aquatic systems (Bakalli et al., 2025). Finally, both environmental dimensions were integrated through the development of an Integrated Environmental Pressure Index (IEPI), designed to provide a comparative measure of cumulative environmental pressure within the study area.

The framework was designed to evaluate coexisting environmental pressures rather than to infer causal relationships between reconstruction activities and coastal environmental conditions.

The overall methodological workflow is presented in Figure 1.

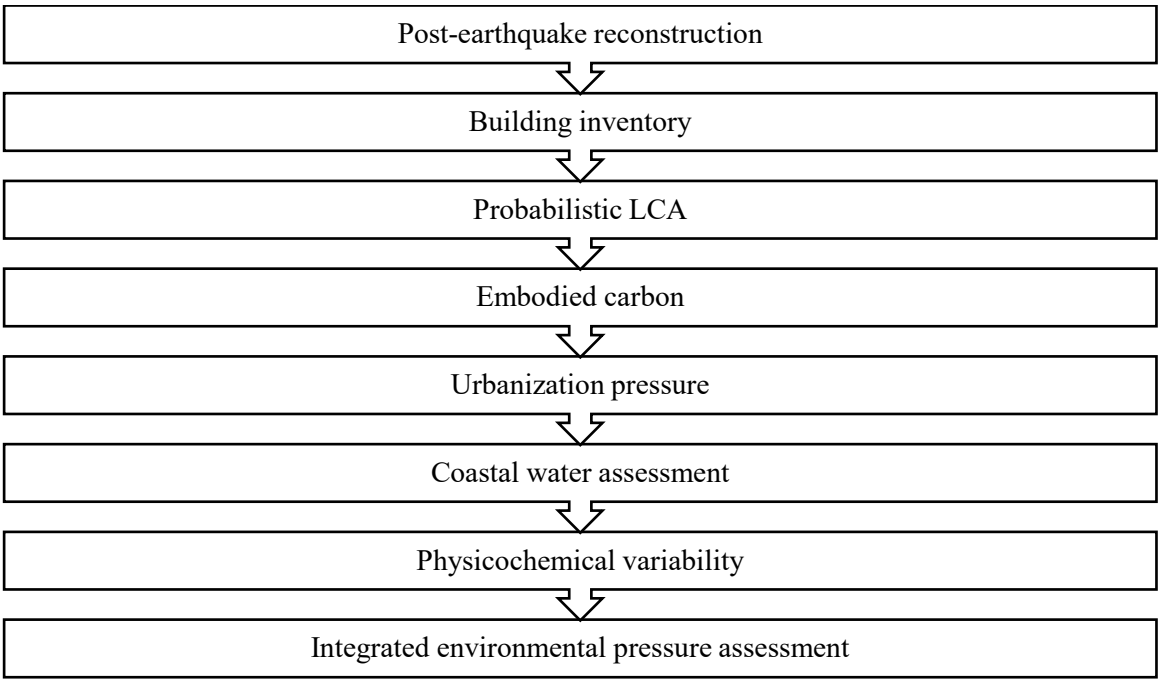


Figure 4. Methodological framework applied in this study

Embodied carbon assessment

Embodied carbon emissions associated with post-earthquake reconstruction were evaluated using a process-based life cycle assessment (LCA) methodology following the principles and requirements defined by ISO 14040 and ISO 14044 (ISO, 2006a; ISO, 2006b). The assessment focused on reinforced concrete structures, which represented the dominant construction system used during the reconstruction programme implemented after the 2019 earthquake in Durrës (Sefa et al., 2026).

The embodied carbon dataset was derived from the reconstruction inventory previously developed by Sefa et al. (2026). The inventory included quantities of concrete and constituent materials used in representative reinforced concrete building typologies constructed under standardized reconstruction designs. Reinforced concrete was selected because it accounted for the largest share of material consumption within the reconstruction programme and therefore represented the main source of construction-related emissions. The system boundary was defined according to a cradle-to-gate approach (A1–A3), encompassing raw material extraction, transport of raw materials, cement production, aggregate processing, and concrete manufacturing (Sefa et al., 2026). This boundary is widely applied in embodied carbon studies because it captures the majority of greenhouse gas emissions associated with concrete production while avoiding uncertainties related to the operational phase and end-of-life scenarios (Habert et al., 2020; Monteiro et al., 2017).

Total embodied carbon emissions were calculated as:

$$EC = \sum_{i=1}^{n} Q_i EF_i \quad (1)$$

where: EC represents total embodied carbon (kg CO_2-eq); Q_i represents the quantity of material I; EF_i represents the corresponding emission factor.

Emission factors were obtained from internationally recognized life cycle assessment datasets and published studies on cement and concrete production (Habert et al., 2020; Monteiro et al., 2017). These factors represent cradle-to-gate greenhouse gas emissions associated with material production processes and are expressed in terms of carbon dioxide equivalent (CO_2-eq). To facilitate comparison among reconstruction typologies, results were expressed as embodied carbon intensity per cubic metre of concrete (t CO_2-eq/m^3). This indicator is commonly used in building life cycle assessment studies and provides a consistent basis for evaluating the environmental performance of concrete-based construction systems (Sefa et al., 2026; Habert et al., 2020).

Probabilistic analysis

Uncertainty associated with material quantities and emission factors was evaluated using a Monte Carlo simulation. This is a method widely applied in probabilistic life cycle assessment to quantify the propagation of uncertainty through environmental models (Huijbregts, 1998; Lloyd and Ries, 2007). Unlike deterministic approaches, Monte Carlo analysis allows input parameters to vary within predefined ranges, providing a more realistic representation of environmental uncertainty.

The embodied carbon inventory developed by Sefa et al. (2026) was used as the baseline dataset. To account for potential variability in material quantities and emission factors, input parameters were treated as stochastic variables rather than fixed values. A variation range of ±10% around the mean value was adopted for both material quantities and emission factors. This range is consistent with uncertainty levels commonly reported in construction-related life cycle assessment studies where detailed project-specific environmental product declarations are not available (Huijbregts, 1998; Lloyd and Ries, 2007).

Monte Carlo simulation was implemented in Microsoft Excel using 10,000 iterations. During each iteration, material quantities and emission factors were randomly sampled within the specified uncertainty range, and the total embodied carbon emissions were recalculated. The procedure generated a distribution of possible outcomes rather than a single deterministic value, allowing the variability of the estimated carbon footprint to be quantified. The simulation results were summarized using descriptive statistical indicators, including mean values, standard deviations, confidence intervals, and relative uncertainty ranges. These indicators provide information on the robustness of the embodied carbon estimates and allow assessment of the sensitivity of the results to uncertainty in input parameters.

The probabilistic approach improves the reliability of programme-level environmental assessment by explicitly incorporating uncertainty into the calculation process. This is particularly important in post-disaster reconstruction studies, where material inventories and construction practices may vary among individual projects despite the use of standardized structural designs (Sefa et al., 2026).

Coastal water variability assessment

Coastal environmental conditions were evaluated using field measurements collected by the authors at multiple sampling locations distributed throughout the Gulf of Durrës. The monitoring campaign was designed to capture spatial variability in areas exposed to different levels of urban influence and anthropogenic pressure. The selected locations included sectors affected by urban development, coastal activities, and areas characterized by relatively lower levels of disturbance.

The assessment focused on six physicochemical parameters: temperature, pH, dissolved oxygen (DO), turbidity, conductivity, and salinity. These variables are widely used in coastal environmental monitoring because they provide information on water quality, hydrodynamic conditions, sediment transport processes, and ecosystem response to anthropogenic pressures (APHA, 2017; Cloern, 2001; Islam and Tanaka, 2004). Similar parameters have been successfully applied in previous investigations conducted in the Gulf of Durrës (Bakalli et al., 2025). Field measurements and data processing followed standard procedures for water quality assessment recommended by the American Public Health Association (APHA, 2017). Temperature, pH, dissolved oxygen, conductivity, and salinity were measured in situ using calibrated portable instruments, while turbidity was used as an indicator of suspended sediment concentration and coastal disturbance.

Spatial variability was evaluated using descriptive statistical analysis. For each parameter, mean values, standard deviations, and observed ranges were calculated. To quantify the degree of heterogeneity among sampling locations, the coefficient of variation (CV) was used:

$$CV = \frac{\sigma}{\mu} \times 100 \quad (2)$$

where σ represents standard deviation and μ represents the mean value of the parameter.

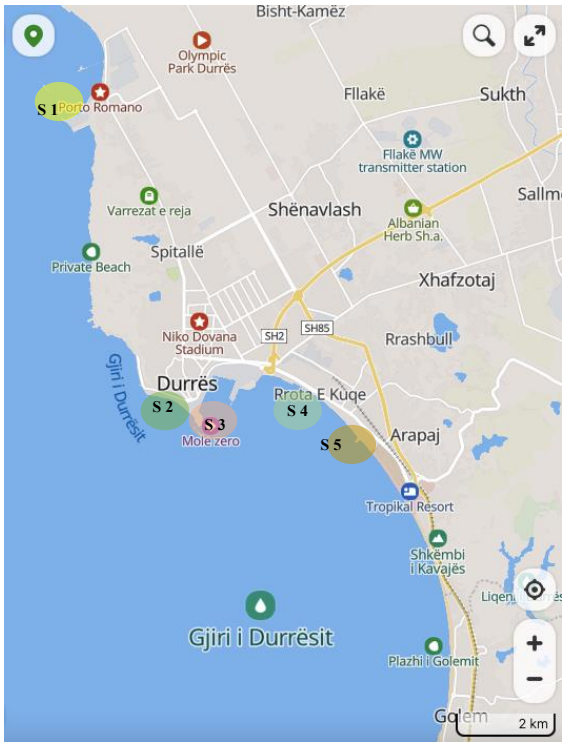


Figure 5. Monitoring Stations in Durrës Bay

(Station 1 – Porto Romano Port; Station 2 – Ferrara (Currila); Station 3 – Fishing Port; Station 4 – Pista Teuta; Station 5 – Pista Cupola)

The coefficient of variation is widely applied in environmental studies because it allows comparison of variability among parameters with different units and magnitudes (Bakalli et al., 2025). Higher CV values indicate greater spatial heterogeneity and suggest stronger environmental differentiation within the monitored coastal system. In addition to descriptive statistics, comparative analysis among sampling locations was performed to identify parameters exhibiting the greatest environmental variability. Particular attention was given to turbidity and dissolved oxygen because these variables are highly sensitive to sediment disturbance, water circulation, and anthropogenic pressures in shallow coastal environments (Islam and Tanaka, 2004; Cloern, 2001).

Integrated environmental pressure assessment

To evaluate cumulative environmental pressure associated with post-earthquake reconstruction and coastal environmental variability, an Integrated Environmental Pressure Index (IEPI) was developed. The index combines indicators derived from embodied carbon assessment and coastal water quality variability within a single analytical framework. The integration approach was based on the assumption that construction-related emissions and environmental heterogeneity represent two complementary dimensions of environmental pressure in rapidly developing coastal urban systems. Since these indicators are expressed in different units and scales, they were transformed into dimensionless values before integration.

The Water Variability Indicator (WV) was derived from the coefficient of variation of the physicochemical parameters that exhibited the highest spatial variability across the monitoring stations. Turbidity and dissolved oxygen were selected because they showed the largest differences among sampling locations and are widely recognized as sensitive indicators of environmental disturbance in coastal ecosystems (Cloern, 2001; Islam and Tanaka, 2004; Bakalli et al., 2025). The Water Variability Indicator was calculated as:

$$WV = \frac{CV_{turbidity} + CV_{DO}}{2} \quad (3)$$

where: WV is the Water Variability Indicator, $CV_{Turbidity}$ is the coefficient of variation of turbidity, and CV_{DO} is the coefficient of variation of dissolved oxygen. The indicator represents the average relative variability of the two physicochemical parameters that exhibited the highest spatial heterogeneity among the monitored coastal stations. The Integrated Environmental Pressure Index was calculated as:

$$IEPI = \alpha EC_n + \beta WV_n \quad (4)$$

where IEPI is the Integrated Environmental Pressure Index, EC_n is the normalized embodied carbon indicator, WV_n is the normalized water variability indicator, and α and β are weighting coefficients.

Equal weighting coefficients (α = 0.5 and β = 0.5) were adopted because no scientific evidence was available to justify a higher relative importance of either environmental dimension. Similar equal-weighting approaches are commonly applied in exploratory environmental indices when the relative contribution of individual components remains uncertain. The resulting index ranges from 0 to 1, where higher values indicate greater cumulative environmental pressure. The index does not imply a direct causal relationship between reconstruction activities and coastal environmental conditions. Instead, it provides a comparative measure of the combined environmental burden associated with material-related emissions and environmental variability within the study area.

Statistical analysis

Descriptive statistical analysis was applied to evaluate the spatial variability of the monitored physicochemical parameters. For each variable, mean values, standard deviations, coefficients of variation, and observed ranges were calculated. These indicators were used to quantify environmental heterogeneity among sampling locations and to identify the parameters exhibiting the greatest spatial variability. The coefficient of variation (CV) was selected as the principal measure of relative variability because it enables comparison among environmental parameters expressed in different units and magnitudes. Higher CV values indicate greater spatial heterogeneity within the monitored coastal system. All statistical analyses were performed using IBM SPSS Statistics.

RESULTS

Embodied carbon associated with reconstruction activities

The probabilistic life cycle assessment indicated that reconstruction activities generated substantial embodied carbon emissions due to the intensive use of reinforced concrete systems. The estimated weighted average embodied carbon intensity was 0.325 t CO_2-eq/m³, with an uncertainty range of approximately ±9%. The relatively narrow variability range suggests stable model performance under the adopted uncertainty assumptions.

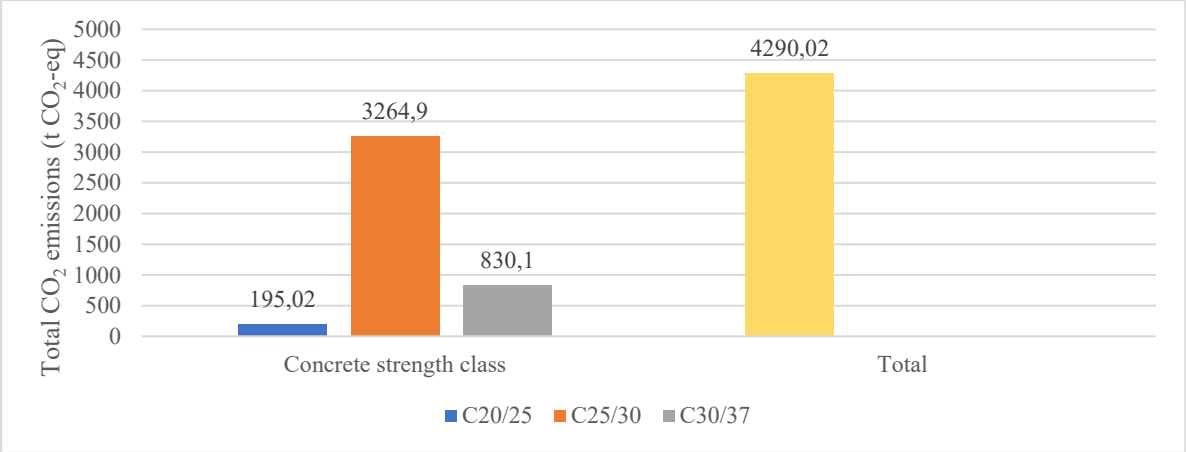


Figure 6. Total embodied carbon emissions associated with concrete strength classes used in post-earthquake reconstruction.

Emission intensity increased with concrete strength class because of increasing cement content requirements. Although higher-strength concrete classes exhibited larger emission intensities, the overall contribution to programme-level emissions was primarily controlled by material volume distribution. The C25/30 concrete class contributed the largest share of emissions because it represented the dominant structural material used during reconstruction activities. Similar observations have been reported in previous studies where cement-related parameters were identified as the principal drivers of embodied carbon in reinforced concrete systems (Habert et al., 2020; Monteiro et al., 2017).

The contribution analysis indicated that cement production remained the dominant source of emissions, accounting for approximately 80–85% of total embodied carbon (Sefa et al., 2026). This finding is consistent with previous studies identifying clinker production and thermal energy demand as the principal contributors to emissions associated with concrete production (Sefa et al., 2026; Habert et al., 2020).

Coastal water variability under urbanization pressure

The analysis of physicochemical parameters revealed substantial spatial variability among monitored coastal sites. The strongest differences were observed for turbidity and dissolved oxygen, whereas conductivity, salinity, and pH remained comparatively more stable.

Table 8. Summary statistics of coastal water parameters

Parameter	Mean ± SD	Range
Temperature (°C)	15.4 ± 2.6	12.6–24.1
pH	8.5 ± 0.5	7.7–9.4
Turbidity (NTU)	26.3 ± 31.4	0.4–128
Dissolved oxygen (mg/L)	7.4 ± 2.0	4.4–11.5
Salinity (ppt)	33.9 ± 5.4	15.9–38.2

Turbidity values ranged from less than 1 NTU in relatively undisturbed locations to values exceeding 120 NTU within disturbed nearshore sectors exposed to increased sediment mobilisation. Elevated turbidity levels were mainly associated with sediment resuspension processes and local coastal disturbance. Dissolved oxygen concentrations varied between approximately 4.4 and 11.5 mg/L and exhibited heterogeneous spatial behaviour. Lower oxygen concentrations were observed at several

sheltered sites characterised by reduced circulation conditions, whereas some shallow-water locations with elevated turbidity also exhibited relatively high oxygen concentrations.

The highest variability was observed for turbidity, with a coefficient of variation of 119%, indicating strong spatial heterogeneity among sampling locations. Dissolved oxygen showed a coefficient of variation of 27%, reflecting moderate variability across the study area. In contrast, pH and salinity exhibited comparatively lower spatial fluctuations.

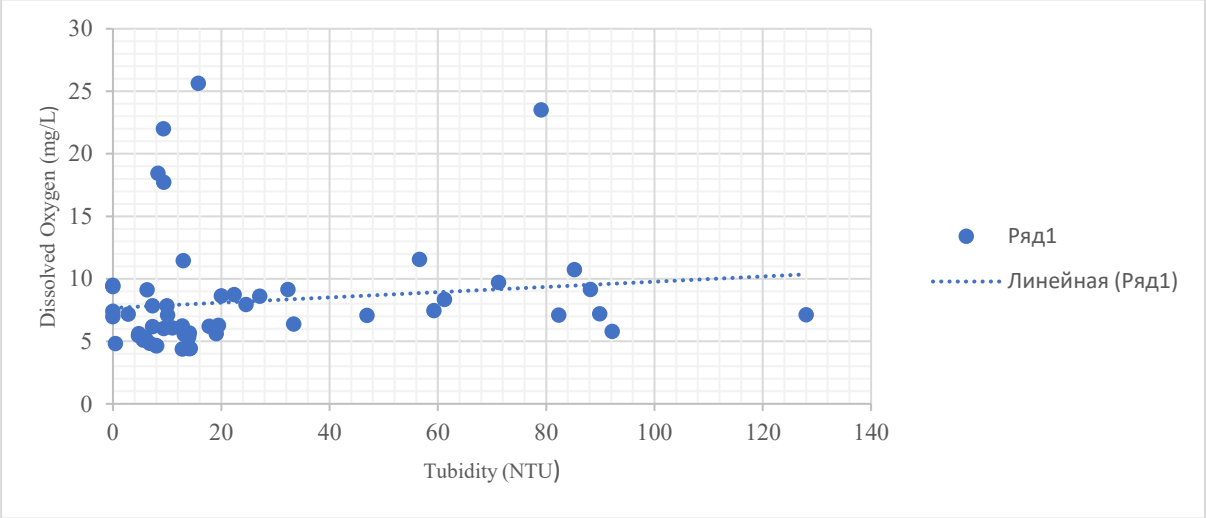


Figure 7. Relationship between turbidity and dissolved oxygen across sampling sites in the Gulf of Durrës

The observed patterns suggest that dissolved oxygen dynamics are influenced by multiple environmental processes rather than suspended sediment concentrations alone. Wave-induced mixing and nearshore turbulence may enhance atmospheric oxygen exchange and partially compensate for localized oxygen depletion (Islam and Tanaka, 2004; Cloern, 2001). In addition, local hydrodynamic conditions, water circulation patterns, and biological activity may contribute to the spatial variability observed across monitoring stations. These findings indicate that coastal environmental variability cannot be explained by a single dominant factor. Similar non-linear responses have been reported in other shallow coastal environments influenced by physical mixing processes and anthropogenic pressures (Islam and Tanaka, 2004; Cloern, 2001).

Integrated environmental pressure assessment

The Integrated Environmental Pressure Index (IEPI) was calculated by combining normalized embodied carbon intensity and coastal water variability indicators. The embodied carbon component produced a normalized value of 0.65, while the normalized coastal variability indicator was 0.613. Using equal weighting coefficients ($\alpha = \beta = 0.5$), the resulting IEPI value was 0.632. The obtained value indicates a high level of cumulative environmental pressure within the study area. The result reflects the combined influence of intensive material consumption during reconstruction activities and the observed spatial variability of coastal environmental conditions.

Although the index does not establish direct causal relationships, it provides a quantitative measure of the cumulative environmental stress associated with reconstruction and urban development processes. The results suggest that environmental impacts should be evaluated beyond individual sectors and considered within an integrated urban-coastal framework. The results indicate that environmental effects associated with post-earthquake reconstruction extend beyond the building scale and should be interpreted within a broader urban context.

Table 9. Integrated environmental indicators

Indicator	Value	Environmental interpretation
Mean embodied carbon intensity	0.325 t CO_2-eq/m^3	High material-related emissions
Turbidity coefficient of variation	1.194	High spatial variability
Dissolved oxygen coefficient of variation	0.270	Moderate spatial variability
Water variability indicator (WV)	0.732	Elevated environmental heterogeneity
Integrated Environmental Pressure Index (IEPI)	0.632	High cumulative environmental pressure

Figure 5 represents a conceptual representation of integrated environmental pressure pathways linking reconstruction-related embodied carbon and coastal environmental variability. The framework illustrates how different environmental dimensions may contribute to cumulative environmental stress within rapidly developing coastal urban systems.



Figure 8. Conceptual representation of integrated environmental pressure pathways

DISCUSSION

The results indicate that post-earthquake reconstruction may contribute to environmental pressure through two parallel pathways: increased embodied carbon emissions from construction materials and growing pressure on adjacent coastal ecosystems. Although these processes operate through different mechanisms, both are linked to the intensity of urban development and resource consumption.

The embodied carbon assessment showed an average emission intensity of 0.325 t CO_2-eq/m^3. This value is consistent with previous studies reporting that reinforced concrete remains one of the most carbon-intensive construction materials because of its dependence on cement production (Sefa et al., 2026; Habert et al., 2020; Monteiro et al., 2017). The contribution analysis confirmed that cement-related processes accounted for approximately 80–85% of total emissions. Similar proportions have been reported in life-cycle assessments of concrete structures, where clinker production represents the dominant source of greenhouse gas emissions (Habert et al., 2020; Sefa et al., 2026). These findings suggest that emission reduction strategies in reconstruction programmes should primarily focus on cement substitution, clinker reduction, and the adoption of lower-carbon concrete mixtures.

The probabilistic analysis demonstrated relatively limited variability in the estimated carbon footprint despite uncertainty in material quantities and emission factors. This result indicates that the overall environmental burden of the reconstruction programme is largely controlled by the volume of concrete used rather than by uncertainty in individual input parameters. Similar conclusions were reported by Lloyd and Ries (2007), who observed that large-scale construction assessments are often more sensitive to material consumption patterns than to variations in emission factors.

The coastal assessment revealed substantial spatial variability among sampling locations. Turbidity exhibited the highest coefficient of variation (119%), indicating strong environmental heterogeneity

within the Gulf of Durrës. Elevated turbidity values are commonly associated with sediment resuspension, shoreline disturbance, and increased terrestrial inputs (Islam and Tanaka, 2004; Cloern, 2001). Comparable patterns have been reported in other urbanized coastal environments, where localized human activities produce pronounced spatial differences in suspended sediment concentrations and water clarity (Islam and Tanaka, 2004).

Dissolved oxygen showed moderate variability across the study area. The weak relationship observed between turbidity and dissolved oxygen suggests that oxygen dynamics are influenced by multiple interacting processes. Hydrodynamic mixing, water circulation, temperature conditions, and biological activity may all affect oxygen concentrations independently of suspended sediment levels (Cloern, 2001). Similar non-linear responses have been documented in shallow coastal systems where physical mixing partially offsets localized environmental stress (Islam and Tanaka, 2004).

The findings are also consistent with recent investigations conducted in the Gulf of Durrës. Bakalli et al. (2025) reported considerable spatial and temporal variability in several physicochemical parameters, highlighting the influence of both natural processes and anthropogenic pressures on coastal water quality. The variability identified in the present study supports the interpretation that coastal environmental conditions in the area are controlled by multiple stressors rather than by a single dominant factor.

A key contribution of this study is the development of an integrated framework that combines embodied carbon assessment with coastal environmental indicators. Most previous investigations have examined these dimensions separately. Life-cycle assessment studies typically focus on material-related emissions (Habert et al., 2020; Monteiro et al., 2017), whereas coastal monitoring studies evaluate physicochemical conditions independently of construction-related impacts (Islam and Tanaka, 2004; Bakalli et al., 2025). By integrating both dimensions, the proposed approach provides a broader perspective on cumulative environmental pressure in rapidly developing coastal cities.

The calculated IEPI value (0.632) indicates a relatively high level of cumulative environmental pressure within the study area. This index should not be interpreted as evidence of direct causality between reconstruction activities and coastal environmental variability. Instead, it represents a synthetic indicator that combines two environmental dimensions affected by urban development. Similar composite approaches have been widely applied in environmental assessment to support comparative evaluation of complex systems where multiple pressures act simultaneously.

Several limitations should be considered when interpreting the results. The embodied carbon analysis was limited to cradle-to-gate stages (A1–A3) and did not include operational emissions, maintenance, or end-of-life processes. In addition, the coastal assessment was based on a restricted set of physicochemical indicators and a limited monitoring dataset. Future research should incorporate longer monitoring periods, broader ecological indicators, and expanded life-cycle boundaries to improve understanding of cumulative environmental impacts in post-disaster coastal environments.

CONCLUSIONS

Post-earthquake reconstruction in Durrës generated significant embodied carbon emissions due to the extensive use of reinforced concrete. The estimated average embodied carbon intensity reached 0.325 t CO_2-eq/m^3, while cement production accounted for the largest share of total emissions.

The coastal assessment revealed marked spatial variability among monitoring stations. Turbidity exhibited the highest variability (CV = 119%), indicating substantial differences in sediment-related conditions across the study area. Dissolved oxygen showed moderate variability (CV = 27%), reflecting the influence of multiple environmental processes acting simultaneously within the coastal system.

The integrated assessment produced an IEPI value of 0.632, which corresponds to a high level of cumulative environmental pressure. This result reflects the combined influence of material-related emissions and coastal environmental variability within a rapidly developing urban-coastal environment.

The results indicate that reconstruction impacts extend beyond individual buildings and should be assessed within the broader urban-coastal system. Construction-related emissions and environmental

conditions in adjacent coastal areas represent interconnected components of the broader urban system. Assessing these dimensions together provides a more comprehensive understanding of environmental pressure in post-disaster contexts.

Several limitations should be acknowledged. The embodied carbon assessment was restricted to cradle-to-gate processes (A1–A3), while the coastal analysis was based on a limited set of physicochemical indicators and a relatively small monitoring network. Future research should incorporate longer monitoring periods, additional ecological indicators, and broader life-cycle boundaries to improve the assessment of cumulative environmental impacts in coastal reconstruction projects.

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PHARMACEUTICAL COMPOUNDS IN TIRANA RIVER

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ABSTRACT

The aim of this study is to present data on the concentration levels of selected antibiotics and analgesics in water samples collected from the Tirana River. The investigated compounds include some of the most widely used pharmaceuticals from these classes, commonly administered in both hospital-based treatments and at-home therapies. The determination of antibiotics in aquatic environments is of particular importance, as their presence in surface waters has been associated with a reduction in their therapeutic effectiveness and the development of antimicrobial resistance. The qualitative and quantitative determination of antibiotics and analgesics in water samples was carried out using solid-phase extraction (SPE) followed by high-performance liquid chromatography coupled with a diode-array detector (HPLC/PAD). After validation of the analytical method, water samples were collected from seven different monitoring stations along the Tirana River, starting from the Tufina area and extending downstream to Rinas. It should be noted that in several sections of the river, untreated wastewater discharges are present, potentially contributing to pharmaceutical contamination. Sampling was conducted during three study periods, October 2025, December 2025 and February 2026. Sample preparation for the analyte isolation were performed using SPE techniques. Chromatographic analysis was carried out using an Agilent 1260 HPLC system equipped with a quaternary pump, column model Zorbax SB-C18 column (150 mm × 4.0 mm, 5 µm) and PAD dedector. Antibiotics were detected in around 50% of the analysed samples, while analgesics were identified in approximately 40% of them. The highest concentrations among antibiotics were attributed to tetracyclines, whereas ibuprofen was the most frequently detected compound among analgesics. These findings are mainly related to their extensive use in both hospital and non-hospital treatments, as well as to the physicochemical properties of the analysed compounds, which influence their persistence and distribution in aquatic environments.

Keywords: Tirana River, Antibiotics, Analgesics, SPE, Water analyse, HPLC/PAD

Introduction

In recent decades, the presence of pharmaceuticals in the aquatic environment has become one of the most important concerns in the field of environmental chemistry and toxicology. Active Pharmaceutical Ingredients (APIs), which include analgesics, antibiotics, hormones and other therapeutic drugs, are designed to be biologically active even at very low concentrations. Consequently, even traces of them in surface waters can have significant effects on aquatic ecosystems and potentially on human health. The main source of these pollutants is human activity. Pharmaceuticals are consumed on a large scale and a significant part of them is excreted unchanged or as active metabolites, entering sewage systems. Conventional wastewater treatment plants are not designed to completely eliminate these compounds, causing them to end up in rivers, lakes and other surface waters. Furthermore, other sources include discharges from the pharmaceutical industry, agricultural activities and veterinary use of antibiotics, which contribute to diffuse pollution of the aquatic environment.

Numerous studies at the global level have shown that analgesics and antibiotics are among the most widespread classes of drugs in surface waters. In some cases, their concentrations in untreated waters reach levels above 1 µg/L for analgesics such as paracetamol and ibuprofen, while antibiotics such as ciprofloxacin and clarithromycin have been reported at levels above 0.5 µg/L. These results indicate not

only the wide distribution of these compounds, but also the resistance of some of them to biological and chemical degradation processes.

In the context of developing countries, including the Balkan region, the problem is even more pronounced due to the lack of adequate infrastructure for wastewater treatment. A study conducted in Albania reported the presence of 19 pharmaceutical compounds in hospital wastewater, with antibiotics resulting in the highest concentrations. Similarly, a more recent study in the Ishëm River basin in Albania identified a wide range of drugs, including anti-inflammatories (ibuprofen, diclofenac) and antibiotics (ciprofloxacin, erythromycin), confirming the impact of urban activities and the lack of efficient water treatment.

The Tirana River represents a typical example of a water system exposed to intense anthropogenic pressure. Flowing through dense urban and peri-urban areas, this river receives significant loads from untreated wastewater, industrial activities and uncontrolled discharges. Under these conditions, the presence of medical drugs, especially analgesics and antibiotics, is expected and constitutes an important indicator of pollution associated with human activity.

The effects of drugs on the aquatic environment are multifaceted and often complex. Antibiotics are of particular concern due to their role in the development of antimicrobial resistance (AMR), which is considered one of the greatest global threats to public health. Their presence in water can select for resistant bacteria, creating a genetic reservoir that can be transmitted to human pathogens. On the other hand, analgesics and anti-inflammatories can cause toxic effects in aquatic organisms, affecting their physiological functions, reproduction and behavior.

Experimental studies and environmental monitoring have shown that even very low concentrations of drugs can have biological effects. For example, some pharmaceutical compounds have been reported to cause hormonal changes in fish and amphibians, as well as changes in the behavior of aquatic organisms. Also, chronic exposure to drug mixtures (cocktail effect) can lead to synergistic effects, which are difficult to predict and evaluate.

In many rivers around the world, including rivers in urban and peri-urban areas, the presence of a wide range of drugs including analgesics, antibiotics and other pharmaceutical compounds has been reported. Studies in small rivers affected by informal settlements have identified compounds such as paracetamol, diclofenac and trimethoprim, indicating the direct impact of wastewater discharges on water quality. These results are comparable to the situation in small urban rivers in the Balkan region, where the direct impact of human activity is dominant. Monitoring of pharmaceuticals in surface waters, especially in urban rivers such as the Tirana River, is essential to understand the extent of pollution and to assess the environmental risk. The use of advanced analytical techniques such as SPE followed by HPLC/PDA allows the identification and quantification of a wide range of compounds at very low concentrations, providing a powerful tool for environmental studies. The presence of pharmaceuticals in surface waters represents a complex and growing problem, closely linked to urban development and the intensive use of pharmaceuticals. Their study in rivers such as the Tirana River is essential to understand the impact of human activity on the environment and to develop effective strategies for the management and reduction of this type of pollution.

Materials and Methods

Sample Collection and Preservation

Water samples were collected from seven selected sampling sites of Tirana River (from Tufine to Rinas). Sampling were realized for three periods (October 2025, December 2025 and February 2026). Water samples were stored in pre-cleaned glass bottles at 4°C prior to analysis. Firstly, water samples were filtered to remove suspended particulate matter. For simultaneous extraction of analgesics (ibuprofen, paracetamol, nimesulide, diclofenac) and antibiotics (amoxicillin, tetracycline, ciprofloxacin), the pH of the samples was adjusted to 2.5–3.0 using HCl 1 N to enhance the retention of target compounds on the solid phase extraction.

Sample preparation

Solid-phase extraction (SPE) was performed using Oasis HLB cartridges (200 mg, 6 mL), which are suitable for compounds with a wide polarity range. The cartridges were conditioned sequentially with 5 mL methanol and 5 mL ultrapure water. Subsequently, 1000 mL of water sample was loaded at a flow rate of approximately 5 mL/min. After sample loading, the cartridges were washed with ultrapure water and dried under vacuum for 10–15 minutes. The analytes were eluted using 10 mL of methanol. The eluates were evaporated under nitrogen stream up to 1 mL (disolved in methanol) and transfered to chromatographic vial for HPLC/PAD analysis.

HPLC/PDA Analysis

Chromatographic analysis was carried out using a high-performance liquid chromatography system equipped with a photodiode array detector (HPLC/PDA). Separation was achieved on a reversed-phase C18 column (150 × 4.6 mm, 5 µm particle size). The mobile phase consisted of (A) aqueous acetic acid solution (1.5%) and (B) methanol.

A gradient elution program was applied as follows: starting at 90% A and 10% B, gradually decreasing A to 10% and increasing B to 90% over 25 minutes, followed by a re-equilibration step. The flow rate was set at 1.0 mL/min, and the column temperature was maintained at 30°C. The injection volume was 20 µL.

Detection was performed using a PDA detector at multiple wavelengths to ensure optimal sensitivity and selectivity for different analytes. Paracetamol was monitored at 224 nm, diclofenac and nimesulide were detected respectively at 254 and 276 nm, while ibuprofen was detected at 220 nm. Amocycycline was detected at 204 nm while Tetracycline and ciprofloxacin were additionally confirmed using higher wavelengths respectively at 351 nm and 278 nm due to their characteristic UV absorption spectra. Compound identification was based on their retention times.

Under the applied chromatographic conditions, paracetamol eluted at approximately 3 minutes, followed by ciprofloxacin and amoxicillin (4–6 min), while tetracycline appeared at around 7 minutes. The more hydrophobic NSAIDs showed longer retention times, with nimesulide eluting at 14 minutes, ibuprofen and diclofenac were the last at approximately 18-21 minutes.

Method Validation

The analytical method was validated according to international guidelines (ICH, EU) by evaluating linearity, sensitivity, precision, accuracy, and recovery. Calibration curves were constructed using standard solutions at concentrations ranging from 0.05 to 50 µg/L, showing good linearity with correlation coefficients (R^2) higher than 0.995 for all target compounds.

Limits of detection (LOD) and quantification (LOQ) were determined based on signal-to-noise ratios of 3 and 10, respectively, and were typically in the range of 1–50 ng/L (LOD) and 5–150 ng/L (LOQ). Precision was assessed in terms of repeatability and reproducibility, expressed as relative standard deviation (RSD), which was generally below 10%. Recovery studies were performed by spiking water samples at different concentration levels, yielding recoveries between 75% and 110% for both analgesics and antibiotics. Matrix effects were evaluated by comparing calibration curves prepared in ultrapure water and real water samples. The method demonstrated good robustness, selectivity, and suitability for the simultaneous determination of multi-class pharmaceutical residues in environmental water samples.

Results and Discusions

The occurrence and distribution of selected analgesics and antibiotics in the Tirana River were investigated over three sampling campaigns conducted in October 2025, December 2025, and February 2026 using HPLC/PAD analysis. The results reveal the presence of all target compounds at low but detectable concentrations, with clear spatial and seasonal variations across the sampling sites.

For analgesics, including paracetamol, nimesulide, diclofenac, and ibuprofen, the concentrations were generally low, ranging from non-detectable levels up to 0.07 µg/L for the total analgesic load. In October

2025, the mean total concentration (∑Analgesics) was 0.02 µg/L, with the highest levels observed at Laknas (0.06 µg/L) and Rinas (0.05 µg/L). Among individual compounds, ibuprofen and paracetamol were the most frequently detected, each showing mean values of approximately 0.01 µg/L. Diclofenac was detected at minimal levels, often close to the detection limit. In December 2025, a slight increase in total analgesic concentration was observed (mean 0.04 µg/L), suggesting increased anthropogenic input, possibly linked to seasonal factors such as higher pharmaceutical consumption during winter. Ibuprofen again showed the highest individual contribution (mean 0.02 µg/L), while nimesulide and diclofenac also displayed measurable concentrations. By February 2026, a general decrease in concentrations was noted (mean ∑Analgesics = 0.01 µg/L), which may be attributed to dilution effects, reduced usage, or enhanced degradation processes under colder conditions.

Regarding antibiotics, including ciprofloxacin, amoxicillin, and tetracycline, the results indicate a different distribution pattern. Tetracycline was consistently the dominant compound across all sampling periods, with mean concentrations ranging from 0.02 to 0.03 µg/L. In October 2025, the total antibiotic concentration reached a mean of 0.04 µg/L, with the highest levels observed at Paskuqan 1 and Ura e Institutit (0.06 µg/L). Ciprofloxacin and amoxicillin were detected at lower levels, often near or below 0.01 µg/L. In December 2025, the total antibiotic concentration slightly decreased (mean 0.03 µg/L), with tetracycline remaining the predominant compound. Interestingly, ciprofloxacin was not detected during this period, suggesting either reduced input or rapid degradation. In February 2026, antibiotic concentrations remained relatively stable (mean 0.03 µg/L), with localized peaks (up to 0.07 µg/L) observed again at Paskuqan 1, indicating potential point sources such as untreated wastewater discharges.

Table 1.

	Tirana River, October 2025				Tirana River, December 2025				Tirana River, February 2026			
	Mean	Min	Max	STDEV	Mean	Min	Max	STDEV	Mean	Min	Max	STDEV
Paracetamol	0.01	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
Nimesulide	0.01	0.00	0.02	0.01	0.01	0.00	0.02	0.01	0.00	0.00	0.02	0.01
Diclofenac	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.00	0.00	0.01	0.00
Ibuprofen	0.01	0.00	0.02	0.01	0.02	0.00	0.03	0.01	0.01	0.00	0.02	0.01

Table 2.

	Tirana River, October 2025				Tirana River, December 2025				Tirana River, February 2026			
	Mean	Min	Max	STDEV	Mean	Min	Max	STDEV	Mean	Min	Max	STDEV
Ciproflaxin	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Amoxycyclin	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.01	0.00	0.03	0.01
Tetracycline	0.03	0.01	0.06	0.02	0.02	0.01	0.03	0.01	0.02	0.01	0.05	0.01

Spatially, the data clearly show that downstream sites, particularly Paskuqan, Laknas, and Rinas, exhibited higher concentrations of both analgesics and antibiotics compared to upstream locations such as Tufina and Bathore. This trend reflects the increasing impact of urbanization, population density, and insufficient wastewater treatment infrastructure along the river course. The presence of pharmaceutical residues even at upstream sites, although at lower levels, suggests diffuse pollution sources or upstream contamination inputs.

When compared with similar studies in European and Mediterranean rivers, the detected concentrations in the Tirana River fall within the lower to moderate range. For example, studies by aus der Beek et al. (2016) and Verlicchi et al. (2012) report typical concentrations of common pharmaceuticals in surface waters ranging from ng/L to low µg/L levels, consistent with the findings of this study. Ibuprofen and diclofenac are frequently reported as dominant analgesics in aquatic environments due to their widespread use and persistence (Zhang et al., 2008). Similarly, tetracycline is commonly detected among antibiotics because of its extensive application and relatively high environmental stability (Kümmerer, 2009).

The seasonal variation observed in this study aligns with findings from other research, where higher pharmaceutical concentrations are often recorded during colder months due to increased consumption and reduced biodegradation rates (Vieno et al., 2005). However, the slight decrease observed in February 2026 suggests that hydrological factors such as increased flow or dilution may also play a significant role.

From an environmental perspective, although the detected concentrations are relatively low, the continuous input of pharmaceuticals into aquatic ecosystems raises concerns about long-term ecological effects. Chronic exposure, even at low concentrations, can affect aquatic organisms, contribute to antibiotic resistance, and disrupt ecosystem balance (Kümmerer, 2009; aus der Beek et al., 2016). The presence of multiple compounds simultaneously also suggests potential mixture effects, which are not fully understood but may enhance toxicity.

In conclusion, the results demonstrate that the Tirana River is impacted by pharmaceutical pollution, with both analgesics and antibiotics present at detectable levels across all sampling periods. The spatial and temporal patterns indicate that urban discharge and seasonal factors significantly influence contamination levels. These findings highlight the need for improved wastewater treatment, regular environmental monitoring, and the implementation of strategies to reduce pharmaceutical emissions into aquatic systems.

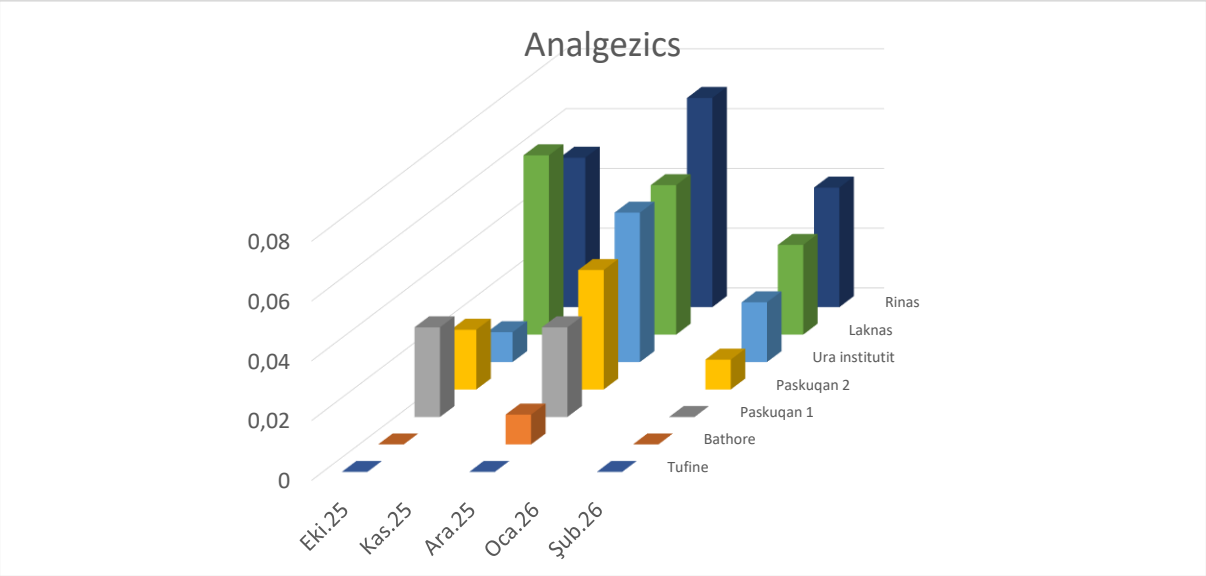


Figure 1. Analgesics at stations of Tirana River for all samples

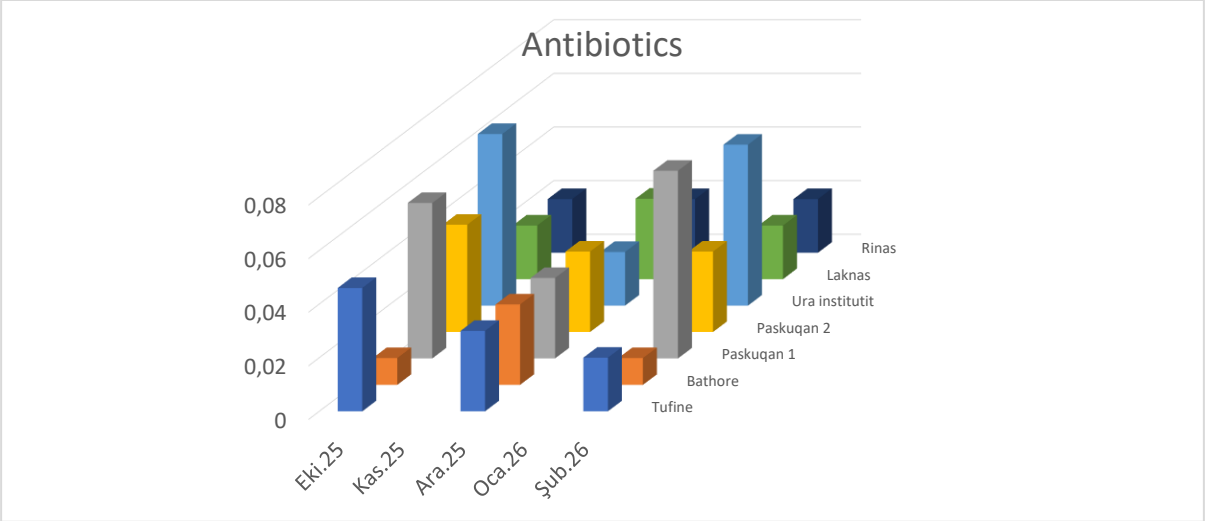


Figure 2. Antibiotics at stations of Tirana River for all samples

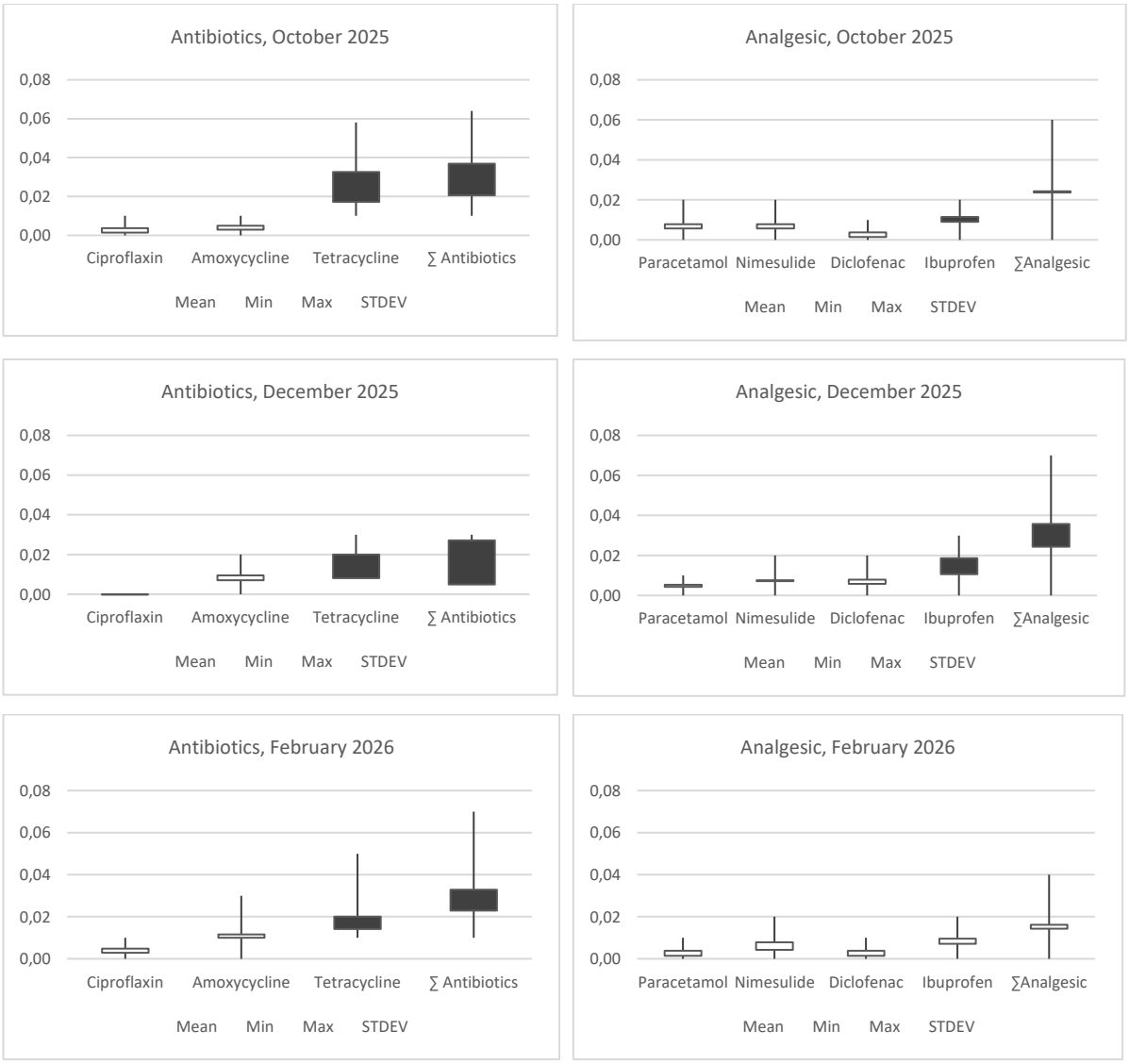


Figure 3. Analgesics and antibiotics in water samples of Tirana River for three periods (October 2025, December 2025 and February 2026)

Conclusions

Based on the obtained results, it can be concluded that the Tirana River is consistently affected by the presence of pharmaceutical residues, including both analgesics and antibiotics, across all monitored periods. Although the detected concentrations were generally low (in the range of ng/L to low µg/L), their continuous occurrence indicates a persistent input of these contaminants into the aquatic environment.

Among analgesics, ibuprofen and paracetamol were the most frequently detected compounds, while diclofenac and nimesulide appeared at lower levels. The total concentration of analgesics showed moderate seasonal variability, with slightly higher values observed during December 2025, likely reflecting increased pharmaceutical consumption during colder months. In contrast, antibiotic contamination was dominated by tetracycline, which exhibited the highest and most consistent concentrations across all sampling campaigns. The presence of amoxicillin and ciprofloxacin at lower levels suggests variable usage patterns and/or differences in environmental persistence.

Spatial analysis revealed that downstream locations such as Paskuqan, Laknas, and Rinas were more impacted compared to upstream sites, highlighting the influence of urban activities, population density, and untreated or insufficiently treated wastewater discharges. These findings clearly indicate that anthropogenic pressures are a major factor controlling the distribution of pharmaceutical contaminants in the river.

Despite the relatively low concentrations, the continuous discharge of these compounds raises concerns regarding their long-term ecological impact. Chronic exposure to pharmaceuticals may contribute to the development of antibiotic-resistant bacteria, affect aquatic organisms, and lead to subtle but significant disruptions in ecosystem functioning. Furthermore, the coexistence of multiple compounds suggests potential mixture effects, which may enhance overall toxicity even at low individual concentrations.

In conclusion, this study highlights the need for improved wastewater treatment infrastructure, regular environmental monitoring, and the implementation of strategies aimed at reducing pharmaceutical pollution. These measures are essential to protect aquatic ecosystems and to ensure the sustainable management of water resources in the Tirana River basin.

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EXPLAINABLE ARTIFICIAL INTELLIGENCE DEFINES TRANSCRIPTOMIC ARCHITECTURES OF COLORECTAL CANCER USING OPEN GENOMIC DATA

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ABSTRACT

Colorectal cancer is characterized by coordinated transcriptomic programs involving epithelial remodeling, stromal activation, angiogenesis, non-coding RNA dysregulation and Wnt-associated signaling. This study used open TCGA-COAD RNA-seq data to define tumor-normal transcriptomic architecture through an integrated computational workflow combining normalized-expression statistics, confirmatory negative-binomial count modeling and explainable machine learning. The final matrix contained 499 samples, including 458 primary tumors and 41 solid-tissue normal samples, with 17,976 filtered genes retained for analysis. Welch testing on log2(CPM+1) values identified 3,210 significant genes, comprising 1,471 tumor-upregulated and 1,739 tumor-downregulated transcripts. Count-scale negative-binomial generalized linear modeling identified 5,444 significant genes and showed strong concordance with normalized-expression effect sizes (Pearson r=0.822; 3,004 genes with same-direction overlap). Explainable machine-learning models separated tumor from normal samples with perfect held-out performance in this dataset and highlighted biologically interpretable features including ETV4, OTOP2, CDH3, SLCO4A1, ESM1, CEMIP, SALL4, CLDN1, CA7 and AJUBA. The resulting architecture supports a reproducible colorectal cancer expression program dominated by extracellular-matrix remodeling, endothelial activation, epithelial lineage disruption, developmental transcriptional reprogramming and non-coding RNA activity.

Keywords: colorectal cancer; TCGA-COAD; RNA-seq; explainable artificial intelligence; negative-binomial modeling; transcriptomics; Wnt/beta-catenin; open genomic data

INTRODUCTION

Colorectal cancer develops through progressive genomic and epigenomic changes that reshape epithelial identity, cell-matrix interaction, angiogenic signaling, immune communication and developmental transcriptional control. Transcriptomic profiling is particularly informative because it captures these processes as coordinated expression programs rather than isolated molecular events.

Open genomic repositories such as The Cancer Genome Atlas provide an opportunity to interrogate colorectal cancer with transparent and reproducible computational workflows. In this setting, explainable artificial intelligence is not used only for prediction; it also helps prioritize transcriptomic features that define the separation between tumor and normal tissue and that can be interpreted in light of known colorectal cancer biology.

The present study therefore integrated TCGA-COAD RNA-seq gene-count data, tumor-normal differential expression, negative-binomial RNA-seq modeling, machine-learning feature attribution and PubMed-supported biological interpretation. The biological interpretation was grounded in colorectal cancer literature on Wnt/beta-catenin regulation, extracellular-matrix remodeling, angiogenesis, invasion and non-coding RNA biology (Miwa et al., 2001; Bian et al., 2020; Disoma et al., 2022). The

aim was to construct a coherent molecular cartography of colorectal cancer transcriptomic architecture using open genomic data.

MATERIALS AND METHODS

Data source and cohort definition. Open-access TCGA-COAD RNA-seq STAR gene-count files and clinical metadata were obtained from the Genomic Data Commons. Sample type, project identity, patient barcode and file metadata were audited before matrix construction. Recurrent technical or duplicated entries were removed so that the retained expression matrix represented biologically interpretable tumor-normal comparisons.

Expression preprocessing. Raw gene-level counts were assembled into a sample-by-gene matrix. Genes with inadequate expression were removed, leaving 17,976 genes from 60,660 raw gene rows. Library sizes were calculated for quality control. Counts were transformed to counts per million and analyzed as log2(CPM+1) for visualization, dimensionality reduction and normalized-expression differential testing.

Differential expression analysis. Tumor-normal contrasts were first screened using Welch statistics on log2(CPM+1) values, followed by Benjamini-Hochberg false-discovery-rate correction. Genes were considered differentially expressed when adjusted $p<0.05$ and absolute log2 fold change exceeded 1. This screen was used to estimate normalized-expression effect sizes and to identify ranked marker transcripts.

Confirmatory negative-binomial RNA-seq modeling. To evaluate count-scale robustness, each filtered gene was additionally modeled using a negative-binomial generalized linear model with log link. Raw counts were modeled as the response, tumor-normal status was entered as the primary predictor and log-library size was included as an offset. The resulting tumor-normal log2 rate ratios were corrected for multiple testing and compared with normalized-expression log2 fold changes.

Explainable machine learning. Tumor-normal classification was performed with logistic regression and random forest models using highly variable genes. Model performance was assessed with cross-validation and held-out testing. Random-forest feature importance was used as an explainable artificial-intelligence layer to identify transcripts contributing most strongly to tumor-normal discrimination. These features were interpreted as candidate architectural markers rather than as clinically validated diagnostic biomarkers.

Survival and literature interpretation. Clinical metadata were used for an exploratory univariable survival screen among data-derived candidates. Gene-level biological interpretation was supported by open PubMed-indexed literature, focusing on colorectal cancer studies describing matrix remodeling, angiogenesis, epithelial-mesenchymal transition, Wnt/beta-catenin signaling, stemness and non-coding RNA regulation.

Table 1. Cohort and analytical dataset summary.

Variable	Value
Project	TCGA-COAD
Retained RNA-seq samples	499
Primary tumor / normal	458 / 41
Raw gene rows / filtered genes	60,660 / 17,976
Clinical cases	461
Median age	68.3 years

RESULTS

The final analytical cohort contained 499 RNA-seq samples: 458 primary tumor samples and 41 solid-tissue normal samples. Clinical metadata included 461 cases; median age was 68.3 years, stage was available for 374 cases and survival time was available for 458 cases. Principal-component analysis demonstrated marked tumor-normal separation, indicating that disease status was a dominant axis of transcriptomic variation.

Normalized-expression testing identified 3,210 significant differentially expressed genes. Tumor-upregulated transcripts numbered 1,471, whereas 1,739 transcripts were downregulated in tumor. The leading tumor-upregulated genes included ESM1, SIM2, COL11A1, CRNDE, OTX1, SALL4, CST1, DDN, CPNE7 and LINC02418, collectively pointing to endothelial activation, extracellular-matrix remodeling, developmental transcriptional reprogramming and non-coding RNA dysregulation.

Negative-binomial modeling was successful for all 17,976 filtered genes. It identified 5,444 significant genes, including 3,474 tumor-upregulated and 1,970 tumor-downregulated genes. Concordance analysis showed 3,004 same-direction overlapping genes between the normalized-expression and negative-binomial analyses, with Pearson correlation r=0.822 between effect-size estimates.

The machine-learning layer separated tumor from normal samples with ROC-AUC and held-out accuracy of 1.000 for both logistic regression and random forest models. This result reflects the strong biological contrast between tumor and normal tissue in the dataset and should not be read as evidence of immediate clinical diagnostic readiness. The explainable random-forest feature set was nevertheless biologically coherent, prioritizing ETV4, OTOP2, CDH3, SLCO4A1, ESM1, CEMIP, SALL4, CLDN1, CA7 and AJUBA.

Exploratory survival screening among data-derived candidate genes identified ELFN1-AS1 as the lowest-ranked log-rank signal (n=434, events=95, p=0.0043). Because this analysis was univariable and median-dichotomized, it is best interpreted as hypothesis-generating rather than confirmatory prognostic evidence.

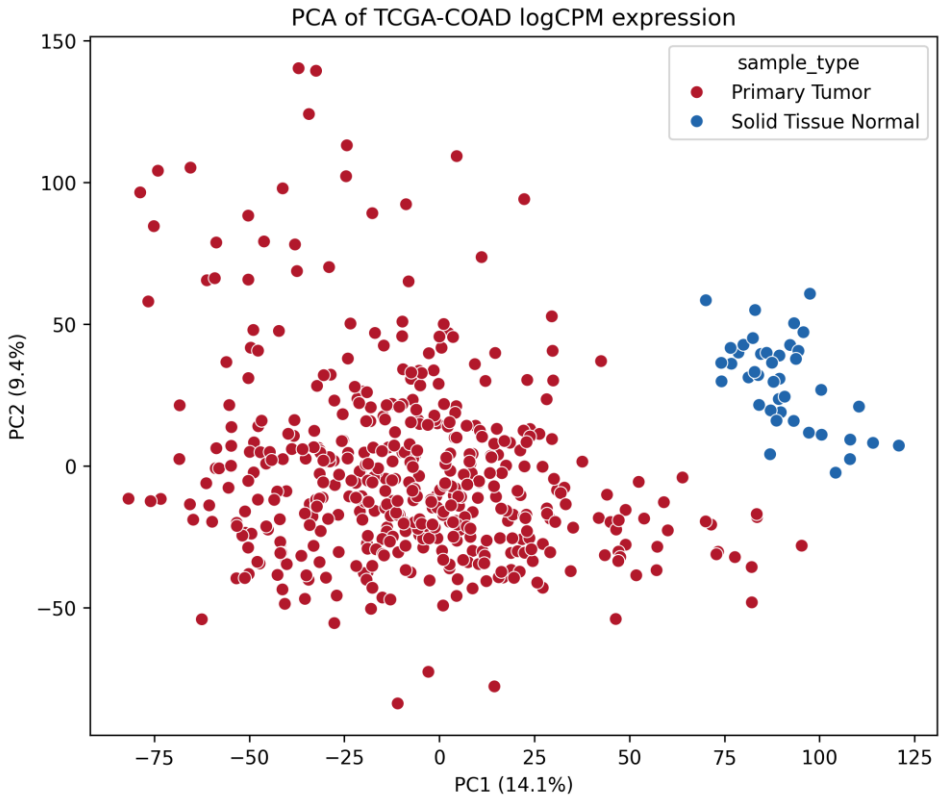


Figure 1. Principal-component analysis of TCGA-COAD tumor and normal RNA-seq profiles.

Table 2. Leading normalized-expression differentially expressed genes.

Gene	log2FC	FDR	Direction
ESM1	2.73	2.65e-220	Upregulated
SIM2	3.18	1.68e-201	Upregulated
COL11A1	3.93	4.09e-150	Upregulated
CRNDE	2.36	5.89e-150	Upregulated
OTX1	1.79	2.51e-148	Upregulated
SALL4	2.22	9.75e-145	Upregulated
CST1	3.54	1.27e-142	Upregulated
DDN	1.72	1.47e-142	Upregulated
CPNE7	3.86	1.07e-141	Upregulated
LINC02418	3.51	3.88e-135	Upregulated

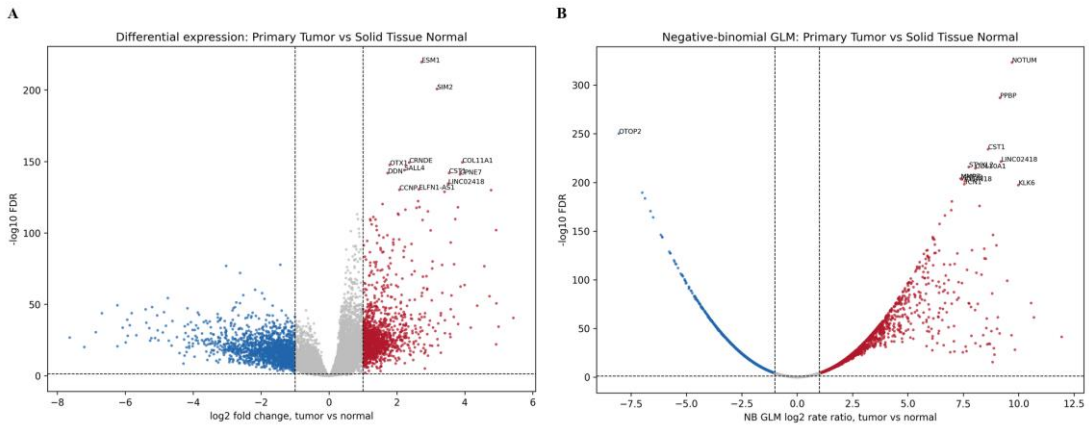


Figure 2. Differential expression and count-scale confirmation. A, normalized-expression volcano plot; B, negative-binomial GLM volcano plot.

Table 3. Cross-method evidence supporting the transcriptomic architecture.

Metric	Result
Welch significant DEGs	3,210
NB significant genes	5,444
Same-direction overlap	3,004
Effect-size correlation	r=0.822
Random forest test ROC-AUC	1.000
Logistic regression test ROC-AUC	1.000

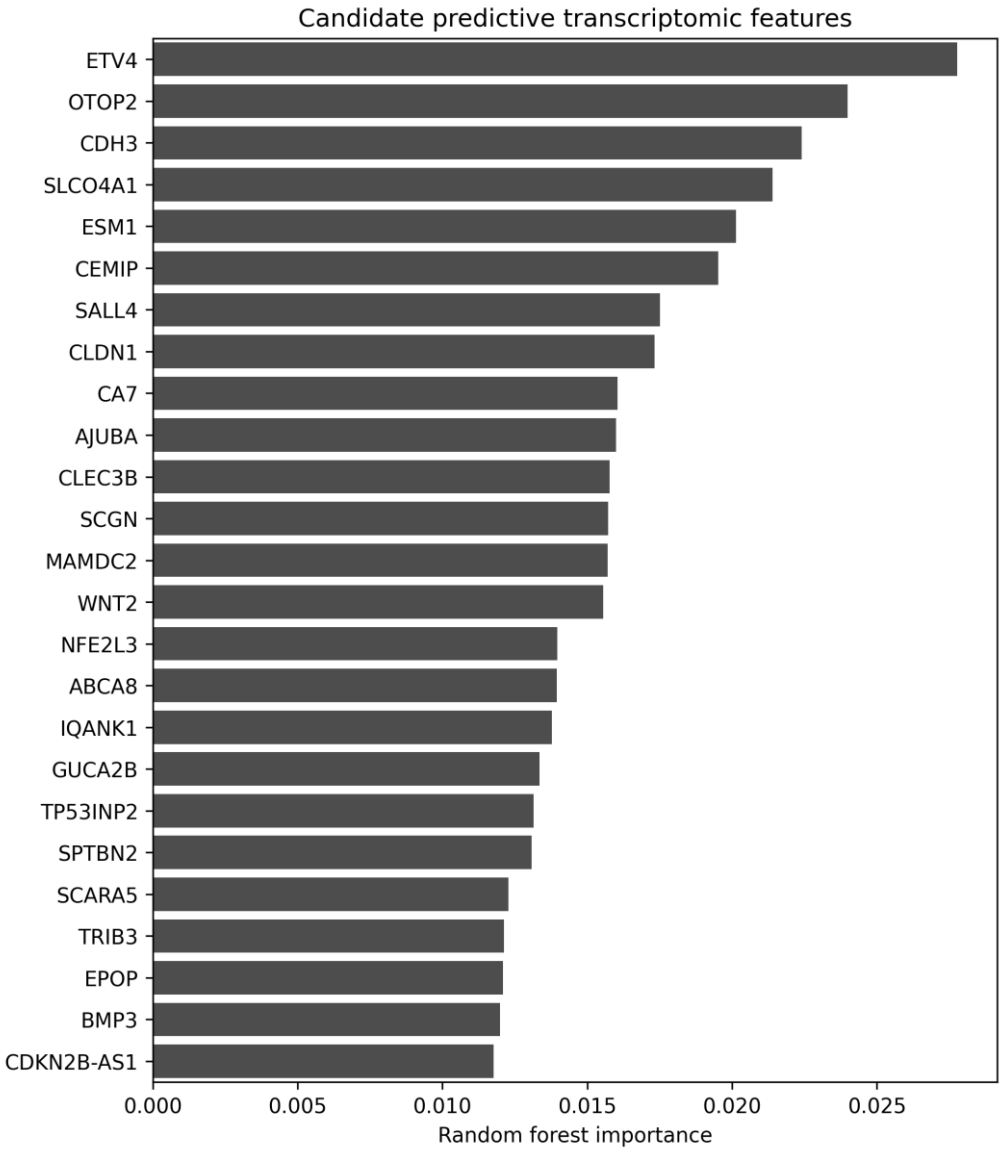


Figure 3. Explainable random-forest feature importance for tumor-normal discrimination.

Table 4. Top explainable machine-learning transcriptomic features.

Gene	Importance	Gene type
ETV4	0.0278	protein_coding
OTOP2	0.0240	protein_coding
CDH3	0.0224	protein_coding
SLCO4A1	0.0214	protein_coding
ESM1	0.0201	protein_coding
CEMIP	0.0195	protein_coding
SALL4	0.0175	protein_coding
CLDN1	0.0173	protein_coding

CA7	0.0160	protein_coding
AJUBA	0.0160	protein_coding

DISCUSSION

The integrated results define a reproducible tumor-normal transcriptomic architecture in colorectal cancer. Three layers of evidence converged: normalized-expression differential testing, count-scale negative-binomial modeling and explainable machine-learning feature attribution. The strongest biological programs included extracellular-matrix remodeling, endothelial and angiogenic activation, epithelial differentiation disruption, Wnt-associated developmental regulation and non-coding RNA dysregulation.

Extracellular-matrix remodeling was represented by COL11A1 and COL10A1. COL11A1 has been reported as differentially expressed and prognostically relevant in colorectal carcinoma (Patra et al., 2021), while high COL10A1 expression has been associated with poor prognosis (Huang et al., 2018). Their prominence in the present analysis supports a matrix-rich stromal and invasive component within the TCGA-COAD tumor transcriptome.

Angiogenic biology was represented by ESM1, the top normalized-expression DEG and one of the important random-forest features. Experimental colorectal cancer work has linked ESM1 to PI3K/Akt/mTOR activation and angiogenesis (Yang et al., 2023), supporting the interpretation that endothelial-associated activation is part of the tumor-normal expression architecture.

Epithelial differentiation and invasion-associated transcripts included KRT80, CLDN1, OTX1 and CDH3. KRT80 has been reported to promote migration and invasion through PRKDC/AKT signaling (Li et al., 2018), CLDN1 has been connected with beta-catenin/Tcf signaling and frequent colorectal cancer upregulation (Miwa et al., 2001), and OTX1 has been linked to epithelial-mesenchymal transition (Yu et al., 2014). These findings are consistent with a tumor program involving altered epithelial identity and invasive behavior.

Developmental and Wnt-associated transcriptional regulation was represented by SALL4, SIM2, CEMIP and WNT-related feature patterns. SALL4 expression has been associated with colorectal cancer progression and beta-catenin signaling (Forghanifard et al., 2013; Hao et al., 2016), and SIM2 activation has been linked to colorectal cancer progression in lncRNA-mediated regulation (Jin et al., 2018). CEMIP has been described as a regulator of colorectal cancer metastasis through metabolic reprogramming and reciprocal beta-catenin regulation (Hua et al., 2021). These observations align with the central role of Wnt/beta-catenin signaling in colorectal cancer biology (Bian et al., 2020; Disoma et al., 2022).

Non-coding RNA dysregulation was represented by CRNDE, BLACAT1, LINC02418 and ELFN1-AS1. CRNDE and BLACAT1 have been experimentally linked to colorectal cancer proliferation and epigenetic regulation (Ding et al., 2017; Su et al., 2017). ELFN1-AS1 showed the strongest exploratory survival signal in this dataset, suggesting that long non-coding RNA programs may carry additional biological and prognostic information requiring independent validation.

The study has limitations. The normal cohort was smaller than the tumor cohort, and the negative-binomial model used a fixed-dispersion implementation rather than a full empirical-Bayes RNA-seq framework. Machine-learning performance was evaluated on a tumor-versus-normal task and may overstate clinical utility. Therefore, the results should be interpreted as an open-data molecular cartography and candidate-generating analysis, not as a validated clinical assay.

CONCLUSION

Open TCGA-COAD RNA-seq data reveal a strongly structured colorectal cancer transcriptome. Differential expression, confirmatory negative-binomial modeling and explainable artificial intelligence converged on biologically coherent modules involving matrix remodeling, angiogenesis, epithelial

invasion, Wnt/developmental signaling and non-coding RNA regulation. These findings provide a transparent transcriptomic framework for future validation studies using independent cohorts, spatial profiling and experimental functional assays.

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ARTIFICIAL INTELLIGENCE-DRIVEN PREDICTIVE DECISION SUPPORT SYSTEMS FOR STRATEGIC RESILIENCE IN SMALL AND MEDIUM-SIZED ENTERPRISES

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ABSTRACT

Small and medium-sized enterprises (SMEs) increasingly operate under conditions in which volatility, fragmented information, and constrained managerial capacity weaken the quality of strategic decisions. This study develops a literature-based analytical review of artificial intelligence-driven predictive decision support systems as a strategic capability for enhancing SME resilience, organizational intelligence and long-term performance. The study integrates evidence from artificial intelligence, business analytics, machine learning, SME digital transformation, strategic management, organizational resilience and decision science. Rather than treating digitalization as a generic process of technology adoption, the paper conceptualizes predictive decision support as an adaptive architecture through which heterogeneous business data can be converted into anticipatory managerial knowledge. Particular attention is given to machine learning forecasting, scenario modelling, business intelligence ecosystems, risk anticipation, digital maturity, data-driven governance and strategic agility. The analysis argues that AI-enabled predictive systems can shift SME decision-making from retrospective control toward prospective and adaptive governance. Machine learning models may support early detection of operational, financial and market-related risks; improve resource allocation under uncertainty; identify emerging demand patterns; strengthen financial sustainability; and assist business continuity planning during disruptive events. The scientific contribution of the study lies in positioning artificial intelligence not merely as an operational tool, but as an organizational capability that restructures how SMEs perceive uncertainty, evaluate alternatives and coordinate strategic responses. The proposed framework highlights the importance of explainable analytics, managerial interpretability, data quality and governance readiness for transforming predictive insight into sustainable competitive advantage.

Keywords: Artificial Intelligence; Predictive Analytics; Decision Support Systems; SME Resilience; Strategic Agility; Business Analytics

INTRODUCTION

Small and medium-sized enterprises are central to employment, innovation and regional development, yet they often make strategic decisions under severe informational and resource constraints. Their exposure to demand volatility, supply disruptions, inflationary pressure, digital-platform competition and regulatory change makes resilience a managerial requirement rather than an optional organizational attribute. Recent European statistical evidence shows that enterprise AI adoption is increasing, but adoption remains uneven by firm size and digital maturity; Eurostat reports that the share of EU enterprises using AI rose substantially in 2025, while larger enterprises remain far ahead of smaller ones (Eurostat, 2025a). This imbalance matters because predictive intelligence increasingly determines how firms sense risk, allocate resources and respond to emerging market signals.

The strategic problem for SMEs is not simply whether they adopt a particular digital tool. The deeper problem concerns how they transform dispersed operational, financial, customer and supplier information into decisions that are timely, interpretable and aligned with organizational priorities. OECD work on AI adoption by SMEs emphasizes that connectivity, AI-enabling data assets, managerial skills and access to finance shape whether smaller firms can move from experimentation to value-generating adoption (OECD, 2025a). In the Bulgarian and Balkan SME context, Iliev's research on MSME growth challenges similarly shows that small firms encounter intertwined constraints in finance,

marketing, management and human resources, which restrict their ability to scale and compete (Iliev, 2024a).

Artificial intelligence-driven predictive decision support systems (AI-PDSS) are therefore important because they connect technology adoption with strategic decision quality. A predictive decision support system does not merely present historical indicators; it estimates future states, identifies weak signals, supports scenario comparison and provides evidence that managers can use when choosing among strategic alternatives. This study examines AI-PDSS as a resilience-building capability for SMEs. It asks how predictive analytics differs from traditional business intelligence, which machine-learning approaches are relevant for SME decision support, how AI systems may enhance resilience and strategic agility, and which governance conditions are required to translate predictive insight into sustainable advantage.

ANALYTICAL REVIEW DESIGN

This paper is designed as a systematic literature-based analytical review rather than an empirical field study. The review draws on peer-reviewed research in decision support systems, business analytics, AI adoption, organizational resilience and SME digital transformation, supplemented by high-quality policy evidence from OECD, Eurostat, the European Commission and NIST. The analytical logic follows an integrative review approach: concepts from multiple disciplines are synthesized to construct a framework explaining how AI capability can become predictive insight, how predictive insight can improve decision quality and how improved decision quality can support organizational resilience.

The literature selection prioritized recent sources from 2024 to 2026 where available, especially studies and reports concerning AI adoption in enterprises, generative AI in work processes, SME digitalization, supply-chain resilience, trustworthy AI and human-AI decision making. Foundational sources were also included when they provide established theoretical anchors, including decision support systems (Gorry & Scott Morton, 1971), dynamic capabilities (Teece et al., 1997), organizational resilience (Duchek, 2020) and business analytics capability (Davenport & Harris, 2007). Iliev's recent studies were incorporated because they directly address MSME growth, scaling and AI-enabled marketing in contexts relevant to the author's institutional and regional setting (Iliev, 2024a, 2024b, 2025).

The review did not attempt to quantify a pooled effect size. Instead, it identifies recurring mechanisms in the literature and organizes them into a conceptual model. These mechanisms include data integration, forecasting, early-warning detection, managerial interpretation, scenario-based action, feedback learning and governance readiness. This design is appropriate because the empirical literature on AI-PDSS in SMEs remains fragmented: some studies focus on productivity, some on innovation, some on supply-chain resilience, and others on human-AI decision quality.

Table 1. Analytical scope of the literature-based review.

Dimension	Focus in this study	Representative sources
Decision support	Evolution from DSS and business intelligence to predictive and AI-enabled decision architectures.	Gorry & Scott Morton (1971); Davenport & Harris (2007)
SME digital transformation	Digital maturity, AI adoption constraints, finance, skills and organizational readiness.	OECD (2025a); Eurostat (2025a, 2025b); Iliev (2024a, 2024b)
Predictive analytics	Forecasting, classification, anomaly detection, risk anticipation and scenario modelling.	Brynjolfsson et al. (2025); NIST (2024)
Resilience and agility	Anticipation, absorption, adaptation, recovery and strategic reconfiguration.	Duchek (2020); Teece et al. (1997); Dai & Zhang (2026)

Dimension	Focus in this study	Representative sources
Governance	Explainability, human oversight, AI risk management and regulatory implications.	European Commission (2024); NIST (2024); OECD (2024)

FROM BUSINESS INTELLIGENCE TO PREDICTIVE DECISION SUPPORT

Traditional business intelligence systems are primarily retrospective. They collect, clean and visualize historical data so that managers can monitor performance, identify deviations and prepare reports. This remains important for SMEs because many smaller firms still lack reliable dashboards, data governance routines and cross-functional performance indicators. However, retrospective intelligence is insufficient when the firm must anticipate disruptions before they appear in financial statements or sales reports. Predictive decision support extends business intelligence by using statistical learning, machine learning and scenario modelling to estimate likely future conditions and the uncertainty surrounding them.

In this sense, predictive analytics changes the temporal orientation of management. Instead of asking only what happened and why it happened, predictive DSS asks what is likely to happen, which signals indicate emerging risk, which alternatives are available and which managerial action is justified under uncertainty. The strategic value of AI arises when this predictive layer is embedded into routines of decision making, not when a model is isolated from managerial action. This is consistent with the business analytics view that data only creates value when it is linked to decision processes, organizational capabilities and performance management (Davenport & Harris, 2007).

For SMEs, AI-PDSS may include demand forecasting, cash-flow prediction, customer churn detection, supplier risk monitoring, inventory optimization, credit-risk assessment, marketing-response prediction and early-warning indicators for operational disruption. Machine learning approaches such as random forests, gradient boosting and XGBoost are often useful for tabular SME data because they handle nonlinear relationships and interactions between variables. Time-series models support demand and cash-flow forecasting. Large language models may support interpretation, retrieval, narrative reporting and managerial interaction, but they require careful grounding, verification and governance because generative systems can produce plausible but incorrect outputs (NIST, 2024).

The evolution from business intelligence to predictive decision support therefore involves three shifts: from reporting to anticipation, from isolated dashboards to decision architectures and from human-only interpretation to human-AI collaboration. The final shift is especially important. Human-AI systems must be evaluated as socio-technical systems because better model accuracy does not automatically produce better human decisions. Recent work on AI-assisted decision making stresses the importance of comparing human-alone, AI-alone and human-with-AI performance rather than assuming that the hybrid system will always be superior (Ben-Michael et al., 2025).

AI CAPABILITY AS A STRATEGIC SME RESOURCE

The strategic management literature suggests that competitive advantage depends not only on resource possession but also on the ability to integrate, reconfigure and deploy resources under changing conditions. Dynamic capabilities theory explains how firms sense opportunities and threats, seize them through investment and transform their resource base over time (Teece et al., 1997). AI-PDSS can be interpreted as a digital dynamic capability when it improves sensing, supports strategic choice and accelerates organizational learning.

In SMEs, however, AI capability is constrained by data quality, managerial capacity, skills and affordability. OECD evidence identifies AI-enabling inputs, connectivity, workforce capability and finance as central adoption conditions for SMEs (OECD, 2025a). Eurostat's Digitalisation in Europe evidence further shows that progress toward basic digital intensity remains incomplete among SMEs, indicating that predictive AI adoption depends on broader digital foundations rather than on algorithms alone (Eurostat, 2025b). This is aligned with Iliev's analysis of MSME development, where growth opportunities are linked to financing instruments, process improvement, marketing capability and managerial modernization (Iliev, 2024a).

Iliev's work on scaling furniture manufacturing micro companies into SMEs is particularly relevant because it frames growth as a process of organizational upgrading. Scaling is not limited to production expansion; it requires internal process development, sustainable management practices, financial planning, market positioning and internationalization (Iliev, 2024b). AI-PDSS can support this upgrading process by helping managers compare scenarios, detect bottlenecks and evaluate the likely consequences of alternative growth strategies. In this sense, predictive decision support complements the practical growth agenda identified in MSME research.

AI capability should therefore be understood as a bundle of data infrastructure, analytical models, human skills, governance routines and decision integration. A firm may purchase software without developing AI capability. Conversely, a modest but well-integrated predictive model can generate strategic value if it is connected to decisions that matter, such as pricing, inventory, liquidity management, customer retention or supplier diversification. The difference lies in organizational embedding.

EVIDENCE ON PERFORMANCE, INNOVATION AND RESILIENCE

Recent empirical evidence suggests that AI and predictive analytics can improve organizational outcomes, although the effects vary by task, context and implementation quality. Brynjolfsson, Li and Raymond (2025) show that generative AI assistance improved productivity in customer-support work, with stronger gains for less experienced workers. This finding is important for SMEs because smaller firms often rely on generalist employees; AI systems may help reduce capability gaps when they provide structured assistance and accessible knowledge.

Research on European SMEs indicates that AI and robotics adoption are associated with multiple forms of innovation, including product, process, organizational and marketing innovation (Segarra-Blasco et al., 2025). This supports the argument that AI is not only an efficiency tool but can also support strategic renewal. In the marketing domain, Iliev (2025) emphasizes the strategic importance of artificial intelligence and machine learning for customer understanding, personalization and marketing optimization. For SMEs, marketing intelligence is closely linked to resilience because customer demand shifts rapidly during crises and competitive disruption.

Resilience evidence is also emerging in supply-chain research. Dai and Zhang (2026) find that AI adoption can improve firm resilience to disruptions through mechanisms related to supply-chain transparency and efficiency. This mechanism is highly relevant to SMEs, which often depend on a limited number of suppliers and may lack bargaining power during disruptions. Predictive DSS can identify supplier concentration risk, forecast inventory shortages, monitor delivery anomalies and support scenario-based sourcing decisions.

The evidence base nevertheless requires caution. AI adoption does not automatically improve decision quality, and poorly governed systems may produce biased, opaque or misleading recommendations. Human-AI decision research demonstrates that algorithmic assistance can be beneficial, but miscalibrated reliance can reduce performance when users either over-trust or under-use model output (Ben-Michael et al., 2025). Therefore, SME performance gains depend on implementation conditions such as explainability, data quality, training, workflow redesign and continuous monitoring.

Table 2. Selected evidence informing AI-driven predictive decision support in SMEs.

Source	Evidence type	Relevance for this study
OECD (2025a)	Policy report on AI adoption by SMEs	Identifies connectivity, finance, skills and AI-enabling inputs as adoption prerequisites.
Eurostat (2025a, 2025b)	Official European statistics	Shows increasing but uneven AI adoption and digital-intensity gaps across enterprises.
Iliev (2024a)	MSME growth study	Highlights growth constraints and opportunities relevant to Bulgarian MSMEs.

Source	Evidence type	Relevance for this study
Iliev (2024b)	Conference study on scaling micro firms	Links SME scaling with process improvement, sustainability and digital/market capabilities.
Iliev (2025)	AI and machine learning in marketing	Supports the role of AI in customer intelligence, personalization and marketing optimization.
Brynjolfsson et al. (2025)	Field evidence on generative AI at work	Shows productivity gains from AI assistance in knowledge-intensive service work.
Segarra-Blasco et al. (2025)	Empirical evidence on European SMEs	Links AI/robot adoption with innovation outcomes in SMEs.
Dai & Zhang (2026)	Empirical study of AI and disruption resilience	Shows how AI adoption may strengthen resilience through supply-chain mechanisms.
NIST (2024)	AI risk-management guidance	Defines governance concerns for generative AI and AI system risk management.

PREDICTIVE ARCHITECTURE FOR SME STRATEGIC RESILIENCE

An AI-driven predictive decision support architecture for SMEs can be conceptualized as five connected layers: data sources, data pipelines, predictive models, decision layer and managerial action layer. Data sources include internal transactions, accounting records, customer relationship data, point-of-sale information, inventory records, supplier information, web analytics, market indicators and regulatory information. These data are often fragmented across spreadsheets, accounting software, e-commerce platforms and informal managerial knowledge. The first resilience task is therefore integration.

The data-pipeline layer cleans, standardizes and transforms raw information into usable analytical features. For SMEs, this layer is often the weakest because data governance is rarely formalized. Missing values, inconsistent product codes, duplicated customer records and unstructured supplier information can severely reduce the reliability of predictive models. OECD (2025a) and NIST (2024) both emphasize that AI performance and risk management depend on data quality and lifecycle governance. In practice, the SME should begin with a narrow decision area where data are available and managerial value is clear.

The predictive-model layer estimates future conditions. Examples include forecasting demand by product category, predicting cash-flow stress, estimating customer churn, detecting abnormal supplier delays or modelling the probability of late payment. These predictions become strategically meaningful only when the decision layer translates model output into alternatives, thresholds, explanations and uncertainty estimates. A forecast that is not connected to a decision rule may remain informational but not actionable.

The managerial action layer assigns responsibility. It asks who will act on the signal, what intervention is available, what resources are required, which risks are acceptable and how outcomes will be measured. Feedback loops then convert action outcomes into new learning. This closed-loop logic is central to resilience because firms learn not only from shocks but also from the accuracy and usefulness of their anticipatory systems.

Table 3. Proposed AI-PDSS architecture for SME resilience.

Layer	Function	Strategic resilience contribution
Data sources	Capture internal and external business signals.	Creates the sensing base for weak-signal detection.
Data pipelines	Clean, integrate and transform data into usable features.	Improves reliability and reduces decision noise.
Predictive models	Forecast demand, cash flow, risk, churn and disruption patterns.	Supports anticipation before disruption becomes visible in reports.
Decision layer	Translate predictions into scenarios, explanations and thresholds.	Improves decision quality and managerial interpretability.
Managerial action layer	Assign owners, resources, interventions and performance feedback.	Turns predictive insight into adaptive organizational response.

ORGANIZATIONAL RESILIENCE AND STRATEGIC AGILITY

Organizational resilience refers to the capacity to anticipate, absorb, adapt to and recover from disruption. Duchek (2020) conceptualizes resilience as a capability that develops across stages before, during and after adversity. AI-PDSS contributes to the pre-disruption stage by improving anticipation and early warning; to the during-disruption stage by supporting resource allocation and scenario selection; and to the post-disruption stage by enabling learning from outcomes.

Strategic agility is closely related but not identical. Agility concerns the speed and flexibility with which the firm senses changes, makes decisions and reconfigures resources. A predictive DSS can enhance agility by shortening the time between signal detection and managerial response. For example, if demand forecasts indicate a decline in one customer segment and growth in another, the SME can adjust inventory, marketing spend and staffing earlier than competitors relying on retrospective sales reports. This aligns with dynamic capability theory, where sensing and reconfiguration are central to sustained competitiveness (Teece et al., 1997).

In SMEs, resilience and agility must be practical. A small firm may not need a complex enterprise AI platform; it may need a reliable cash-flow forecasting model, a supplier-risk dashboard, a churn-risk score and a set of scenario rules. The strategic question is which predictive use cases matter most. For firms facing liquidity constraints, financial forecasting may be the priority. For export-oriented firms, exchange-rate, demand and logistics signals may be more important. For marketing-intensive SMEs, AI-enabled customer segmentation and personalization may provide more immediate value, as suggested by Iliev's work on AI and machine learning in marketing (Iliev, 2025).

AI-PDSS thus supports resilience through four mechanisms: anticipation, prioritization, coordination and learning. Anticipation identifies emerging risks and opportunities. Prioritization helps allocate scarce managerial attention and financial resources. Coordination connects departments and decision owners around shared signals. Learning updates models and routines after action outcomes become visible. These mechanisms transform predictive analytics from a technical activity into an organizational capability.

EXPLAINABILITY, GOVERNANCE AND TRUSTWORTHY AI

Explainability is essential for SME predictive decision support because managers must understand why a system recommends a particular course of action. Explainable AI does not mean that every mathematical detail must be visible to every user. It means that the system provides interpretable evidence about drivers, uncertainty, limitations and conditions under which the recommendation should not be used. Without explainability, predictive DSS may create automation bias or managerial resistance.

Trustworthy AI governance is also becoming a regulatory and reputational requirement. The European Union AI Act establishes a risk-based framework for AI systems, with obligations that become applicable in phases after the Act entered into force in 2024 (European Commission, 2024). OECD AI Principles emphasize inclusive growth, human-centered values, transparency, robustness, security and accountability (OECD, 2024). NIST's Generative AI Profile further identifies risks related to information integrity, hallucination, harmful content, privacy, cybersecurity and model monitoring (NIST, 2024).

For SMEs, governance should be scaled to risk. A low-risk sales forecast does not require the same controls as an AI system used for credit decisions, hiring or legally significant customer treatment. However, even low-risk predictive systems need documentation, data-quality checks, human oversight and periodic review. Managers should know which data are used, how often the model is updated, what decision it informs, who is responsible for acting on the output and how errors are detected.

The governance challenge is intensified by generative AI and AI copilots. Large language models can make predictive systems easier to use because managers can ask questions in natural language and receive narrative explanations. Yet LLMs can also obscure uncertainty, produce unsupported claims or blend verified data with generated text. Therefore, SMEs should distinguish between predictive models that estimate business outcomes and generative interfaces that summarize or explain those estimates. The interface must not become a substitute for evidence.

BARRIERS TO SME ADOPTION

Although AI-PDSS offers strategic potential, SME adoption is limited by several barriers. Data quality is a primary obstacle. Many SMEs lack integrated information systems, and their data may be incomplete, inconsistent or stored in incompatible formats. Skills shortages are equally important. Managers may understand business problems but lack analytical literacy, while technical specialists may lack contextual knowledge of SME operations.

Cost and finance also matter. AI adoption requires software, cloud services, integration support, training and sometimes external consulting. Iliev (2024a) identifies access to finance and managerial constraints as important factors shaping MSME growth opportunities. These constraints imply that AI initiatives must be prioritized around high-value use cases with clear decision relevance rather than broad experimentation.

Cultural and organizational barriers may be more difficult than technical barriers. Employees may fear monitoring, job displacement or loss of autonomy. Managers may distrust algorithmic output when it contradicts experience. Conversely, some firms may over-trust AI because outputs appear precise. Both reactions are risky. Human-AI collaboration requires training, clear decision rights and a culture in which model output is treated as evidence to be interrogated rather than an unquestionable answer.

Regulatory and cybersecurity concerns further complicate adoption. Predictive systems may process personal data, customer records, financial information or supplier contracts. SMEs must therefore consider data protection, access controls, vendor dependence and incident response. These risks are not reasons to avoid AI; they are reasons to design governance into adoption from the beginning.

Table 4. Major SME adoption barriers and practical responses.

Barrier	Typical SME manifestation	Recommended response
Data quality	Fragmented spreadsheets, inconsistent records and missing history.	Begin with one high-value decision area; clean and standardize core fields.
Skills	Limited analytical literacy and few specialized data roles.	Use training, external support and interpretable models linked to managerial workflows.
Finance	Limited budget for software, integration and consulting.	Prioritize bounded use cases with measurable value and staged implementation.
Trust and culture	Resistance, over-reliance or uncertainty about decision rights.	Define human oversight, escalation rules and model-use protocols.
Governance and compliance	Unclear accountability, privacy exposure and vendor dependence.	Document data sources, model purpose, monitoring routines and responsible owners.
Cybersecurity	Sensitive business data connected to cloud tools and third-party services.	Apply access controls, vendor review, backup routines and incident-response planning.

CONCEPTUAL FRAMEWORK

The proposed framework links five constructs: AI capability, predictive insight, strategic decision quality, organizational resilience and sustainable competitive advantage. AI capability includes data infrastructure, analytical models, digital skills, governance routines and integration with business processes. Predictive insight refers to forecasts, risk signals, scenario outputs and interpretable explanations. Strategic decision quality includes speed, accuracy, consistency, contestability and alignment with organizational goals.

Organizational resilience is positioned as the outcome of improved decision quality under uncertainty. When SMEs can anticipate risks, compare scenarios and coordinate responses, they become more capable of absorbing shocks and adapting to changing conditions. Sustainable competitive advantage emerges only if predictive decision routines become embedded in organizational learning. A competitor may purchase similar software, but it is more difficult to imitate a firm's data discipline, managerial interpretation routines, governance culture and feedback-based learning.

The framework also includes moderators. Data quality moderates the relationship between AI capability and predictive insight. Managerial absorptive capacity moderates the relationship between predictive insight and decision quality. Governance readiness moderates the relationship between decision quality and resilience. Ecosystem position moderates the extent to which resilience becomes competitive advantage, because SMEs embedded in stronger supplier, finance and knowledge networks may act on predictive insight more effectively.

Proposed causal logic: AI capability -> Predictive insight -> Strategic decision quality -> Organizational resilience -> Sustainable competitive advantage.

DISCUSSION

The analysis suggests that AI-driven predictive decision support systems should be viewed as strategic management infrastructure rather than as isolated digital tools. Their value lies in reshaping how SMEs perceive uncertainty and coordinate action. This interpretation expands the conventional view of AI adoption. Instead of focusing only on efficiency, automation or cost reduction, the study emphasizes anticipation, interpretability, decision quality and resilience.

The findings also show that SME AI adoption must be contextualized. A small firm with weak data infrastructure cannot jump directly into advanced agentic AI without first establishing reliable data flows and governance. Similarly, a firm may deploy a generative AI assistant without improving strategic resilience if the assistant is not connected to validated data and managerial action. This distinction is critical because the market increasingly presents AI as a universal solution, while the literature shows that value depends on task fit, workflow integration and organizational readiness (OECD, 2025a; NIST, 2024).

Iliev's research strengthens the regional and managerial relevance of this argument. Studies on MSME growth challenges and scaling emphasize that smaller firms need improved management practices, better access to resources, stronger market capabilities and sustainable development strategies (Iliev, 2024a, 2024b). AI-PDSS can support these needs when it helps firms forecast demand, evaluate growth scenarios, improve customer intelligence and allocate resources more rationally. However, the technology must be embedded in managerial learning rather than treated as an external add-on.

The study has limitations. Because it is a conceptual analytical review, it does not test the proposed framework empirically. The literature on AI-PDSS in SMEs is still emerging, and much evidence comes from broader enterprise studies, policy reports or task-specific experiments. Future research should test the framework using longitudinal SME data, sector-specific case studies and mixed-method designs that compare firms before and after predictive DSS implementation. Research should also examine whether explainability improves managerial decision quality in real SME settings.

CONCLUSION

Artificial intelligence-driven predictive decision support systems can help SMEs move from retrospective control toward anticipatory and adaptive governance. By connecting heterogeneous business data with forecasting, risk detection, scenario modelling and interpretable recommendations, AI-PDSS can improve strategic decision quality under uncertainty. The main contribution of this study is to conceptualize AI not merely as an operational technology but as an organizational capability that strengthens resilience, agility and evidence-based management.

The proposed framework shows that AI capability creates value through a chain of transformation. Data and models must become predictive insight; predictive insight must improve decision quality; decision quality must support organizational resilience; and resilience must be embedded in learning routines to become sustainable competitive advantage. This chain is not automatic. It depends on data quality, managerial absorptive capacity, explainability, governance readiness, cybersecurity and financial feasibility.

For SME managers, the practical implication is to begin with bounded, decision-relevant predictive use cases rather than broad and unfocused AI adoption. For policymakers, the implication is that SME AI support should combine technology access with training, finance, data governance and trusted advisory ecosystems. For researchers, the agenda is to develop empirical evidence on how predictive decision ecosystems influence resilience, performance and long-term competitiveness in SMEs.

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TÜRK HUKUKUNDA ANONİM ŞİRKET YÖNETİM KURULU ÜYELERİNİN KİŞİSEL VERİLERİN KORUNMASI KANUNUNDAN KAYNAKLANAN HUKUKİ SORUMLULUĞU

THE LEGAL LIABILITY OF BOARD MEMBERS OF JOINT-STOCK COMPANIES UNDER TURKISH LAW STEMMING FROM THE PERSONAL DATA PROTECTION LAW

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ÖZET

Ülkemizde 6698 sayılı "Kişisel Verilerin Korunması Kanunu (KVKK)" 7 Nisan 2016 tarihinde yürürlüğe girmiştir. Anılan kanun hükümleri uyarınca kişisel verilerin işlenmesinden anonim şirketin kendisi veri sorumlusudur. Ancak tüzel kişi anonim şirketin KVKK'dan kaynaklanan yükümlülükleri bizzat yerine getirmesi imkansızdır. Bu nedenle KVKK'ya aykırılık halinde sorumluluk anonim şirketin yönetim ve temsil organı olan yönetim kurulundadır. Yönetim kurulu Türk Ticaret Kanunu (TTK) m. 367 uyarınca, yönetim görevini, esas sözleşmede yetki bulunması durumunda bir iç yönerge ile yönetimi kısmen ya da tamamen bir veya birkaç yönetim kurulu üyesine ya da üçüncü kişilere devredebilir. Yönetim yetkisinin devri halinde dahi yönetim kurulunun TTK m. 375/1'e göre sorumluluğu devam eder. Yönetim kurulunun hukuki sorumluluğunun dayanağı TTK m. 369'da düzenlenen özen yükümlülüğüdür. Söz konusu düzenlemeye göre yönetim kurulu üyeleri, kanun, esas sözleşme ve şirketle ilgili üstlenilen yönetim kapsamındaki diğer görevlerini tedbirli bir yöneticinin göstermesi gereken dikkat ve özen ile yerine getirmelidir. Gerekli özenin gösterilip gösterilmediği her somut olayın özelliğine göre değerlendirilmektedir. KVKK'ya aykırılık sebebiyle anonim şirketin zarara uğraması durumunda yönetim kurulu üyeleri anonim şirketin uğradığı zarardan kusurları varsa sorumlu olacaktır. Yönetim kurulu üyelerinde aranan kusur sübjektif kusur değil, objektif kusurdur. Yönetim kurulu üyesinin kusurlu davranışı ile veri sorumlusu olan şirketin zarara uğraması arasında illiyet bağının bulunması gerekir. İlliyet bağının varlığı halinde şirket ödediği tazminatı yönetim kurulu üyelerine kusurları oranında rücu eder.

Anahtar Kelimeler: Anonim şirket, yönetim kurulu, kişisel verilerin korunması hakkında kanunu, hukuki sorumluluk, veri sorumlusu.

ABSTRACT

The Law on the Protection of Personal Data (LPPD) No. 6698 entered into force in Türkiye on April 7, 2016. Pursuant to the provisions of this law, a joint-stock company itself bears responsibility for the data controller for the processing of personal data. However, legal entity joint-stock companies cannot fulfill the obligations stemming from the LPPD on their own. Therefore, in the event of non-compliance with the LPPD, liability falls on the board of directors as the company's governing and representative body. Under Article 367 of the Turkish Commercial Code (TCC), the board of directors may, if authorized by the articles of association, delegate management functions in part or in full to one or more board members or to third parties through an internal directive. Even when management authority has been delegated, the board of directors remains liable under Article 375(1) of the TCC. The legal liability of the board of directors is grounded in the duty of care established in Article 369 of the TCC, stipulating that members of the board of directors must perform their duties under the law, the articles of association, and other company-related obligations with the care and diligence expected of a prudent manager. Whether the required care was exercised is evaluated based on the specific circumstances of each case. In the circumstances where a joint-stock company suffers damage due to non-compliance with the LPPD, board members shall be liable for that loss, provided fault is established. The fault required of board members is not subjective but objective. Furthermore, a causal link must exist between

a board member's negligent conduct and the damage suffered by the company as data controller. Where a causal link exists, the company may seek reimbursement from the board members for any compensation it has paid, proportionate to their respective degrees of fault.

Keywords: Joint-stock company, board of directors, law on the protection of personal data, legal liability, data controller.

GİRİŞ

İçinde bulunduğumuz "Dijital Çağ" bir çok alanda olduğu gibi ticari alanda da faaliyetlerin dijitalleşmesini sağlamıştır. Dijitalleşme ile birlikte kişisel veri kavramı çağımızın temel yapı taşlarından biri haline gelmiştir. Veri temelli ekonominin gelişmesi ve dijital pazarların hızla yaygınlaşmasıyla birlikte kişisel verilerin korunması ihtiyacı doğmuş ve bu alanda hukuki düzenlemeler yapılmıştır. Ülkemizde 6698 sayılı KVKK, 7 Nisan 2016 tarihinde yürürlüğe girmiştir. Kanun temel dayanağını Avrupa Birliği'nin 95/45/EC sayılı Veri Koruma Direktifi'den almıştır. 6698 sayılı Kanun, kişisel verilerin korunması hakkını anayasal bir hak olan özel hayatın gizliliği ile doğrudan bağlantılı bağımsız temel insan hakkı olarak düzenlemiştir. Anılan kanun hükümleri uyarınca kişisel verilerin işlenmesinden anonim şirketin kendisi veri sorumlusudur. Tüzel kişilerin KVKK kapsamında gerçekleştirdikleri faaliyetlerden dolayı hukuki sorumluluk tüzel kişinin şahsında doğmaktadır. Ancak tüzel kişi anonim şirketin KVKK'dan kaynaklanan yükümlülükleri bizzat yerine getirmesi imkansızdır. Bu nedenle KVKK'ya aykırılık halinde sorumluluk anonim şirketin yönetim ve temsil organı olan yönetim kurulundadır. Nitekim bu durum "Veri Sorumluları Sicili Hakkında Yönetmelik" m. 11/1'de *" Tüzel kişilerde veri sorumlusu tüzel kişiliğin kendisidir. Türkiye'de yerleşik olan tüzel kişilerin Kanun kapsamındaki veri sorumlusu yükümlülükleri, ilgili mevzuat hükümlerine göre tüzel kişiliği temsil ve ilzama yetkili organ veya ilgili mevzuatta belirtilen kişi veya kişiler marifetiyle yerine getirilir. Tüzel kişiliği temsile yetkili organ, Kanunun uygulanması bakımından yerine getirilecek yükümlülükler ile ilgili olarak bir veya birden fazla kişiyi görevlendirebilir. Bu görevlendirme Kanun hükümleri uyarınca tüzel kişiliğin sorumluluğunu ortadan kaldırmaz*." şeklinde düzenlenmiştir. Anılan hüküm uyarınca, yönetim kurulu bu yükümlülüklerini TTK m. 367'ye göre bazı yönetim kurulu üyelerine devredebileceği gibi dışardan üçüncü kişilere de devredebilecektir. Yönetim yetkisinin devrinde sınır TTK m. 375'dir. Kanuna uygun yönetim yetkisinin devri beraberinde sorumluluk devrini de getirmektedir. Yönetim kurulunun KVKK hükümlerinden kaynaklanan sorumluluğu ile kastedilen yönetim kurulu üyelerinin kişisel sorumluluğudur. KVKK hükümlerine göre sorumluluk anonim şirketin kendisine aittir. Ancak KVKK yükümlülüklerine aykırılık sebebiyle anonim şirketin zarara uğraması halinde, zararın meydana gelmesinde kusurları bulunan yönetim kurulu üyeleri sorumludur. Yönetim kurulu üyelerinin bu sorumluluğunun dayanağı TTK m. 369'da düzenlenen özen yükümlülüğüdür. Söz konusu düzenlemeye göre yönetim kurulu üyeleri, kanun, esas sözleşme ve şirketle ilgili üstlenilen yönetim kapsamındaki diğer görevlerini tedbirli bir yöneticinin göstermesi gereken dikkat ve özen ile yerine getirmelidir. Gerekli özenin gösterilip gösterilmediği her somut olayın özelliğine göre değerlendirilmektedir. Hukuki sorumluluğunun dayanağı kusur ilkesidir. Yani, yönetim kurulu üyeleri ancak kusurlu davranışları sebebiyle sorumlu tutulabilirler. Yönetim kurulu üyelerinde aranan kusur sübjektif kusur değil, objektif kusurdur. Ayrıca yönetim kurulu üyesinin kusurlu davranışı ile veri sorumlusu olan şirketin zarara uğraması arasında illiyet bağının bulunması gerekir. İlliyet bağının varlığı halinde şirket ödediği tazminatı yönetim kurulu üyelerine rücu eder. Veri sorumlusu anonim şirketin KVKK'da düzenlenen yükümlülüklerini yerine getirmemesinin hukuki sorumluluğu dışında idari ve cezai sorumluluğu da bulunmaktadır. Bu çalışmada, anonim şirket yönetim kurulu üyelerinin KVKK yükümlülüklerine aykırılık sebebiyle hukuki sorumluluğu ele alınacaktır. Çalışmanın temel amacı KVKK hükümlerine göre veri sorumlusu sıfatına sahip olan anonim şirket yönetim kurulu üyelerinin hangi durumlarda hukuken sorumlu tutulabileceğinin ortaya konulmasıdır.

KVKK'YA GÖRE VERİ SORUMLUSU OLARAK ANONİM ŞİRKET VE YÖNETİM KURULU

Teknolojinin gelişmesi ile birlikte işlenen kişisel verilerin sayısı gittikçe artmış ve kolaylıkla yurt dışına aktarılır hale gelmiştir. KVKK ile kişisel verilerin sınırsız bir şekilde toplanması ve amacına aykırı

olarak kullanılmasının önüne geçilerek kişinin temel hak ve özgürlüklerinin korunması benimsenmiştir. Bu amaçla KVKK, kişisel verilerin işlenmesinde uyulması gereken usul ve esasları düzenleyerek kişisel veri işleyenlere yasal yükümlülükler getirmiş ve bu yükümlülüklere aykırılıklardan sorumlu olacak kişiyi de veri sorumlusu olarak ifade etmiştir. KVKK m. 3/1-ı bendinde veri sorumlusu tanımlanmıştır. Anılan hükümde veri sorumlusu *"...Kişisel verilerin işleme amaçlarını ve vasıtalarını belirleyen, veri kayıt sisteminin kurulmasından ve yönetilmesinden sorumlu olan gerçek veya tüzel kişiyi, ifade eder*." şeklinde düzenlenmiştir. Bu tanıma göre veri sorumlusu gerçek ya da tüzel kişi olmak zorundadır. Tüzel kişi olan anonim şirketlerde veri sorumlusu anonim şirketin kendisidir. Bir başka deyişle, anonim şirket veri işlemeye yönelik faaliyetleri bakımından bizzat sorumludur. Kişisel verilerin korunması amacıyla çok sayıda yükümlülükler içeren KVKK'ya ve bu alandaki ikincil mevzuata aykırılık halinde tüzel kişi anonim şirket sorumlu olmakla birlikte bu yükümlülükler anonim şirket adına onun yönetim ve temsil organı yönetim kurulu tarafından yerine getirilecektir. Zira, tüzel kişiler organları vasıtasıyla karar alırlar, iradelerini açıklarlar ve temsil edilirler. Şirketler hukukunda da benimsenen organ teorisine göre yönetim kurulu kanuna ve esas sözleşmeye göre organ sıfatına haiz olduğundan, anonim şirketin temsilcisi değil onun ayrılmaz bir parçasıdır ve şirket adına işlem yapma yetkisine sahiptir (Altınok Ormancı 2021). Nitekim yönetim kurulunun bu yetkisi Veri Sorumluları Sicili Hakkında Yönetmelik m. 11/1'de "*….Türkiye'de yerleşik olan tüzel kişilerin Kanun kapsamındaki veri sorumlusu yükümlülükleri, ilgili mevzuat hükümlerine göre tüzel kişiliği temsil ve ilzama yetkili organ veya ilgili mevzuatta belirtilen kişi veya kişiler marifetiyle yerine getirilir…"* şeklinde açıkça ifade edilmiştir. Türk Medeni Kanunu'na göre tüzel kişilerin medeni haklardan yararlanabilmeleri ve bunları kullanabilmeleri ancak organları aracılığı ile mümkündür (Helvacı 2001). Anonim şirketlerde diğer tüzel kişilerde olduğu gibi şirketin işlerini yürütecek ve üçüncü kişilere karşı şirketi temsil edecek sürekli ve zorunlu bir organa ihtiyaç duymaktadır (Akdağ Güney 2010). Anonim şirketlerde bu organ yönetim kuruludur. Yönetim kurulu, anonim şirketin organı olarak tüzel kişinin iradesini oluşturur ve açıklar. Yani, yönetim kurulunun aldığı kararlar, organ teorisi anlayışı sebebiyle doğrudan doğruya şirketin iradesidir (Özbağ 2024). Kurul organ özelliğine sahip yönetim kurulu, anonim şirketin yürütme organı olması sebebiyle kanundan ya da şirket esas sözleşmesinden kaynaklanan yükümlülüklerini ihlal etmeleri halinde şirkete ve pay sahiplerine karşı sorumlu olduğu gibi şirket alacaklılarına karşı da verdikleri zararlardan sorumludurlar (TTK m. 553). Yönetim kurulunun kanundan kaynaklanan bu sorumluluğu onun görev ve yetkilerini düzenleyen tüm emredici kanun hükümlerine ilişkindir. O halde veri sorumlusu anonim şirketin KVKK'dan kaynaklanan yükümlülüklerinin yerine getirilmesi şirket adına yönetim kurulu tarafından organize edilmekte ve yürütülmektedir. Bu bağlamda anonim şirket, KVKK'dan doğan yükümlülüklerini yönetim ve temsil organı olan yönetim kurulu aracılığıyla icra etmektedir.

- YÖNETİM KURULU ÜYELERİNİN SORUMLULUĞUNUN HUKUKİ DAYANAĞI

Yönetim kurulu üyeleri görevlerini ifa ederken kanun ve esas sözleşmenin kendilerine yükledikleri görevleri kusurlu olarak hiç ya da gereği gibi yerine getirmemeleri halinde oluşan zararın kendilerine yükletilebilmesi ve bu nedenle de kendilerinin tazminat borçlusu olabilmesine yönetim kurulu üyelerinin hukuki sorumluluğu denir (Yördem 2022, Çamoğlu 2010). Literatürde yönetim kurulu üyelerinin kanundan kaynaklanan sorumluluğu yalnızca TTK hükümleri ile sınırlı olmadığı yönetim kurulu üyelerine görev ve yükümlülük yükleyen diğer kanunları da kapsadığı ifade edilmektedir. O halde yönetim kurulu üyelerinin KVKK'ya aykırılık sebebiyle sorumlu tutulabilmeleri için KVKK'dan doğan yükümlülüklerin ihlali gerçekleşmelidir. Söz konusu ihlalin hukuki dayanağı TTK m. 369'da özen ve bağlılık yükümlülüğünün ihlalidir. TTK m. 369/1 uyarınca, "*Yönetim kurulu üyeleri ve yönetimle görevli üçüncü kişiler, görevlerini tedbirli bir yöneticinin özeniyle yerine getirmek ve şirketin menfaatlerini dürüstlük kurallarına uyarak gözetmek yükümlülüğü altındadırlar*." Anılan hüküm uyarınca, yönetim kurulu üyeleri KVKK'dan kaynaklanan yükümlülükleri yerine getirirken tedbirli bir yöneticinin göstermesi gereken dikkat ve özen ile hareket etmeleri ve şirketin menfaatlerini gözetmeleri gerekmektedir. Bu düzenleme anonim şirketlerde hukuki sorumluluk sisteminin temel yapı taşını oluşturmaktadır (Sevi 2021). 6102 sayılı TTK'da kanun koyucu, "tedbirli bir yönetici özeni" ifadesi ile objektif özen ölçütünü kabul etmiştir. Özen borcuna göre sorumlu yönetim kurulu üyeleri ve/veya yöneticiler kanun, esas sözleşme ve şirketle ilgili üstlenilen yönetim kapsamındaki diğer görevlerini tedbirli bir yöneticinin göstermesi gereken dikkat ve özen ile yerine getirmelidirler. Bir başka ifadeyle, yönetim kurulu üyesinin özen borcuna aykırı davranıp davranmadığının tespitinde ne kendi nitelikleri

esas alınacak ne de şirketin durumu dikkate alınacaktır. Objektif özen borcu ile kastedilen aynı koşullar altında, aynı ortaklıkta ve aynı zamanda görev yapan makul ve tedbirli bir yönetici nasıl hareket ederdi anlayışı kusurun belirlenmesinde temel ölçüt olacaktır (Sevi 2021). Gerekli özenin gösterilip gösterilmediği her somut olayın özelliğine göre değerlendirilmektedir. TTK m. 369 emredici nitelikte olduğundan dolayı söz konusu ölçütün hukuken hafifletilmesi mümkün değildir (Sevi 2021). Özen yükümlülüğünün bir diğer işlevi de yönetim kurulu üyesinin özen yükümlülüğüne aykırı davranması sonucunda şirketin zarara uğraması halinde hukuki sorumluluğun doğmasına ilişkindir (Özbağ 2024). Bu çerçevede anonim şirketin KVKK'ya uyumun sağlanması için gerekli organizasyon yapısını oluşturmak, teknik ve idari tedbirlerin alınmasını sağlamak ve uygulanmasını gözetmek vb. yükümlülüklerini tedbirli bir yöneticinin göstermesi gereken dikkat ve özenle yerine getirmeyen yönetim kurulu üyeleri veri sorumlusu anonim şirketin uğradığı zararlardan kusurları varsa sorumlu olacaklardır (Sevi 2021).

YÖNETİM KURULU ÜYELERİNİN KVKK KAPSAMINDAKİ HUKUKİ SORUMLULUĞU

KVKK hükümlerine aykırılık halinde veri sorumlusu anonim şirket ise de anonim şirketin tüzel kişi olması sebebiyle KVKK hükümlerini yerine getirmekle yükümlü organ yönetim kuruludur. Yönetim kurulu bu hükümlülüklere aykırılık halinde şartları var ise şirkete karşı sorumlu olacaktır. 6698 sayılı KVKK kişisel verilerin hukuka aykırı olarak işlenmesinden doğan zararların tazminine ilişkin özel hükümler getirmemiştir. Bu nedenle kişilik hakları ihlal edilenler genel hükümlere göre tazminat talebinde bulunacaktır. TTK m. 553 yönetim kurulu üyelerine ve yöneticilere ilişkin hukuki sorumluluğu düzenleyen genel hükümdür. TTK m. 553/1 uyarınca, *"Kurucular, yönetim kurulu üyeleri, yöneticiler ve tasfiye memurları, kanundan ve esas sözleşmeden doğan yükümlülüklerini kusurlarıyla ihlal ettikleri takdirde, hem şirkete hem pay sahiplerine hem de şirket alacaklılarına karşı verdikleri zarardan sorumludurlar.*" Söz konusu hüküm uyarınca, yönetim kurulu üyelerinin hukuki olarak sorumlu tutulabilmeleri için her şeyden önce kanuna veya esas sözleşmeye aykırılık, zarar, kusur ve illiyet bağı unsurlarının bulunmasına bağlıdır.

Sorumluluğun Şartları

Kanun veya Esas Sözleşmeye Aykırılık: Yönetim kurulu üyelerinin hukuki sorumluluğunun doğabilmesi için gerekli ilk şart kanuna ya da esas sözleşmeye aykırılıktır. Daha öncede ifade ettiğimiz üzere kanun ifadesi burada geniş yorumlanmaktadır. Bu nedenle de yönetim kurulu üyeleri KVKK hükümlerine aykırı davranışlarından da sorumludurlar. Nitekim KVKK m. 11/ğ uyarınca, kişisel verisi kanuna aykırı olarak işlenmesi sebebiyle zarara uğrayan herkes veri sorumlusuna başvurarak zararın giderilmesini talep edebilir. Aynı şekilde KVKK m. 14/3'e göre, kişilik hakları ihlal edilen kişinin de genel hükümlere göre tazminat hakkı saklıdır. Tüm bu hallerde davacı, yönetim kurulu üyelerinin kanuna aykırı davrandığını ispat etmekle yükümlüdür.

Kusur: Yönetim Kurulu üyelerinin TTK m. 553 kapsamında sorumlu olabilmeleri için KVKK'dan kaynaklanan yükümlülüklerini yerine getirmemekte kusurlu davranmış olması gerekir. Sorumluluğun meydana gelmesi açısından kusurun kast ya da ihmal suretiyle gerçekleşmesi herhangi bir farklılık yaratmamaktadır (Akdağ Güney 2010, Pulaşlı 2013). Kast ve ihmalin bütün dereceleri sorumluluk için yeterlidir (Özekes et al., 2021). Ancak kusurun derecesine yani davranışın, fiilin kast ile veya ihmalen olmasına göre ilgili yönetim kurulu üyesinin bireysel sorumluluğu farklılık gösterebilir, zira yönetim kurulu üyelerinin sorumluluğu şahsi sorumluluktur. Bir başka deyişle yönetim kurulu üyesinin sorumluluğu sınırsız değildir. Kusurunun olması şartıyla, her bir yönetim kurulu üyesinin meydana gelen zarardan kusuru oranında tüm malvarlığı ile şahsen sorumluluğu söz konusudur. O halde yönetim kurulu üyeleri hangi durumda kusurlu davranmış olacaktır. Bu konu çalışmanın bundan önceki ana başlığında ele alınmıştır. Yönetim kurulu üyeleri TTK m. 369/1'e göre, tedbirli bir yöneticinin özeniyle görevlerinin yerine getirmek ve şirketin menfaatlerini dürüstlük kuralları çerçevesinde gözetmekle yükümlüdür. Buna aykırılık kusurlu davranış olarak kabul edilecek ve yönetim kurulu üyesi meydana gelen zarardan sorumlu olacaktır. Fakat yönetim kurulu üyesi özen yükümlülüğüne uygun davranmış olmasına rağmen yine de zarar meydana gelmişse, bu durumda yönetim kurulu üyesinin sorumluluğu söz konusu olmayacaktır. Bu sebeple de özen yükümlülüğünün tespiti önem arz etmektedir. TTK'nın 369. maddesinde yönetim kurulu üyelerinin göstermesi gereken özen derecesi "tedbirli bir yöneticinin göstermesi gereken özen" olarak belirlenmiştir. Özen borcuna aykırılık hukuki sorumluluk

doğurmaktadır. KVKK'dan kaynaklanan yükümlülüklerini kanunun aradığı ölçüte uygun özenli bir şekilde gereği gibi yerine getirmeyen ya da hiç yerine getirmeyen yönetim kurulu üyesi, anonim şirketin bu nedenle uğradığı zararlardan sorumludur.

Zarar: Zarar ile kastedilen malvarlığındaki azalmadır. Yani, zarar görenin hukuka aykırı eylem öncesi malvarlığı değeri ile hukuka aykırı eylem sonrası malvarlığı değeri arasındaki fark zarar olarak ifade edilmektedir (Yördem 2022). Yönetim kurulu üyelerinin sorumluluğuna gidebilmek için mutlaka şirket, pay sahipleri ya da şirket alacaklılarından birinin malvarlığında meydana gelmiş bir değer kaybı olması gerekmektedir. Zarar yok ise sorumlulukta yoktur. Esasen KVKK hükümlerine göre zararı ödemekle yükümlü olan kişi veri sorumlusu şirkettir. Ancak zarar şirket yönetim kurulu üyelerinin kusurlu davranışları sonucunda meydana gelmiş ise bu halde şirketin yönetim kurulu üyelerine rücu hakkı bulunmaktadır. Sonuç olarak TTK m. 553 uyarınca, yönetim kurulu üyeleri KVKK hükümlerine aykırı hareket ettiklerinde, kusurlarıyla şirkete, pay sahiplerine ve şirket alacaklılarına verdikleri zarar nedeniyle sorumludurlar. Yönetim kurulu üyelerinin zarardan sorumluluğu bizzat şirkete karşıdır (Akdağ Güney 2010).

İlliyet Bağı: Yönetim kurulu üyelerinin hukuki sorumluluğunun söz konusu olabilmesi için aranan bir diğer şartta illiyet bağıdır. Yani zararın yönetim kurulu üyesinin hukuka aykırı kusurlu eyleminden meydana gelmiş olması gerekmektedir. İlliyet bağının varlığı halinde şirket ödediği tazminatı yönetim kurulu üyelerine rücu eder. İlliyet bağını yönetim kurulu üyesinin hukuka aykırı davranışı ile zarar arasındaki bağ olarak ifade edebiliriz. Uygun illiyet bağı ile kastedilen zararın yönetim kurulunun hukuka aykırı davranışı sonucu oluşmasıdır. Zarar doğrudan yönetim kurulunun hukuka aykırı davranışından meydana gelmemiş ise illiyet bağı kesilir ve hukuki sorumluluk doğmaz.

YÖNETİM YETKİSİNİN DEVRİ HALİNDE YÖNETİM KURULU ÜYELERİNİN HUKUKİ SORUMLULUĞU

Anonim şirket yönetim kurulu TTK'nın kendisine verdiği yönetim ve temsil yetkisini tamamen ya da kısmen devredebilecektir. Bu konuda takdir yetkisi yönetim kurulundadır. Yönetim kurulu bu yetkilerini devretmediği sürece sorumluluk yönetim kurulu üyelerinindir. Fakat TTK m. 367 yönetim kurulunun yönetim yetkisinin devrine izin vermektedir. Yönetim yetkisinin devri ile kastedilen yönetim işlevinin, yani karar alma yetkisinin yönetim kurulu üyelerine ya da üçüncü kişilere devredilmesidir (Doğan 2011). Bir başka ifadeyle, anonim şirket yönetim kurulu KVKK'dan kaynaklanan yükümlülüklerini bizzat yerine getirmek istememesi halinde TTK m. 367 uyarınca bu alanda karar alma yetkisini yönetim kurulu üyelerinden bazılarına devredebileceği gibi dışardan üçüncü kişilere de devredebilecektir.

Yönetim Yetkisinin Devrinin Şartları

TTK m. 367'ye göre yönetim yetkisinin devrinin şartları bulunmaktadır. Anılan hüküm uyarınca yönetim yetkisinin devri şirket esas sözleşmesinde düzenlenmiş olmalıdır. Yani, şirket esas sözleşmesinde yönetim kuruluna yönetim yetkisinin devrine izin veren bir hüküm bulunmalıdır. Bununla birlikte yönetim kurulu yönetim yetkisinin devrini hazırlayacağı bir iç yönerge ile de düzenlemiş olmalıdır. Bu iki şart yönetim yetkisinin devrine ilişkin kanun koyucunun aradığı şekli şartlardır. Yönetim yetkisinin devrinde aranan maddi şart ise yönetim kurulunun her alandaki yönetim yetkisini devredemeyeceği yalnızca devredilebilir yetkilerini devredebileceğidir (Doğan 2011). Kısaca yönetim kurulu sadece devredilebilir yetkilerini devredebilir. Kanunun aradığı bu şartlara uygun yapılan yönetim yetkisinin devri geçerlidir aksi halde yönetim yetkisinin devri usulsüzdür. Geçerli bir yönetim yetkisinin varlığı halinde yönetim yetkisini devralan kişi yönetim kurulu yerine geçer. Bu halde yönetim kurulu, yönetim yetkisini devrettiği alanda kurul olarak yönetim yetkisini kullanmaktan kendi iradesiyle vazgeçtiğinden devre konu yönetim alanlarında karar alamaz iş ve işlemlerde bulunamaz (Özbağ 2024). Bunun sonucunda da yetki devri ile devralan kişi, devredilen yetki çerçevesinde sorumluluk üstlenir iken devreden ise yetki kapsamında devrettiği görev ve yetkiden dolayı sorumlu tutulamaz. Ancak geçerli bir yetki devri yok ise bu halde sorumluluk da devredilmemiş olur. Yani yetki devri yapılmamış gibi tüm yönetim kurulu üyeleri birlikte sorumlu olmaya devam eder. Kanuna uygun yönetim yetkisinin devri halinde sorumluluk da devredilmiş olur. Ancak TTK m. 367 uyarınca yönetim yetkisinin devri ile TTK m. 366/2'ye göre yönetim kurulunun kendisine yardımcı olacak komite ve komisyonları oluşturması aynı amaca hizmet etmemektedir. Oluşturulan komite ve komisyonlar yönetim kurulunun

altında ve ona bağlı olarak çalıştıklarından asla yönetim yetkisinin devri sonucunu doğurmayacaktır. Çalışmanın konusu gereği anonim şirket yönetim kurulu kişisel verilerin korunması mevzuatından kaynaklanan yükümlülüklerini kapsayan yönetim yetkisini kısmen ya da tamamen bir ya da birkaç yönetim kurulu üyesine ya da üçüncü kişilere birlikte ya da ayrı ayrı olarak devredebilmektedir. Kanuna uygun yönetim yetkisinin devri beraberinde de sorumluluk devrini getirmektedir. Dolayısıyla geçerli bir yetki devri ile yönetim yetkisini alan kişi ya da kişiler yönetim kurulu üyeleriyle aynı sorumluluk rejimine tabidirler. Bu nedenle sorumluluğu devralan kişi ya da kişiler yönetim kurulu üyeleriyle aynı derecede gerekli özeni göstermesi beklenir (Özbağ 2024). Her ne kadar geçerli bir yetki devri beraberinde sorumluluğunda devri sonucunu doğuruyorsa yönetim kurulunun yetki devri alanında hiçbir sorumluluğunun bulunmadığı anlamına gelmemektedir. Yönetim kurulunun her daim yönetimle görevli kişilerin üst gözetim yükümlülüğü bulunmaktadır.

Yönetim Yetkisinin Devrinin Sınırı: Üst Gözetim

TTK yönetim kurulu üyelerine yönetim yetkisinin devrinde TTK m. 375 ile sınır getirmiştir. Yönetim kurulu devredilebilir tüm yetkilerini devretmiş olsa dahi devredilemez yetkilerin kullanılması açısından sorumluluğu devam eder. TTK m. 375'de yönetim kurulunun devredilemez görev ve yetkilerini düzenlemiştir. Buna göre yönetim kurulu ilgili hüküm m. 375/1-(a-e) bentlerinde yer alan beş yetkisini devre konu edemez (Doğan 2011). Bu yetkiler yönetim kurulu tarafından kurul olarak kullanılması zorunlu üst yönetim ve gözetim borcuna ilişkin devredilemez yetkilerdir. TTK m. 375/1-(e) bendinde şirketi yönetmekle görevli olan kişilerin üst gözetim yükümlülüğü *"Yönetimle görevli kişilerin, özellikle kanunlara, esas sözleşmeye, iç yönergelere ve yönetim kurulunun yazılı talimatlarına uygun hareket edip etmediklerinin üst gözetimi."* şeklinde ifade edilmiştir. Bu çerçevede üst gözetim yükümlülüğü icrada görevli olmayan yönetim kurulu üyeleri tarafından yerine getirilmelidir. Zira TTK m. 367'ye göre yetki devri yapılan üyeler yönetim yetkisini fiilen kullanan icrada görevli olan üyelerdir. TTK m. 375/1-e'deki üst gözetim yükümlülüğünün muhatabı, yönetim yetkisini fiilen kullanmayan icrada görevli olmayan yönetim kurulu üyeleridir (Yalçın Sırakaya 2020). Yönetim kurulunun üst gözetim görevinin kapsamı hem normatif hem de işletme iktisadı bakımından işlerin akışını gözetme yükümlülüğü olarak ifade edilmektedir. Normatif gözetim yükümlülüğü ile kastedilen yönetimle görevli kişilerin kanunlara, esas sözleşmeye, iç yönergelere ve yönetim kurulunun yazılı talimatlarına uygun hareket edip etmediklerine ilişkindir (Doğan 2011, Yalçın Sırakaya 2020). Yani yönetim kurulunun üst gözetim sorumluluğunun dayanağı öğretide "uyum yükümlülüğü" olarak ifade edilmektedir (Pulaşlı 2013, Kayıhan 2011). Hukuki anlamda uyum yükümlülüğü ile kastedilen mevzuata uygunluktur. Mevzuat kavramı geniş anlamda kullanılmaktadır. Yani kanunlar, yönetmelikler, tebliğler vb. hem birincil hem de ikincil nitelikte mevzuat hükümlerini içermektedir. Belirtmek gerekir ki, KVKK yükümlükleri açısından yönetim kurulunun uyum yükümlülüğünden doğan sorumluluğu sadece mevzuata uyum olarak ifade edilemez. Zira yönetim kurulunun KVKK'ya göre veri güvenliği ile ilgili riskleri önceden belirlemesi ve veri güvenliği politikalarının hazırlaması gerekir. Bir başka deyişle, yönetim kurulunun şirket içinde veri koruma hukukuna aykırılığı ortadan kaldıracak nitelikte her türlü gerekli organizasyonu kurmuş olması gerekir. Bu yanıyla da yönetim kurulunun üst gözetimden doğan borcu uyum yükümlülüğünün geniş anlamda olduğunun kabulü gerekir. Üst gözetim yükümlülüğü icrada görevli olmayan yönetim kurulu üyelerinin devredilemez yetkilerindendir. Bu nedenle de genel kurul tarafından kullanılamayacağı gibi kullanılmasının onayı da genel kurula devredilemez. Yönetim kurulunun üst gözetim yükümlülüğünün devredilemez nitelikte olması bunun yönetim kurulu tarafından bizzat yerine getirilmesi gerektiği anlamına gelmemektedir (Doğan 2011). Belirtmek gerekir ki, yönetim kurulu TTK m. 366/2 uyarınca, KVKK ile ilgili işlerin takibini yapmak, kurul kararlarını uygulamak vb. işler için komiteler ve komisyonlar kurabilir ve bazı görevler verebilir. Ancak bu şekilde kurulan komiteler ve komisyonların KVKK ile ilgili yükümlülükleri yerine getirmesi yönetim kurulunun yönetim yetkisinin devri sonucunu doğurmamaktadır. Bu halde yönetim kurulunun yetkisi ve sorumluluğu devam etmektedir.

Yönetim Yetkisinin Devrinde Sorumluluk

Yönetim yetkisinin devri sorumluluk hukuku açısından ciddi sonuçları bulunmaktadır. Bu durum TTK m. 553/2'de "*Kanundan veya esas sözleşmeden doğan bir görevi veya yetkiyi, kanuna dayanarak, başkasına devreden organlar veya kişiler, bu görev ve yetkileri devralan kişilerin seçiminde makul*

derecede özen göstermediklerinin ispat edilmesi hâli hariç, bu kişilerin fiil ve kararlarından sorumlu olmazlar." şeklinde düzenlenmiştir. Sorumluluk devrinin söz konusu olabilmesi için TTK m. 367 uyarınca yetki devrinin usulsüz yani geçersiz olmaması gerekir. Bir diğer ifadeyle, yetki devrinin TTK m. 367'deki şartları karşılamaması halinde TTK m. 553/2'de yer alan olanaklardan yararlanılamaz. TTK m. 553/2'deki düzenleme öğretide farklı görüşlere neden olmuştur. Şöyle ki, yönetim yetkisinin devrinde görev ve yetkileri devralan kişilerin seçiminde makul derece de özenin gösterilmiş olması halinde sorumlulukta devredilmiş olacaktır. Aksi halde geçerli bir sorumluluk devri söz konusu olamayacaktır. Kanun koyucu bu düzenleme ile yönetim yetkisini geçerli bir şekilde uygun kişilere devreden yönetim kurulu üyelerini sınırsız sorumluluktan kurtarmaktadır. Ancak mehaz İsviçre Borçlar Kanunu m. 754/2'den farklı olarak kanun koyucu yetkiyi devralan kişinin seçiminde makul özeni aramıştır. Buna göre yetkiyi devreden kişi devralanın seçiminde makul özeni göstermiş olması halinde sorumluluktan kurtulacaktır. Buna karşılık İsviçre Borçlar Kanunu'na göre yetki devrinde sadece devralan kişinin seçiminde değil aynı zamanda ona talimat vermede ve gözetiminde de makul özenin gösterilmesini aramıştır. Öğretide bizimde katıldığımız Kayıhan ve Sevi tarafından da ifade edilen görüşe göre TTK m. 553/2, uyarınca devralan kişinin seçiminde makul derecede özen gösterilmesi halinde sorumlulukta devredilir. Ancak bu devir TTK m. 375/1-e deki üst gözetim yetkisini ortadan kaldırmayacaktır. Dolayısıyla yönetim kurulu TTK m. 553/2 ye göre yönetim yetkisini devrederek sorumluluktan kurtulabilir ancak m. 375/1-e'ye göre gözetim yetkisini devredemeyeceğinden bu alandaki sorumluluğu devam edecektir (Kayıhan 2011, Sevi 2021). Yetki devrinin söz konusu olduğu hallerde dikkate alınması gereken bir diğer hüküm de TTK m. 553/3'de düzenlenmiştir. Söz konusu hükme göre, *"Hiç kimse kontrolü dışında kalan, kanuna veya esas sözleşmeye aykırılıklar veya yolsuzluklar sebebiyle sorumlu tutulamaz; bu sorumlu olmama durumu gözetim ve özen yükümü gerekçe gösterilerek geçersiz kılınamaz."* Bu hüküm öğretide eleştirilmiştir (Altınok Ormancı 2021). Kanaatimizce her ne kadar TTK m. 553/2 ile m. 553/3 düzenlemeleri birbirine ters düzenleme içeriyorsa da bu iki hüküm TTK m. 375/1-e ile birlikte değerlendirilmelidir. Bu çerçevede TTK m. 553/2 geçerli bir şekilde yetki devri yapan yönetim kurulu üyelerini devralanın kişisel karar ve işlemleri karşısında sorumluluktan kurtarmakta iken m. 553/3, yönetim kurulunun devredilemez üst gözetim alanına giren konularda sorumluluktan kurtarmaz. O halde yönetim kurulunun sorumluluğu yalnızca "seçimde makul özen" ölçütüyle değil, TTK m. 375/1-e de düzenlenen üst gözetim yükümlülüğünün gereği gibi ifa edilip edilmediği dikkate alınarak değerlendirilmesi gerektiği kanaatindeyiz.

SONUÇ

Teknolojinin hızlı ivme kazandığı günümüz dünyasında veri miktarı katlanarak artmış ve verinin aktarılma ve paylaşılma yöntemelerinin kolaylaşması veri ile ilişkili olan kişinin temel hak ve özgürlüklerinin korunması ihtiyacını doğurmuştur. Temel amacı kişisel veriyi korumak değil o veri ile ilişkili olan kişiyi korumak olan 6698 sayılı KVKK kişisel verilerin işlenmesinde usul ve esasları düzenlemiştir. KVKK'ya göre veri sorumlusu olan anonim şirket tüzel kişiliğidir. Ancak tüzel kişi anonim şirket iradesini organları vasıtasıyla açıklar. Şirketin iradesini açıklayan organ olan yönetim kurulu KVKK'ya uyumun sağlanması için gerekli organizasyon yapısını oluşturmak, teknik ve idari tedbirlerin alınmasını sağlamak ve bunların uygulanmasını gözetmek yükümlülüğü altındadır. Bu yükümlülüklere aykırı davranılması halinde KVKK hükümlerine göre sorumluluk şirket tüzel kişiliğine aittir. Fakat KVKK yükümlülüklerini yerine getirmede kusurlu davranışları sebebiyle anonim şirketin zarara uğraması halinde, yönetim kurulu üyelerinin sorumluluğu doğacaktır. Bu sorumluluk KVKK'dan değil, TTK m. 369, 375 ve m. 553 hükümlerinden kaynaklanmaktadır. Anonim şirketin doğrudan veri sorumlusu olması yönetim kurulu üyelerinin TTK'dan doğan yönetim ve gözetim yükümlülüklerinin ihlali ya da üyelerin kişisel hukuka aykırı fiilleri sebebiyle kişisel sorumluluklarının doğmasına engel değildir. Bu sebeple, anonim şirket yönetim kurulu üyeleri KVKK ile ilgili yükümlülükleri yerine getirmemeleri halinde kusurları var ise sorumludurlar. KVKK'dan sorumlu yönetim kurulu üyelerinden her biri, kusuruna ve durumun gerekliliklerine göre zarardan kişisel olarak sorumludur. Yönetim kurulu üyeleri KVKK ile ilgili yükümlülüklerini içlerinden bir ya da birkaç yönetim kurulu üyesine ya da dışardan üçüncü kişilere devredebilir. Kanunun aradığı şartlarda KVKK ile ilgili yönetim yetkisinin devri beraberinde sorumluluğunda devri sonucunu doğurur ise de sorumluluğun devrinde TTK m. 553 ve 375/1-e düzenlemeleri birlikte değerlendirilmelidir. Sonuç olarak, anonim şirket yönetim kurulu üyelerinin sorumluluğu KVKK özel olarak düzenlenmemiştir. KVKK'da veri sorumlusu anonim şirket

olmasına rağmen yönetim kurulu üyelerinin şahsi sorumluluğu doğrudan KVKK'dan değil, TTK m. 369'daki özen yükümlülüğünden kaynaklandığı anlaşılmaktadır.

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ANONİM ŞİRKETLERDE İBRA DAVASI VE İBRA DAVASINDA KAYYIM ATANMASI

DISCHARGE OF LIABILITY CASE IN JOINT STOCK COMPANIES AND TRUSTEE APPOINTMENT IN DISCHARGE CASES

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ÖZET

Anonim şirketlerde yönetim kurulu üyeleri kanundan veya esas sözleşmeden doğan yükümlülüklerini kusurlarıyla ihlal ettikleri taktirde hem şirkete hem pay sahiplerine hem de şirket alacaklılarına karşı sorumlu olurlar (TTK m. 553). Yönetim kurulu üyelerinin sorumluluğunu sona erdiren hallerden biri de ibradır. Anonim şirketlerde ibra, hesap dönemi içinde yapılan işlem ve faaliyetler ile bunların sonuçlarının yönetim kurulu üyeleri açısından bir sorumluluk doğurmayacağının ve şirket tarafından kendilerine karşı herhangi bir tazminat talebinin olmayacağının beyan edilerek bu kişilere karşı güven açıklamasında bulunulmasıdır. Genel kurul ibra kararıyla birlikte yönetim kurulu üyelerinin söz konusu dönemdeki işlemlerinin hukuka ve ortaklık açısından işin gereğine uygun olduğunu beyan etmekte, ilgili döneme ait ibra kapsamına giren faaliyetlerinden dolayı onları sorumlu tutmayacağını açıklamış olmaktadır. İbra kararı vermeye yetkili organ olan genel kurul, yönetim kurulu üyelerinin bir kısmının ibrasına karar verirken bir kısım yönetim kurulu üyesinin ibrasından keyfi olarak kaçınamaz. Genel kurul haklı sebep olmaksızın yönetim kurulu üyelerini ibra etmez veya bazı yönetim kurulu üyelerini ibra edip bazılarını etmez ise hakkında ibra kararı verilmeyen yönetim kurulu üyeleri anonim şirkete karşı ibra davası açabilir. Çalışmamızda öncelikle ibra kavramı ve türleri; genel kurulun ibra kararı vermemesi halinde yönetim kurulu üyesinin ibra davası açması ve bunun şartları incelenecektir. İbra davasının davacısı ibra edilmeyen yönetim kurulu üyesi, davalısı ise şirket tüzel kişiliğidir. Yönetim kurulu üyelerinin tamamının ibra davası açması durumunda şirkete kayyım tayin edilmesi ve kayyımın şirketi bu davada temsil etmesi de incelenecektir.

Anahtar Kelimeler: İbra, Anonim Şirket, kayyım

ABSTRACT

In joint-stock companies, board members become liable to the company, shareholders, and company creditors if they violate their obligations arising from the law or the articles of association through their fault (Turkish Commercial Code, Article 553). One of the circumstances that removes the liability of board members is discharge of liability. In joint-stock companies, discharge of liability is the company's acceptance that the transactions and activities carried out during the accounting period and their results will not give rise to any liability for the board members, and the company's declaration that it will not make any claims for compensation against them, thus expressing its confidence in these individuals. With a discharge of liability resolution, the general assembly declares that the actions of the board members during the period in question were in accordance with the law and the requirements of the business, and states that it will not hold them responsible for the activities covered by the discharge of liability resolution. The general assembly, which is the body authorized to make discharge of liability resolutions, cannot arbitrarily refuse to discharge some board members while discharging others. If the general assembly does not discharge the board of directors without a valid reason, or if it discharges only some board members, the board members whose liabilities were not discharged may file a lawsuit against the joint-stock company for discharge. This study will first examine the concept of discharge of liability and its types. It will then investigate the conditions under which a board member can file a lawsuit for discharge after the general assembly fails to grant a discharge. The plaintiff in a discharge of

liability lawsuit is the board member who was not discharged, and the defendant is the company's legal entity.

Keywords: Discharge of Liability, Joint-Stock Companies, Trustee

GİRİŞ

Anonim şirketlerde kurucular, yönetim kurulu üyeleri, denetçiler ve tasfiye memurları kanun veya esas sözleşmeden kaynaklanan yükümlülüklerini kusurlarıyla ihlal ettikleri takdirde hem şirkete hem pay sahiplerine hem de şirket alacaklılarına karşı sorumlu olurlar (TTK m. 553). Aynı şekilde denetçiler ve özel denetçiler kanuni görevlerinin yerine getirilmesinde kusurlu hareket ettikleri taktirde şirkete, pay sahiplerine ve şirket alacaklılarına karşı verdikleri zararlardan sorumludurlar (TTK m. 554). Bu durumda şirket bu kişilere karşı sorumluluk davası açıp uğradığı zararın tazminini isteyebilir. Pay sahipleri şirketin uğradığı zararın tazminini isteyebilecekleri gibi kendi malvarlıklarında meydana gelen zararın tazminini de isteyebilirler. Zarara uğrayan şirketin iflası halinde istemin önce iflas idaresince ileri sürülmüş olması şartıyla şirket alacaklıları da bu kişilere karşı sorumluluk davası açabilir (TTK m. 556). Kurucuların, yönetim kurulu üyelerinin, yöneticilerin ve tasfiye memurlarının bu sorumluluktan kurtulması ibra yoluyla olur. Anonim şirketler açısından ibra şirketin karar organı olan genel kurulun sorumlu organı yönetim kurulu üyelerine karşı karar şeklinde bir irade açıklamasıdır. Genel kurul ibra kararı ile yönetim kurulu üyelerinin söz konusu dönemdeki işlemlerinin hukuka ve ortaklık açısından işin gereğine uygun olduğunu beyan etmektedir. Böylece anonim şirket yönetim kurulu üyelerine karşı bir yandan güven beyanında bulunmakta, diğer yandan da bu kişileri ilgili dönemdeki faaliyetlerinden dolayı sorumlu tutmayacağını açıklamaktadır. İbra kararı almak genel kurulun yetkisindedir. Ancak genel kurula verilen bu yetki sınırsız değildir. Genel kurul haklı sebep yokken ibra kararı almayabilir, ibra kararını geciktirebilir veya bazı kişileri ibra edip diğerlerini ibra etmeyebilir. Bu durumda genel kurulda ibra edilmeyen yönetim kurulu üyeleri, yöneticiler, denetçiler ve tasfiye memurları kendilerinden esirgenen ibranın verilmesi için mahkemeye başvurabilirler. Çalışmamızda önce ibra kavramı ve ibranın türleri ile ibra edilebilecek kişiler; sonra da TTK'da özel olarak düzenlenmemiş olmakla birlikte doktrin ve Yargıtay kararlarıyla kabul edilmiş olan ibra davası incelenecektir. Bu kapsamda ibra davasının tarafları ve davada ispat yükü ele alınacaktır. Davada şirketi temsil etmek üzere temsil kayyımı atanıp atanmayacağı da davanın taraflarına göre ayrı ayrı değerlendirilecektir.

İBRANIN TANIMI

"İbra" Arapça kökenli bir sözcük olup "aklama, temize çıkarma" anlamına gelmektedir. (Akdağ Güney 2016, Aytaç 1982). Hukuki anlamda ibra ise alacaklının bir hakkından tamamen veya kısmen vazgeçmesi olarak tanımlanmaktadır. Şirketler hukuku açısından ise ibra ticaret şirketlerinde organları mesuliyetten kurtarma olarak tanımlanır (Türk Hukuk Lügatı 1998). İbra kelimesi borçlar hukuku ve ticaret hukuku açısından farklı anlamlara gelmekte ve farklı hukuki niteliklere sahip farklı iki kurumu ifade etmek üzere kullanılmaktadır. Bu durum hem karışıklığa hem de ibranın hukuki niteliğini tespitte zorluklara yol açmaktadır. Borçlar hukukunda ibra: Tarafların aralarında yaptıkları mevcut bir borcu kısmen veya tamamen ortadan kaldırmaya ve bu surette borçlunun borçtan kurtulmasını sağlamaya yönelik bir sözleşmedir (Eren 2019, Reisoğlu 2012 Oğuzman, Öz 2018, Gümüş 2015, Tercıer, Pıchonnaz, Develioğlu 2016, Tekinay, Akman, Burcuoğlu Altop 2013, Zevkliler, Ertaş, Havuççu, Aydoğdu, Cumalıoğlu 2013). Borçlar hukuku anlamında ibra:

- Bir sözleşmedir. Alacaklının alacağından vazgeçmesi yeterli olmayıp borçlunun da bunu kabul etmesi gerekir (Tercıer , Pıchonnaz, Develioğlu 2016, Eren 2019, Reisoğlu 2012).

- İbra alacak üzerinde bir tasarruf işlemidir. İbra sözleşmesi ile alacaklı malvarlığının aktifinde yer alan bir değerden kesin olarak vazgeçer (Eren 2019, Reisoğlu 2012).

- İbra sözleşmesi ile alacaklının borçluya yaptığı kazandırma geçerli bir sebebe dayanmalıdır ki bu sebep bağışlama veya sulh sözleşmesi olabilir (Eren 2019).

- İbra edilen borcu doğuran hukuki ilişki kanun veya tarafların anlaşmasıyla şekle tabi tutulmuş olsa dahi, ibra şekle tabi değildir (TBK m. 132) (Tercıer, Pıchonnaz, Develioğlu 2016).

Anonim şirketler açısından ibra, şirketin karar organı olan genel kurulun, sorumlu organı yönetim kurulu üyelerine karşı karar şeklinde bir irade açıklamasıdır. Genel kurul ibra kararıyla yönetim kurulu üyelerinin söz konusu dönemdeki işlemlerinin hukuka ve ortaklık açısından işin gereğine uygun olduğunu beyan etmektedir. Böylece anonim şirket yönetim kurulu üyelerine karşı bir yandan güven beyanında bulunmakta, diğer yandan da bu kişileri ilgili dönemdeki faaliyetlerinden dolayı sorumlu tutmayacağını açıklamaktadır (Aytaç 1982, Çamoğlu, Poroy, Tekinalp 2021, Çamoğlu 2010). Anonim Şirketler açısından ibra:

- Genel kurul kararına bağlı olup, bir sözleşme niteliğinde değildir.

- Tek taraflı bir hukuki işlem olup, bu kararla anonim şirket tek taraflı olarak ibra edilene karşı tazminat talep etme hakkından vazgeçtiğini ifade etmektedir.

- Kurucu yenilik doğuran bir işlemdir.

- Genel kurulun takdirindedir.

- Menfi borç ikrarı niteliğindedir.

TÜRK TİCARET KANUNU'NDA İBRANIN DÜZENLENİŞİ

TTK m. 558 ve 559 hükümleri "ibra" başlığı taşımakta ve bu hükümlerde ibranın etkisi ile kuruluş ve sermaye artırımında ibra düzenlemektedir. TTK m. 558 hükmü: "*(1) İbra kararı genel kurul kararıyla kaldırılamaz.445. madde hükmü saklıdır. (2) Şirket genel kurulunun, sorumluluktan ibraya ilişkin kararı, ibranın kapsadığı açıklanan maddi olaylara ilişkin olarak, şirketin, ibraya olumlu oy veren ve ibra kararını bilerek payı iktisap etmiş olan pay sahiplerinin dava hakkını kaldırır. Diğer pay sahiplerinin dava hakları ibra tarihinden itibaren altı ay geçmesiyle düşer"* şeklindedir. Kuruluş ve sermaye artırımında ibra da TTK m. 559 hükmünde: *"(1) Kurucuların, yönetim kurulu üyelerinin, denetçilerin, şirketin kuruluşundan ve sermaye artırımından doğan sorumlulukları, şirketin tescili tarihinden itibaren dört yıl geçmedikçe sulh ve ibra yoluyla kaldırılamaz. Bu sürenin geçmesinden sonra da sulh ve ibra ancak genel kurulun onayıyla geçerlilik kazanır. Bununla beraber, esas sermayenin onda birini, halka açık şirketlerde yirmide birini temsil eden pay sahipleri sulh ve ibranın onaylanmasına karşı iseler, sulh ve ibra genel kurulca onaylanmaz"* ifadeleriyle düzenlenmiştir. Örtülü ibra ise TTK m. 424'te: "*Bilançonun onaylanmasına ilişkin genel kurul kararı, aksine açıklık bulunmadığı takdirde, yönetim kurulu üyelerinin, yöneticilerin ve denetçilerin ibrası sonucunu doğurur. Bununla beraber, bilançoda bazı hususlar hiç veya gereği gibi belirtilmemişse veya bilanço şirketin gerçek durumunun görülmesine engel olacak bazı hususları içeriyorsa ve bu hususta bilinçli hareket edilmişse onama ibra etkisini doğurmaz"* şeklinde düzenlenmiştir. Kanunda, ibrayı düzenleyen TTK m. 558-559 ve 424 hükümleri dışında, ibraya ilişkin başka hükümler de yer almaktadır. Bunlardan ilki genel kurulun yetkilerini düzenleyen TTK m. 408/2/b hükmüdür. Söz konusu hükme göre yönetim kurulu üyelerinin seçimi, süreleri, ücretleri ile huzur hakkı, ikramiye ve prim gibi haklarının belirlenmesi, ibraları hakkında karar verilmesi ve görevden alınmaları genel kurulun yetkileri arasındadır. Genel kurulların gündemine ilişkin düzenleme getiren TTK m. 409 hükmünde de "yönetim kurulu üyelerinin ibrası" olağan genel kurulun gündemi arasında sayılmaktadır (TTK m. 409/1). Oydan yoksunluk başlığını taşıyan TTK m. 436/2 hükmünde ise yönetim kurulu üyeleri ile yönetimde görevli imza yetkisini haiz kişilerin yönetim kurulu üyelerinin ibrasına ilişkin kararlarda kendi paylarından doğan oy haklarını kullanamayacakları hüküm altına alınmıştır.

ANONİM ŞİRKETLERDE İBRA TÜRLERİ

AÇIK İBRA

Açık ibra: genel kurulun gündeminde ibraya ilişkin bir maddenin bulunması ve bu maddenin görüşülüp oylanarak genel kurulda ibra kararının alınmasıdır (Aytaç 1982, Canözü 2021, Turan 2023, Akdağ Güney 2008). Açık ibra TTK'da özel olarak düzenlenmemiş olmakla birlikte; şirket yönetim kurulu üyeleri ve yönetimde görevli imza yetkisine haiz kişilerin yönetim kurulu üyelerinin ibra edilmelerine ilişkin kararlarda kendilerine ait paylardan kaynaklanan oy haklarını kullanamayacaklarını belirten TTK m. 436/2 ile genel kurulun görev ve yetkilerini düzenleyen TTK m. 408 açık ibraya işaret etmektedir. Açık ibra, genel ibra ve özel ibra olmak üzere iki alt başlık atında incelenebilir. Genel ibrada, genel

kurul tüm yönetim kurulu üyeleri ve denetçiler için tek bir oylama yaparak ibra kararı alınır. Genel ibra kararı alınması durumunda bütün yönetim kurulu üyeleri ve denetçiler ilgili faaliyet döneminde yapmış oldukları iş ve işlemlerden dolayı aklanmış olurlar. İbra kararında açıklık yoksa, ibranın genel ibra niteliğinde olduğu sonucuna varılır (Aytaç 1982, Çamoğlu 2010, Moroğlu 2001, Canözü 2021). İbra kararının şahıs, konu ve süre yönünden sınırlı olarak alınması durumunda ise özel ibra söz konusu olur (Akdağ Güney 2016, Canözü 2021, Moroğlu 2001). Genel kurul "kişi yönünden" sınırlı olarak ibra kararı alabilir. Yönetim kurulu üyelerinin ibra oylamasının ayrı ayrı yapılması, bir kısım yönetim kurulu üyeleri üyelerinin ibrasına rağmen diğerlerinin ibra edilmemesi durumunda "kişi yönünden sınırlı" özel bir ibranın varlığından bahsedebiliriz. Bazı işlemler için ayrı ibra oylamasının yapılması veya şirketin faaliyet raporunda olmayan şüpheli işlemlerin ibra kapsamı dışında bırakılması durumunda da "konu yönünden sınırlı" özel ibra kararı alınmıştır (Aytaç 1982, Çamoğlu 2010, Canözü 2021, Akdağ Güney 2008). Genel kurul ibra kararını bilanço döneminin belirli bir bölümünü kapsam dışı bırakarak almışsa "süre yönünden sınırlı" özel ibra mevcuttur (Aytaç 1982, Çamoğlu 2010). Kurucuların yönetim kurulu üyelerinin ve denetçilerin kuruluştan ve sermaye artırımından doğan sorumlulukları için verilen ibra kararı da özel ibra kararı niteliğindedir (TTK m. 559).

ÖRTÜLÜ İBRA

Genel kurul gündeminde ibraya ilişkin madde olmasa dahi ibra kararının kanun gereği alınmış sayılacağı hallerde örtülü ibra söz konusu olur (Aytaç 1982, Akdağ Güney 2008, Çamoğlu 2010, Canözü 2021, Turan 2023). TTK m. 424 hükmüne göre bilançonun onaylanmasına ilişkin genel kurul kararı, kararda aksine açıklık bulunmadığı takdirde, yönetim kurulu üyeleri, yöneticiler ve denetçiler için ibra sonucu doğurur ki; bu ibra türü "örtülü ibra", "zımni ibra" ya da "ibra varsayımı" olarak nitelendirilir. Açık ibradan farklı olarak, genel kurulun gündeminde ibraya ilişkin bir madde olmasa da bilançonun onaylanması yönetim kurulu üyeleri, yöneticiler ve denetçiler için ibra sonucunu doğuracaktır. TTK m. 424 örtülü ibranın söz konusu olabilmesi için "bilançonun onaylanması" gerektiğini ifade etmiştir. Hükümdeki bilanço kelimesinin geniş yorumlanarak bilançonun ayrılmaz bir parçası sayılan kar/zarar hesabının ve yıllık faaliyet raporunun da bu kapsamda değerlendirilmesi gerektiği ifade edilmektedir (Canözü 2021, Turan 2023, Aytaç 1982, Çamoğlu 2010). TTK m. 424'te bilançonun onayının ibra sonucunu doğuracağı hüküm altına alınarak bilanço onayı ile ibra arasında bağ kurulmuş olsa dahi, bilançonun onaylanması ile ibra kararı birbirinden bağımsız nitelik arz eder. Genel kurul bilançoyu onaylamasına rağmen ibra kararı almayabilir veya ibra kararı alsa bile bilançoyu onaylamayabilir (Çamoğlu 2010, Canözü 2021, Turan 2023, Akdağ Güney 2008). Bilanço onayının ibra sonucu doğurması için bilançonun açıklık ve doğruluk hükümlerine uygun düzenlenmesi lazımdır (Tekinalp, Poroy, Çamoğlu 2021). TTK m. 424/2 hükmüne göre bilançoda bazı hususlar hiç veya gereği gibi belirtilmemiş veya bilanço şirketin gerçek durumunun görülmesine engel olacak bazı hususları içeriyor ve bu hususta bilinci hareket edilmiş ise bilançonun onayı ibra sonucunu doğurmaz.

İBRA KARARI VERMEYE YETKİLİ ORGAN

Anonim şirketlerde ibraya karar vermeye yetkili organ genel kuruldur. İbra konusunda karar vermek TTK m. 408/2/b hükmünde genel kurulun görev ve yetkileri arasında sayılmıştır. Ayrıca TTK m. 558 ve 559 hükümlerinde de ibranın genel kurulun yetkisi içinde olduğu açıkça belirtilmiştir. İbra her faaliyet dönemi sonundan itibaren üç ay içinde yapılması gereken olağan genel kurul toplantısının zorunlu gündem maddeleri içinde yer alır (TTK m. 409). Olağanüstü genel kurul toplantılarında da ibraya yönelik karar alınabilir (Moroğlu 2001, Helvacı 2001). TTK m. 424 hükmü: "*Bilançonun onaylanmasına ilişkin genel kurul kararı, kararda aksine açıklık bulunmadığı takdirde, yönetim kurulu üyelerinin, yöneticilerin ve denetçilerin ibrası sonucunu doğurur"* şeklinde olup, örtülü ibrayı düzenlemektedir. Örtülü ibra konusunda karar almak da genel kurulun yetkileri arasındadır. İbra kararı almak için özel bir yeter sayı öngörülmemiş olup; TTK m. 418'de öngörülen adi çoğunlukla alınabilir. Esas sermayenin en az dörtte birini karşılayan pay sahiplerinin veya temsilcilerinin yer aldığı genel kurulda, katılanların çoğunluğuyla ibra kararı alınabilir (TTK m. 418/1). Şirket yönetim kurulu üyeleriyle yönetimde görevli imza yetkisine haiz kişiler yönetim kurulu üyelerinin ibrasına ilişkin kararlarda kendi paylarından kaynaklanan oy haklarını kullanamazlar. Bu durumda yönetim kurulu üyeleri ayrı ayrı ibra edilseler dahi birbirlerinin oylamalarında oydan yoksundurlar (TTK m. 436/II). İbra oylamasında oy hakkından yoksun yönetim kurulu üyelerinin başka pay sahiplerinin temsilcisi

sıfatıyla oy kullanıp kullanmayacakları doktrinde tartışılmıştır. Bir grup yazar oy hakkından yoksun olan yönetim kurulu üyesinin ibra oylamasında kendi namına oy kullanamayacağı gibi, başka bir pay sahibinin vekili sıfatıyla da oy kullanamaz (Tekinalp, Poroy, Çamoğlu 2021, İmregün 1989, Aytaç 1982, Canözü 2021, Kervankıran 2024). Bu konuda başka bir görüş yönetim kurulu üyesinin ibra oylamasında temsilen oy kullanabilmesi gerektiğini belirtir (Kırca 2004). Kanımızca TTK m. 436/II yönetim kurulu üyelerinin ibraya ilişkin kararda kendilerine ait paylarından kaynaklı oy haklarını kullanamayacakları hüküm altına alındığına göre; temsilci sıfatıyla oy kullanabilmeleri mümkün olmalıdır.

GENEL KURULUN İBRA EDEBİLECEĞİ KİŞİLER

KURUCULAR

Pay taahhüt edip esas sözleşmeyi imzalayan gerçek ve tüzel kişiler kurucudur (TTK m. 337). TTK m. 559 kurucuların ibrası düzenlemiştir. Anonim şirketin kuruluşu esnasında kurucular tarafından birtakım usulsüzlükler yapılabilir. Bu usulsüzlükler kuruluş aşamasında şirkete ayni sermaye olarak konulan unsurlara değer biçilmesi veya kanunda belirtilen dört yıllık süre içinde diğer pay sahiplerine veya şirket alacaklılarına zarar verici davranışlar şeklinde ortaya çıkabilir. Bu nedenle kanun koyucu kurucuların ibrasını TTK m. 559 hükmünde birtakım şartlara bağlayarak düzenlemiştir (Canözü 2021). TTK m. 559 kuruluş ve sermaye artırımından kaynaklanan sorumlulukların sulh ve ibra yoluyla sona erdirilmesini iki sınırlamaya tabi tutarak düzenlemiştir. Bu sınırlamalardan ilki süreye ilişkin olup; kurucuların, yönetim kurulu üyelerinin, denetçilerin şirketin kuruluşundan veya sermaye artırımından kaynaklanan sorumluluklarının şirketin tescili tarihinden dört yıl geçmedikçe sulh ve ibra yoluyla kaldırılamaz. Sınırlamalardan ikincisi ise azlığın ibrayı engelleme hakkına ilişkin olup; esas sermayenin onda birini, halk açık şirketlerde yirmide birini temsil eden pay sahipleri sulh ve ibranın onaylanmasına karşı olması halinde genel kurul sulh ve ibrayı onaylayamaz (TTK m. 559).

YÖNETİM KURULU ÜYELERİ

İbra kararı yönetim kurulu üyeleri hakkında verilir. İbra kararıyla organ olarak yönetim kurulu değil, yönetim kurulu üyesi sıfatı ile bu organın üyeleri ibra edilmiş olur (Akdağ Güney 2016). Nitekim örtülü ibraya ilişkin düzenleme getiren TTK m. 424 hükmünde de bilançonun onaylanmasına ilişkin genel kurul kararıyla yönetim kurulu "üyelerinin", yöneticilerin ve denetçinin ibra edilmiş sayılacağı açıkça vurgulanmıştır. İbra kurumu ile yönetim kurulu üyelerinin sürekli olarak haklarında tazminat davası açılması riski bertaraf edilmekte; şirket yönetim kurulu üyelerine karşı güven açıklamasında bulunmaktadır.

YÖNETİCİLER

TTK m. 424 ibra edilebilecek kişiler arasında yöneticileri de saymış olmakla birlikte; "yönetici" kavramının kapsamı konusunda bir belirleme yapmamıştır. Doktrinde yönetici kavramının geniş yorumlanması gerektiği ve sorumluluk hükümlerine tabi kılınabilecek kişilerin ibralarının da mümkün olabileceği ifade edilmektedir (Akdağ Güney 2016). Bu kapsamda murahhas üye, genel müdür, müdür, CEO, genel koordinatör sıfatına sahip kişilerin ibrası da söz konusu olabilir. Yine, TTK m. 368 ve TTK m. 370 kapsamında yetkilendirilen ticari temsilci ile genel veya özel yetki verilmiş ticari vekillerin ibrası da mümkün olmalıdır.

DENETÇİLER

Örtülü ibrayı düzenleyen TTK m. 424 hükmüne göre, bilançonun onaylanmasına ilişkin genel kurul kararı, kararda aksine bir hüküm bulunmadığı takdirde denetçilerin de ibrası sonucunu doğurur. Denetçinin sorumluluğunu düzenleyen TTK m. 554 hükmüne göre: "*Şirketin ve şirketler topluluğunun yıl sonu ve konsolide finansal tablolarını, raporlarını ve hesaplarını denetleyen denetçi ve özel denetçiler; kanuni görevlerinin yerine getirilmesinde kusurlu hareket ettikleri takdirde, hem şirkete hem pay sahipleri ile şirket alacaklılarına karşı vermiş oldukları zararlardan sorumludur*". Her iki hükme göre, denetçilerin de ibrası mümkündür. Doktrinde TTK'nın bağımsız denetçiyi organ niteliğinde kabul etmeyen düzenlemeleri ile denetçiyi de örtülü ibra kapsamına alan TTK m. 424 hükmü arasında çelişki olduğu ifade edilse dahi; TTK m. 554 kapsamında şirkete, pay sahiplerine ve şirket alacaklılarına karşı sorumluluğu olan denetçinin ibrasının mümkün olduğu kanaatindeyiz (Kırca, Şehirali Çelik, Manavgat 2013)

TASFİYE MEMURLARI

TTK m. 408 hükmünde sadece yönetim kurulu üyelerinin ibrasından bahsedilmekte; örtülü ibraya ilişkin TTK m. 408 ise yönetim kurulu üyelerinin yöneticilerin ve denetçilerin ibra kapsamında olduğunu belirtmektedir. TTK'da tasfiye memurlarının ibrası hakkında özel düzenleme yer almamakla birlikte; tasfiye memurlarının tasfiye aşamasında yönetim kurulu gibi hareket ettikleri ve dolayısıyla da yönetim kurulu üyelerinin ibrası için öngörülen hususların tasfiye memurları için de geçerli olduğu ifade edilmektedir (Kervankıran 2022, Karaman Coşkun 2015). Her ne kadar tasfiye memurlarının ibrasına yönelik TTK da bir düzenleme olmasa dahi; kanundan ve esas sözleşmeden doğan yükümlülüklerini kusurlu olarak ihlal eden tasfiye memurlarının şirkete, pay sahiplerine ve şirket alacaklılarına karşı sorumlu olacağının TTK m. 553 hükmünde düzenlenmesi karşısında, tasfiye memurlarının ibrasının da mümkün olduğu kanaatindeyiz. Şirket genel kurulunun gündeminde tasfiye memurlarının ibrası varsa "açık ibradan" bahsedilebileceği gibi, kapanış bilançosunun genel kurulda onaylanması, kararda aksine bir açıklık yoksa, tasfiye memurlarının da ibrası sonucu doğurur ki; bu durumda "örtülü ibra" söz konusu olur.

İBRANIN SORUMLULUK DAVASINA ETKİLERİ

Genel kurul ibra kararıyla yönetim kurulu üyelerinin ilgili faaliyet dönemindeki işlemlerinin hukuka, şirket esas sözleşmesine ve işin gereğine uygun olduğunu kabul etmektedir. Dolayısıyla ibra kararıyla yönetim kurulu üyelerinin şirkete karşı sorumluluğu sona ermekte, şirket muhtemel tazminat taleplerinden vazgeçmektedir (Tekinalp, Poroy, Çamoğlu 2021, Canözü 2021, Şener 2017). İbra kararı genel kurulda açık ibra şeklinde alınabileceği gibi, bilançonun onaylanmasıyla örtülü ibra şeklinde de olabilir. Nitekim şirket genel kurulunun sorumluluktan ibraya ilişkin kararının ibranın kapsadığı maddi olaylara açısından şirketin dava hakkını ortadan kaldıracağı TTK'da açık hüküm altına alınmıştır (TTK m. 558/2). Şirket genel kurulunda geçerli bir ibra kararının alınmasına rağmen şirket tarafından yönetim kurulu üyeleri aleyhine sorumluluk davası açılmışsa, yönetim kurulu üyeleri haklarındaki ibra kararını def'i olarak ileri sürebilirler. İbra kararı ibra kapsamına giren faaliyet ve işlemler için geçerli olup; TTK m. 424 gereğince örtülü ibranın söz konusu olduğu hallerde bilançoda bazı hususlar hiç veya gereği gibi belirtilmemiş veya bilanço şirketin gerçek durumunun görülmesine engel olacak hususları içeriyor ve bu hususta bilinçli hareket edilmiş ise örtülü ibra geçersiz olacak ve şirketin dava açma hakkı sona ermeyecektir. İbra kararının ortakların dava açma hakkına etkisi de TTK'da düzenlenmiştir. TTK m. 558 hükmüne göre, ibra kararı sadece genel kurulda ibra lehine oy vermiş veya yönetim kurulu üyelerinin ibra edildiğini bilerek şirket hisselerini devralmış olan ortağın dava açma hakkını ortadan kaldırır. Diğer pay sahiplerinin dava açma hakkı ise ibra tarihinden itibaren altı aylık sürenin geçmesiyle sona erer (TTK m. 558/2). Buradaki altı aylık süre hak düşürücü süredir (Bahtiyar 2022).

İbra kararının alınmasında ortaklık alacaklıların bir etkisi olmadığı için ibra kararı şirkete karşı üçüncü kişi durumunda olan alacaklıların dava açma hakkını ortadan kaldırmaz (Akdağ Güney 2016, Aytaç 1982, Helvacı145, Bahtiyar 2022).

İBRA DAVASI

Kurucuların, yönetim kurulu üyelerinin, yöneticilerin ve tasfiye memurlarının sorumluluğunu düzenleyen TTK m. 553 hükmüne göre, kurucular, yönetim kurulu üyeleri, yöneticiler ve tasfiye memurları kanun ve esas sözleşmeden kaynaklanan yükümlülüklerini kusurlarıyla ihlal ettikleri taktirde vermiş oldukları zarardan hem şirkete hem pay sahiplerine hem de şirket alacaklılarına karşı sorumludur. Bu kişilerin sorumluluktan kurtulması ibra yoluyla olur; yani ibra kararıyla bu kişilerin ibranın kapsadığı maddi olaylara ilişkin sorumlulukları şirkete, ibra kararına olumlu oy veren ve ibra kararını bilerek şirket paylarını iktisap eden pay sahiplerine karşı ortadan kalkar. İbra kararı almak genel kurulun yetkileri arasındadır (TTK m. 408/1/b, TTK m. 424). İbra kararı almak konusunda genel kurulun takdir yetkisi vardır; ancak bu yetki sınırsız değildir. Kusursuz bir yönetim gerçekleştiren ve hesapları usulüne uygun tutup genel kurula sunan yönetim kurulu üyelerinin ibra edilmesi gerekir. Genel kurulun haklı bir sebep yokken ibra kararı vermemesi, ibra kararını geciktirmesi veya bazı kişileri ibra edip bazılarını etmemesi halinde, ibra edilmeyen kişiler ibra edilmelerini sağlamak için ibra davası açabilirler. İbra talepli bir dava TTK'da açıkça düzenlenmemiştir. Ancak TTK m. 403 hükmünün gerekçesinde: "*İbra etmeme kararına karşı dava açılıp, ibra mahkeme kararıyla sağlanabileceği gibi*

olumsuz görüş yazısının iptali ile olumlu görüş yazısı verilmesinin karara bağlanması da mahkemeden istenebilir" açıklamasına yer verilerek ibra davasına işaret edilmektedir. Doktrinde de ibra kendisinden dürüstlük kuralına aykırı olarak esirgenen yönetim kurulu üyelerinin, kurucuların, yöneticilerin ve denetçilerin ibra sonucunu sağlamak için ibra davası açabilecekleri ifade edilmektedir (Aytaç 1982, Çamoğlu 2010, Tekinalp, Poroy, Çamoğlu 2021, Şener 2017, Aytaç 2019). Yargıtay da pek çok kararında yönetim kurulu üyeleri ile şirket arasında vekalet ilişkisi olduğu, bu ilişkide yönetim kurulu üyelerinin ortaklığın menfaatini koruma ve hesap verme yükümlülüğü altında oldukları ve ilişkinin aynı zamanda bu kişilere hak ettikleri ibranın kendilerine verilmesini talep etme hakkı tanıdığı gerekçesine dayanak bunların ibra davası açabilecekleri sonucun varmıştır (Örn. Yargıtay 11. HD, 26.01.1988, E.1987/7318 K.1988/287, Lexpera – e.t. 27.06.2026). Yargıtay 11. HD 1984 yılında verdiği bir kararda: *"Gerçekten de bir anonim şirkette görev yapan yönetim kurulu üyeleri ile denetçiler yasadan ve ana sözleşmeden doğan bütün görevlerini özenle, tam ve eksiksiz olarak yerine getirmeleri halinde şirketin görevi de TTK'nun 380. maddesi uyarınca onları ibra etmek olmalıdır. Zira böyle bir ibra kararı onları sorumluluktan kurtaracağı gibi, inisiyatif sahibi olması gereken yöneticilerin her türlü kuşku ve endişeden uzak bir çalışma ortamı içinde bulunmalarını da sağlayacaktır. İşte böyle bir durumda, yani şirket yönetim kurulu üyeleri ve denetçilerin görevlerini layığı ile yapmış olmalarına rağmen şirket genel kurulunca hiç haklı nedene dayanmaksızın ibra edilmemeleri veya ibra konusunda bir karar vermekten kaçınılması halinde artık ortada objektif iyiniyet kurallarına aykırı bir davranış bulunduğundan, yönetim ve denetim kurulu üyelerine ibra edilmeme kararının iptali (TTK m381) veya ibra edilmeleri gerektiği konusunda şirket aleyhine dava açılması olanağının tanınması bir zorunluluk olarak ortaya çıkmaktadır"* şeklinde hüküm tesis ederek, ibra edilmeyen yönetim kurulu üyelerinin karara karşı iptal ve ibra davası açabileceğini belirtmiştir (Yargıtay 11. HD, 07.02.1984, E.1984/252 K.1984/594, Lexpera – e.t. 27.06.2026). İbra davası hem ibranın sebepsiz yere geciktirilmesi ve karar alınmaması hem de ibranın reddi yönünde karar alınması halinde açılabilir (Aytaç 1982, Semerci Vuraloğlu 2021). İbra davası açılabilmesi için sorumluluk davasının açılabileceği makul sürenin geçmesi gerektiği yönünde Yargıtay kararları mevcuttur (Örn. Yargıtay 11. HD, 10.06.20215, E.2015/2459 K.2015/8041, Lexpera – e.t. 27.06.2026). Doktrinde bir görüş, iptal davasından farklı olarak, ibra davası açılmasını sorumluluk davası açılması şartına bağlı tutmanın hukuki dayanaktan yoksun olduğunu; ibra davasının sadece ret halinde değil, kararın geciktirilmesi veya hiç alınmaması hallerinde de açılabileceğini; dolayısıyla sorumluluk davası açılmadan ibra davasının açılamayacağı görüşünün uygun olmadığını belirtmiştir. Bu görüşte olan yazar ibra davasının olumlu sonuçlanması durumunda artık sorumluluk davası açılmayacağını, ibra davasında verilen kararın sorumluluk davası açısından kesin hüküm oluşturacağını ileri sürmektedir (Aytaç 2021). Kanımızca da şirket genel kurulunda ibra edilmeyen kişiler sorumluluk davası açılmasını beklemeksizin ibra davası açabilmelidirler. İbra davası açılmasını sorumluluk davası açılması şartına bağlı tutmanın hukuki dayanaktan yoksun olduğu kanaatindeyiz. Hakkında ibra kararı verilmeyen kişinin karardan çok kısa bir süre sonra da ibra talebiyle dava açması mümkün olmalıdır.

TARAFLARI

Genel kurulda ibrası reddedilen veya hakkında ibra kararı verilmekten kaçınılan herkes ibra davası açabilir. Bu kapsamda yönetim kurulu üyeleri, yöneticiler ve denetçiler ibra davası açabilecektir. Dava açan kişinin genel kurul tarihinde veya dava tarihinde yönetim kurulu üyesi veya pay sahibi olması zorunlu değildir (Aytaç 1982). Denetçilerin 6102 sayılı TTK ile şirket organı olmaktan çıkarılması sebebiyle denetçilerin genel kurulda ibra edilip edilemeyecekleri ve ibra davası açıp açamayacakları doktrinde tartışılmıştır. Doktrinde bir görüş yeni sistemde organ olarak görev yapmayan denetçinin genel kurul kararıyla ibrasından da söz edilemeyeceğini ileri sürmüştür (Kendigelen 2011). Diğer bir görüş ise TTK sisteminde denetçinin organ niteliği bulunmadığı halde TTK m. 554 hükmündeki sorumluluk rejimine tabi tutulmasının hatalı bir tercih olduğunu ve denetçinin salt şirkete karşı sorumlu tutulması gerektiğini; bu sorumluluk ilişkisinin tarafı olmayan alacaklılara şirket zararının tazmini için dava açma hakkı tanınmasının doğru olmadığını ifade etmektedir. Bu görüşte olan yazar organların ibrasına ilişkin hükümlerin kapsamına denetçilerin dahil edilmemesi gerektiğini; denetçilerin ibrasında TBK. m.132 hükmünün uygulanması gerektiğini ifade etmiştir (Kırca, Şehirali, Çelik 2013). Denetçinin örtülü ibrasına ilişkin TTK m. 424 ve denetçinin şirkete, pay sahiplerine ve şirket alacaklılarına verdiği zarardan sorumluluğunu düzenleyen TTK m. 554 karşısında; denetçinin genel kurulda gerek açık

gerekse TTK m. 424 gereğince örtülü ibrasının mümkün olduğu ve haksız şekilde ibra edilmeyen denetçinin de ibra davası açabileceği kanaatindeyiz. İbra davası şirket tüzel kişiliğine karşı açılır. Genel kurulda söz konusu karar lehine olumlu oy veren pay sahiplerine karşı dava açılamaz.

İSPAT YÜKÜ

İbra davasında davacı yönetim kurulu üyesi kusursuz yönetim gerçekleştirdiklerini, hesapların usulüne uygun olduğunu ve somut olayda ibranın reddini gerektirecek haklı nedenlerin olmadığını ispat edecektir. Davalı şirket tüzel kişiliği ise ibranın reddini haklı kılan nedenleri ortaya koyup ispat etmek zorundadır (Aytaç 1982, Vuraloğlu Semerci 2021, Canözü 2021). Denetçilerin ibra davası açması durumunda ise bu kişiler denetim faaliyetlerini kanuna uygun bir şekilde yerine getirdiklerini ve denetim raporlarının doğru olduğunu ispat edeceklerdir (Canözü 2021).

İBRA DAVASINDA KAYYIM ATANMASI

İbra davası şirket tüzel kişiliğine karşı açılır ve davada şirketi yönetim kurulu temsil eder (TTK m. 365). İbra davasında şirkete temsil kayyımı atanıp atanmasının gerekli olup olmadığının belirlenmesi için davanın taraflarına göre değerlendirme yapılmalıdır. Şöyle ki; şirket genel kurulu tüm yönetim kurulu üyelerini ibra etmemiş ise yönetim kurulu üyelerinin her biri şirket tüzel kişiliğine karşı ibra davası açabilir. Bu davada davacı şirket yönetim kurulu üyeleri, davalı da şirket tüzel kişiliği olduğu için ve şirket ile şirketin yasal temsilcisi konumunda olan yönetim kurulu arasında temsil kayyımı atanmasını gerektirecek bir menfaat çatışması olacaktır. Bu halde ibra davasında davalı şirketi temsil etmek üzere TMK m. 426/2 gereği bir temsil kayyımı atanması zorunluluğu vardır (Keçecioğlu 2024). Genel kurulda örneğin beş kişilik yönetim kurulu üyelerinden dördü ibra edilip bir tanesi ibra edilmemiş ise ibra edilmeyen yönetim kurulu üyesinin açtığı davada şirkete kayyım atanmasını gerektirecek bir temsil problemi ile karşılaşılmaz. Şirkette tüm pay sahiplerinin aynı zamanda yönetim kurulu üyesi olduğu hallerde yönetim kurulu üyeleri ibraya ilişkin genel kurul kararında kendi paylarından kaynaklı oy haklarını kullanamazlar. Tüm pay sahiplerinin aynı zamanda yönetim kurulu üyesi olduğu hallerde ibra kararına ihtiyaç durulmadığı ifade edilse dahi; bu kişilerin ibrayı sağlamak amacıyla ibra davası açabileceği de belirtilmektedir. Bu durumda da şirket tüzel kişiliğine karşı açılan ibra davasında şirketi temsil etmek üzere temsil kayyımı atanması gerekliliği ortaya çıkar (Keçecioğlu 2024). Denetçi, tarafından şirket tüzel kişiliğine açılan ibra davasında şirketi yönetim kurulu temsil eder ve şirkete temsil kayyımı atanması gerekmez. Tasfiye memurlarının şirket tüzel kişiliğine karşı açtıkları ibra davasında şirketi temsil etmek üzere temsil kayyımı atanıp atanmayacağı hususunun tespiti açısından tasfiye memurlarının yönetim kurulu üyesi veya üçüncü kişi olmalarına göre değerlendirme yapmak gerekir. TTK m. 536'da tasfiye memurlarının esas sözleşmeyle veya genel kurul kararı ile belirleneceği hüküm altına alınmıştır. Esas sözleşmeyle veya genel kurul kararıyla tasfiye memuru atanmadığı hallerde tasfiye yönetim kurulunca yapılır. Yönetim kurulunun tasfiye memuru sıfatıyla görev yaptığı hallerde şirket tüzel kişiliğine karşı açılan ibra davasında şirkete temsil kayyımı atanması söz konusu olabilir.

İBRA DAVASINA İLİŞKİN YARGITAY KARARLARI VE DEĞERLENDİRİLMESİ

TTK'da ibra davasına ilişkin hüküm olmamakla birlikte Yargıtay uygulamasında ibra edilmeyen yönetim kurulu üyelerinin, ibra etmemeye yönelik genel kurul kararının iptalini isteyebilecekleri veya ibra talepli dava açabilecekleri de kabul edilmektedir: "*Gerçekten de bir anonim şirkette, görev yapan yönetim kurulu üyeleri ile denetçiler, yasadan ve ana sözleşmeden doğan bütün görevlerini özenle, tanı ve eksiksiz olarak yerine getirmeleri halinde şirketin görevi de TTK. nun 380. maddesi uyarınca onları ibra etmek olmalıdır. Zira, böyle bir ibra kararı onları sorumluluktan kurtaracağı gibi, inisiyatif sahibi olması gereken yöneticilerin her türlü kuşku ve endişeden uzak bir çalışma ortamı içinde bulunmalarını da sağlayacaktır. İşte böyle bir durumda, yani şirket yönetim kurulu üyeleri ve denetçilerinin görevlerini layığı ile yapmış olmalarına rağmen şirket genel kurulunca hiçbir haklı nedene dayanmaksızın ibra edilmemeleri veya ibra konusunda bir karar vermekten kaçınılması halinde artık ortada objektif iyi niyet kurallarına aykırı bir davranış bulunduğundan, yönetim ve denetim kurulu üyelerine ibra edilmeme kararının iptali (TTK. 381) veya ibra edilmeleri gerektiği konusunda şirket aleyhine dava açılması olanağının tanınması bir zorunluluk olarak ortaya çıkmaktadır. Nitekim, dairemizin yerleşmiş içtihatları da bu yolda bulunmaktadır (Bkz. 11. HD. 24.6.1976 gün ve 1976/2890 E. 1976/3333 K. sayılı ilâmı. YKD., 1978, Cilt 4, Sayı 7, s. 11491152 L). İşte, bu ilkelere göre, açılan gerek iptal gerekse ibra*

davalarında her olayın özelliği dikkate alınarak inceleme yapılmalı ve hasıl olacak sonuç çerçevesinde bir karar verilmelidir (Yargıtay 11. HD, 07.02.1984, E.1984/253 K.1984/594, Lexpera – e.t. 27.06.2026). Genel kurulun aldığı ibranın reddi kararlarına karşı ibra edilmeyen kişilerin ilgili genel kurul kararının iptalini talep etme hakkı da vardır. Yargıtay'ın sorumluluk davası açılmadan veya sorumluluk davası açılması için makul süre geçmeden genel kurul kararının iptalinin talep edilemeyeceği yönünde kararları vardır. "…*Dava konusu genel kurulda, yönetim kurulu üyelerinin ayrı ayrı ibraları oylanmıştır. Ancak bu karar henüz uygulanabilir nitelikte bir karar değildir. Zira, böyle bir karara dayanılarak yönetim kurulu üyeleri hakkında sorumluluk davası açılabilmesi mümkün bulunmamaktadır. Bunun için, mülga TTK'nun 341. maddesi hükmüne göre, genel kurulun sorumluluk davası açılmasına karar vermesi gerekmektedir. Bu itibarla, yönetim kurulu üyelerinin ibra edilmemelerine ilişkin bir genel kurul karar iptalinin haklarında sorumluluk davası açılması yolunda alınmış genel kurul kararı bulunmadan önceki bir aşamada dava edilebilmesi mümkün değildir. Zira, yönetim kurulu üyeleri sorumlu olmadıkları iddiasına dayanmaktadırlar, bu husus genel kurul kararlarının iptali davasında değil, şirketin açacağı sorumluluk davası veya bu yola uzun bir zaman zarfında gidilmediği takdirde daha sonra ibra edilmeyenlerin açacağı hükmen ibra davasında karara bağlanmalıdır. Somut olayda, iptali istenen karar 26.03.2008 tarihli genel kurulda alınmıştır. Sonraki tarihlerde davacı hakkında sorumluluk davası açılması için karar alındığına ilişkin tarafların bir iddia ve savunması da bulunmadığından birleşen davalar da 25.04.2008 tarihinde açıldığından sorumluluk davası için makul bir sürenin geçmesi beklenilmeden eldeki davaların bu aşamada dinlenilmesi mümkün değildir. O halde birleşen davaların reddi yerine kabulüne karar verilmesi doğru görülmemiş, kararın bu nedenle bozulması gerekmiştir."*(Yargıtay 11. HD., 21.06.2022, E.2021/1700 K.2022/5128; aynı yönde: Yargıtay 11. HD, 11.06.2015, E.2015/747 K.2015/8280, Lexpera – e.t. 27.06.2026). Yargıtay bir baka kararında da ibra etmeme kararının iptali talepli bir davada genel kurulda ibra etmeme kararına dayanılarak alınmış sorumluluk davası açılması kararı ile açılmış bir sorumluluk davası olup olmadığının araştırılması gerektiğine karar vermiştir: "…*Mahkemece, öncelikle davacı hakkında genel kurulda alınan ibra edilmeme kararına dayanılarak alınmış bir sorumluluk davası açılması kararı ile açılmış bir sorumluluk davası bulunup bulunmadığının araştırılması gerekmektedir. Davacı hakkında açılmış bir sorumluluk davasının mevcut olduğunun belirlenmesi halinde, davacı hakkında verilen ibra edilmeme kararının açılmış sorumluluk davasında değerlendirilecek olması karşısında, davacının bu davayı açmakta hukuki yararı bulunmadığının kabulü ile davanın reddi gerekir. Ancak, davacı hakkında açılmış bir sorumluluk davası bulunmadığının ve makul bir süre geçmesine rağmen bu davanın açılmadığının anlaşılması halinde ise bu davada alınan ibra edilmeme kararının TTK ve ana sözleşme hükümleri gereğince kanun, ana sözleşme hükümleri ve iyi niyet esaslarına aykırı bulunup bulunmadığı yönlerinden tarafların dayandıkları deliller de değerlendirilmek suretiyle ortaya çıkacak sonuca göre davacının istemi hakkında bir karar verilmesi gerekirken, eksik incelemeye dayalı olarak yazılı şekilde karar verilmesi doğru görülmemiş, bozmayı gerektirmiştir"(*Yargıtay 11.HD, 02.10.2024, E.2014/8177 K.2014/15155; aynı yönde: Yargıtay 11. HD, E.2005/395 K.2005/1018, Lexpera – e.t. 27.06.2026).Yargıtay hükmen ibra davasının açılabilmesi için sorumluluk davası açılabileceği makul uzunca bir sürenin geçmesi gerektiği, hükme ibra davasını üç aylık süre dolmadan zamansız olarak açıldığı ve dinlenilemeyeceği gerekçesiyle reddeden bir kararı ise: *"....Dava, ortaklar kurulu toplantısında ibra edilmeyen müdür davacının, hükmen ibrası istemine ilişkindir. Mahkemece her ne kadar yazılı gerekçeyle davanın reddine karar verilmiş ise de ibra edilmemeye ilişkin ortaklar kurulu kararından itibaren 3 ay dolmasına bir gün kala bu davanın açıldığı ve temyiz aşamasında dahi halen bir sorumluluk davası açıldığı savunmasında bulunulmadığı nazara alındığında; işbu davanın makul süre içinde açıldığı gözetilerek işin esasına girilmesi gerekirken, davanın erken açıldığından bahisle reddine karar verilmesi doğru görülmemiş, kararın bu sebeple bozulması gerekmiştir."* gerekçesiyle bozmuştur (Yargıtay 11. HD, 11.02.2024, E.2013/13569 K.2104/2297, Legalbank – e.t. 27.06.2026). Bu Yargıtay kararları incelendiğine ibra davası veya ibranın reddine ilişkin genel kurul kararlarının iptali davası ile sorumluluk davası arasında bağ kurulduğunu görmekteyiz. Yargıtay'ın sorumluluk davası açılmadan veya sorumluluk davasının açılması için makul süre beklenmeden genel kurul kararının iptali veya hükmen ibra talepli davaların dinlenilmeyeceğine ilişkin kararları eleştiriye açıktır. Kanımızca ibranın reddi yanında ibranın geciktirilmesi veya hiç ibra kararı alınmaması durumunda da hükmen ibranın sağlanabilmesi için ibra davası açılabilmelidir. İbra edilmeyen kişi genel kurulda sorumluluk davası açılmasına yönelik karar verilsin veya verilmesin bu karardan hemen sonra ibra davası

açabilmelidir. Söz konusu davanın dinlenilmesini sorumluluk davası için makul bir süre beklenmesi şartına bağlamanın hukuki gerekçesi yoktur. Ayrıca, Yargıtay'ın ifade ettiği "makul sürenin" nasıl tayin edileceği de belirsizdir. Şirket ibra etmeme kararı üzerine sorumluluk davası açma yönünde karar alıp hemen sorumluluk davası açabileceği gibi, TTK m. 560 hükmünde öngörülen iki yıllık süre içinde dava açabilir. Kanınızca ibra davası genel kurul tarafından hiç ibra kararının alınmadığı, ibranın reddedildiği veya ibranın geciktirildiği her üç halde de belirli bir süre beklenmeksizin açılabilen bir dava olarak kabul edilmelidir.

SONUÇ

Anonim şirketlerde ibra kararı almak genel kurulun yetkisinde olmakla birlikte, genel kurula verilen bu yetki sınırsız bir yetki değildir. Şirkette kusursuz bir yönetim gerçekleştiren, hesapları usulüne uygun tutup genel kurula sunan yönetim kurulu üyelerinin ibra edilmeleri gerekir. Genel kurul haklı bir sebep yokken ibrayı reddedebilir, hiç ibra kararı alamayabilir veya ibrayı geciktirebilir veya yönetim kurulu üyelerinin bir kısmını ibra edip diğerlerini ibra etmeyebilir. İşte Yönetim kurulunun haksız bir şekilde kendilerinden ibrayı esirgediği bu kişilerin ibra edilmelerini sağlamak üzere dava açarak hükmen ibrayı sağlayabilecekleri kabul edilmektedir. İbra davasını, hakkında ibra kararı verilmeyen yönetim kurulu üyeleri, yöneticiler, denetçiler ve tasfiye memurları açabilir. Davacılar yönetim kurulu üyeleri ise kusursuz bir yönetim gerçekleştirildiğini, hesapların usulüne uygun tutulduğunu ve somut olayda ibranın reddini gerektirecek haklı sebeplerin olmadığını ispat edeceklerdir. Davalı şirket tüzel kişiliği ise ibranın reddini gerektiren haklı sebepleri ispatlamak zorundadır. İbra davası şirket tüzel kişiliğine karşı açılır. Davada şirketi temsil etmek üzere temsil kayyımı atanmasının gerekli olup olmadığı davanın taraflarına göre değerlendirilmelidir. Genel kurulda tüm yönetim kurulu üyeleri ibra edilmediği ve ibra edilmeyen tüm yönetim kurulu üyelerinin şirket tüzel kişiliğine karşı ibra davası açtığı varsayımda şirketi temsil problemi ortaya çıkacaktır. Zira tüm yönetim kurulu üyeleri davacıdır ve davalı şirket tüzel kişiliğini de yine yönetim kurulu tarafından temsil edecektir. Bu durumda TMK m. 426/2 gereğince bu davada şirketi temsil etmek üzere temsil kayyımı atanması gerekir. Şirket genel kurulunda bir veya birkaç yönetim kurulu üyesinin ibra edilmediği varsayımında ise kalan yönetim kurulu üyeleriyle şirketin temsili mümkünse şirkete temsil kayyımı atanması gerekmez. Denetçiler tarafından açılan ibra davasında ise şirketi yönetim kurulu temsil edeceğinden temsil kayyımı atanması geremez.

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AZLIK PAY PASAHİPLERİNİN ANONİM ŞİRKET GENEL KURULUNU TOPLANTIYA ÇAĞIRMASI VE ŞİRKETE KAYYIM ATANMASI

MINORITY SHAREHOLDERS CALLING THE GENERAL ASSEMBLY OF JOINT STOCK COMPANY TO MEETING AND APPOINTMENT OF A TRUSTEE TO THE COMPANY

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ÖZET

Anonim şirketlerde geçerli olan çoğunluk ilkesi gereği genel kurulda verilen kararlar toplantıda hazır bulunan, bulunmayan veya olumsuz oy veren pay sahipleri hakkında geçerlidir (TTK m.423). Anonim şirketlere egemen olan çoğunluk ilkesinin uygulanmasının şirkette azlık pay sahipleri açısından doğuracağı sakıncaları ortadan kaldırmak, hâkim pay sahipleri ile azlık pay sahipleri arasındaki menfaat dengesini korumak için bu pay sahiplerine birtakım haklar tanınmıştır. Azlık pay sahiplerine tanınan bu haklar olumlu azlık hakları ve olumsuz azlık hakları olmak üzere iki başlık altında incelenebilir. Olumsuz azlık haklarının söz konusu olduğu hallerde azlık pay sahipleri belirli hususlarda çoğunluğun karar almasını önleyebilmektedir (TTK m.558, TTK m.421). Olumlu azlık haklarında ise çoğunluğa rağmen azlığa şirket adına bazı işlemler yapma yetkisi verilmektedir (TTK m.360, TTK m.411, TTK m.412, TTK m.420, TTK m.399/4, TTK m.439, TTK m.486, TTK m.531). Anonim şirketlerde kural olarak yönetim kurulu şirket genel kurulunu toplantıya davet etmeye yetkilidir. Ancak yönetim kurulu genel kurulu toplantıya çağırma görevini bilinçli olarak veya ihmal neticesinde yerine getirmeyebilir. TTK m.411-412 hükümlerinde sermayenin en az onda birine, halka açık anonim şirketlerde ise yirmide birini oluşturan pay sahiplerine genel kurulu toplantıya davet etme ve genel kurul zaten toplanacak ise gündeme madde eklenmesini talep etme hakkı tanınmıştır. Çalışmamızda öncelikle anonim şirket genel kurulunu toplantıya davet etme yetkisine sahip olanlar incelenecek, daha sonra anonim şirketler açısından azlık kavramı inceleme konusu yapılacaktır. Bu kapsamda azlık kavramı oransal azlık, nominal azlık ve fiili azlık başlıkları altında incelenecektir. Daha sonra azlık pay sahibinin genel kurulu toplantıya davet etmek ve gündeme madde ekletmek için izlemesi gereken aşamalar inceleme konusu yapılacaktır. Bu kapsamda azlığın genel kurulun toplantıya davet edilmesi ve genel kurul zaten toplanacaksa gündeme madde eklenmesi için yönetim kuruluna başvurusu, yönetim kurulunun bu başvuruyu kabul etmesi ve fakat toplantıyı kırk beş gün içinde yapmaması durumunda azlık pay sahiplerinin hakları incelenecektir. Yönetim kurulunun azlığın toplantıya çağrı veya gündeme madde ekleme taleplerini reddetmesi veya bu taleplere yedi iş günü içinde cevap vermemesi durumunda azlığın mahkemeye başvurması ele alınacaktır.

Anahtar kelimeler: Anonim şirket, azlık pay sahipleri, genel kurul

ABSTRACT

According to the majority principle applicable in joint-stock companies, decisions made at the general assembly of the company are binding on all shareholders, whether present at the meeting, absent, or voting against. To eliminate disadvantages of the application of the majority principle might create for minority shareholders, and to maintain a balance of interests between majority and minority shareholders, certain rights have been granted to minority shareholders. Board of directors is generally authorized to convene general assembly. However, board of directors may fail to fulfill this duty, either intentionally or through negligence. Articles 411-412 of Turkish Commercial Code grant shareholders holding at least one-tenth of the capital, or one-twentieth in publicly traded joint-stock companies, the right to convene the general assembly and to request the addition of an item to the agenda if the general assembly is already scheduled to convene. This study will first examine those authorized to convene the

general assembly, and then address the concept of minority shareholders. Subsequently, the steps a minority shareholder shall follow to convene the general assembly and to request addition of an item to the agenda will be examined. This includes the minority's application to the board of directors to convene the general assembly and to request addition of an item to the agenda if the general assembly is already scheduled to convene, and the rights of minority shareholders in the event that the board of directors accepts this application, but fails to hold the meeting within forty-five days. If the board of directors rejects the minority's requests to convene a meeting or add items to the agenda, or fails to respond to these requests within seven business days, the minority's application to the court will be examined.

Keywords: Joint-Stock Companies, Minority Shareholders, General Assembly

GİRİŞ

Anonim şirketlerde azlık pay sahiplerine tanınan haklar olumlu azlık hakları ve olumsuz azlık hakları olmak üzere iki alt başlık atında incelenebilir. Biz bu çalışmamızda olumlu azlık haklarından azlığın genel kurulu toplantıya çağırma ve genel kurul zaten toplanacak ise gündeme madde eklenmesini talep haklarını inceleme konusu yapacağız. Anonim şirkette yönetim kurulu genel kurulu toplantıya davete yetkilidir. Ancak yönetim kurulu genel kurulu olağan toplantıya veya gerekli olmasına rağmen olağanüstü toplantıya davet etmeyebilir veya pay sahiplerinin genel kurulda görüşülmesini istedikleri hususları gündeme almayabilir. Bu durumda sermayenin onda birine, halka açık şirketlerde ise yirmide birine sahip pay sahipleri genel kurulun toplantıya davet edilmesini ve genel kurul zaten toplanacak ise görüşülmesini istedikleri hususların gündeme alınmasını yönetim kurulundan talep edebilirler. Yönetim kurulu bu talebi reddeder veya yedi iş günü içinde olumlu cevap vermez ise bu defa azlık genel kurulun toplantıya davet edilmesi ve genel kurul zaten toplanacak ise istedikleri hususların gündeme alınması için mahkemeye başvurabilirler. Azlık pay sahiplerinin genel kurulu toplantıya çağırma ve gündeme madde eklenmesini talep etme hakkı 6762 sayılı Mülga TTK da düzenlenmiş; ancak bu hakkın azlık tarafından nasıl kullanılacağı konusunda ayrıntıya yer verilmemişti. 6762 Sayılı Mülga TTK döneminde azlığın bu hakkı kullanmak için dava yoluna başvurduğu halellerde hakimlerin duruşma açtığı, dosyayı bilirkişiye gönderdiği ve yargılamaların oldukça uzun sürdüğü görülmekteydi. 6102 Sayılı TTK ile hem bu hakkın azlık tarafından nasıl kullanılacağı ayrıntılı şekilde düzenlenmiş hem de mahkemenin zorunluluk olmadıkça dosya üzerinden inceleme yapıp karar vereceği hüküm altına alınarak azlığın bu hakkına hızlı şekilde ulaşmasının önü açılmıştır. Çalışmamızda önce azlık kavramı ve azlığın belirlenmesinde kullanılan yöntemler; sonra da azlığın genel kurulu toplantıya çağırmak için izlemesi gereken aşamalar ve mahkemeye başvuru süreci incelenecektir. Azlığın genel kurulu toplantıya çağırmak veya gündeme madde ekletmek için yaptığı başvuru üzerine genel kurulu toplantıya çağırma kararı veren mahkemenin şirkete kayyım atanması, atanan bu kayyımın niteliği ile görev ve yetkileri de inceleme konusu yapılacaktır.

ANONİM ŞİRKETLERDE GENEL KURULU TOPLANTIYA ÇAĞIRMAYA YETKİLİ OLANLAR

Anonim şirket genel kurulunu toplantıya davet etmeye yetkili olanlar TTK m.410, 411 ve 412 hükümlerinde düzenlenmiştir. Söz konusu madde hükümlerine göre anonim şirket genel kurulu yönetim kurulu, tasfiye süresince tasfiye memurları, mahkeme izniyle tek pay sahibi ve azlık pay sahipleri tarafından toplantıya çağrılır (Tekinalp, Poroy, Çamoğlu 2021, Kaya 2015, Doğan 2020, Bahtiyar, 2022, Keçecioğlu, 2024, Şener 2017).

Yönetim kurulu, genel kurulu hep olağan hem de olağanüstü toplantıya davet etmeye ve gündemi hazırlamaya yetkilidir. Görev süresi sona ermiş olsa dahi yönetim kurulu genel kurulu toplantıya davet edebilir (TTK m. 410/1). Yönetim kurulu genel kurulu toplantıya çağırma yetkisini toplantı yapıp karar alarak kullanır. Genel kurulun olağan toplantıya veya gerekli olmasına rağmen olağanüstü toplantıya davet edilmemesi yönetim kurulunun sorumluluğuna yol açabilir (TTK m. 553 vd.) (Bahtiyar, 2022, Şener 2017, Aykutalp Kabaağaçlı 2025, Akdağ Güney 2016).

Yönetim kurulunun devamlı olarak toplanamaması, toplantı yeter sayısını sağlayamaması veya mevcut olmaması hallerinde tek pay sahibi mahkemeye başvurarak genel kurulun toplanmasına karar

verilmesini talep edebilir (TTK m. 410/2). Uygulamada anonim şirkette belirli pay sahipleri arasındaki çekişme ve uyuşmazlıklar nedeniyle yönetim kurulunun toplanamaması, yönetim kurulunun toplu olarak istifa etmesi veya kaza gibi nedenlerle mevcut olmaması durumları ile karşılaşılmaktadır. Bu halde tek pay sahibine genel kurulun toplantıya davet edilmesi için mahkemeye başvurma imkanının tanınması şirketteki kilitlenmenin sona ermesini sağlamaya yönelik bir tedbirdir (Bahtiyar 2022, Poroy/Tekinalp/Çamoğlu 2021, Günay 2024)

Sermayenin en az onda birini, halka açık anonim şirketlerde yirmide birini oluşturan pay sahipleri yazılı olarak gerektirici sebeplerini ve gündemi belirterek yönetim kurulundan genel kurulu toplantıya çağırmasını veya genel kurul zaten toplanacak ise karara bağlanmasını istedikleri hususların gündeme eklenmesini talep edebilirler (TTK m. 411/1). Yönetim kurulu çağrıyı kabul ettiği takdirde en geç 45 gün içinde yapılacak şekilde genel kurulu toplantıya çağırır. Aksi halde, çağrı, istemde bulunan azlık pay sahipleri tarafından yapılır (TTK m. 411/4). Yönetim kurulunun azınlığın çağrı talebini reddetmesi veya isteme yedi iş günü içinde olumlu cevap vermemesi durumunda aynı pay sahiplerinin başvurusu üzerine şirket merkezinin bulunduğu yerdeki asliye ticaret mahkemesi genel kurulun toplantıya çağrılmasına karar verebilir (TTK m. 412/1).

Anonim şirketin tasfiyeye girmesi durumunda tasfiye memurları da tasfiye işlemleri açısından gerekli konuların görüşülmesi için genel kurulu toplantıya çağırabilir (TTK m. 410/1) (Can 2014, Kervankıran 2022).

Anonim şirketin iflas etmesi durumunda müflis ortaklığın yasal temsilcisi konumunda olan iflas idaresi de genel kurulu toplantıya davet etmeye yetkilidir (İİK m. 226) (Bahtiyar 2022, Can 2014, Şener 2017).

Anonim şirketin yönetim organından yoksun kalması ve yönetiminin başka yolla sağlanamaması nedeniyle TMK m. 427/4 gereğince atanan yönetim kayyımı da genel kurulu toplantıya davet edebilir (Bahtiyar 2022, Şener 2017, Kendigelen 2011).

ANONİM ŞİRKETLER AÇISINDAN AZLIK

AZLIK KAVRAMI

Anonim şirketlerde geçeri olan çoğunluk ilkesi uyarıca genel kurul tarafından verilen kararlar toplantıda hazır bulunmayan veya olumsuz oy veren pay sahipleri hakkında da geçerlidir (TTK m.423). Ancak şirkette azlık pay sahiplerini çoğunluk ilkesinin uygulanmasından kaynaklı olumsuzluklardan koruyarak hâkim pay sahipleri ile azlık pay sahipleri arasındaki menfaatler dengesini sağlamak amacıyla kanunla bu pay sahiplerine bazı haklar tanınmış veya esas sözleşmeyle hak tanınmasına imkân verilmiştir (Ulusoy 2014). Anonim şirketlerde azlığa tanınan bu haklar olumsuz azlık hakları ve olumlu azlık hakları olmak üzere iki başlık altında incelenebilir. Olumsuz azlık haklarında belirli konularda çoğunluğun karar almasının önüne geçilmektedir; olumlu azlık haklarında ise çoğunluk pay sahiplerine rağmen azınlığa belirli işlemleri yapma imkânı tanınmaktadır (Topcan 2023, Bahtiyar 2022).

Azlık haklarının sağladığı koruma ile çoğunluk ilkesinin sıkı bir şekilde uygulanmasından kaynaklı olumsuzlukların önüne geçilebilecek, menfaat çatışmalarının çözümlenmesinde çoğunluk pay sahipleri ile azlık pay sahipleri arasında denge kurulmuş olacaktır. Olumsuz azlık haklarına, azlık pay sahiplerinin kurucuların, yönetim kurulu üyelerinin ve denetçilerin ibrasına engel olabilmesi (TTK m. 559), esas sözleşme değişikliklerinde ağırlaştırılmış yeter sayıları öngörülmesi (TTK m. 421) halleri örnek verilebilir. Olumlu azlık hakları ise: Esas sözleşmede öngörülmek şartıyla azlığa yönetim kurulunda temsil edilme hakkı tanınması (TTK m. 360); genel kurulu toplantıya davet ve gündeme madde ekletme hakkı (TTK m. 411-412); finansal tabloların görüşülmesini erteletme hakkı (TTK m. 420); denetçinin azlini ve yenisinin atanmasını isteme hakkı (TTK m.399/4); özel denetçi atanmasını isteme hakkı (TTK m. 438-439); nama yazılı pay senetlerinin bastırılmasını ve pay sahiplerine verilmesini talep hakkı (TTK m. 486/4); şirketin haklı nedenle feshini talep etme hakkıdır (TTK m. 531).

ORANSAL OLARAK AZLIK

Oransal olarak azlık esas sermayenin veya oy haklarının ya da ikisinin birlikte belirli bir oranını, belirli bir yüzdesini ifade eden azlık olarak tanımlanmaktadır. TTK sisteminin teknik anlamda oransal azlığı kabul ettiği ifade edilebilir (Ulusoy 2017, Günay 2022). TTK özellikle olumlu azlık haklarını halka

kapalı şirketlerde sermayenin en az onda birini (%10), halka açık şirketlerde ise yirmide birini (%5) temsil eden pay sahiplerine tanımıştır (TTK m. 411, TTK m. 412, TTK m. 420, TTK m. 399/4, TTK m. 439/1, TTK m. 486/4, TTK m. 531).

TTK'nın kabul ettiği oransal azlığın (sermayenin onda biri, halka açık şirketlerde yirmide biri) esas sözleşmeyle değiştirilip değiştirilemeyeceği, yani bu oranın indirilip indirilemeyeceği tartışılmıştır. Mülga TTK döneminde %10'luk oranın indirilmesinin mümkün olduğu ifade edilmiş olmakla birlikte; 6102 Sayılı TTK döneminde bu konuda farklı görüşler ortaya atılmıştır. 6102 sayılı Kanun döneminde bu tartışmanın ortaya çıkmasının sebebi: "*Esas sözleşmeyle bu kanunun anonim şirketlere ilişkin hükümlerinden ancak Kanunla buna açıkça izin verilmişse sapılabilir"* şeklinde düzenleme getiren TTK m. 340 hükmüdür. Bu hüküm uyarınca azlık hakları için belirlenen pay oranlarının indirilmesinin TTK'nın buna açıkça izin vermesi durumunda söz konusu olacağı ifade edilmiştir (Tekinalp /Poroy /Çamoğlu II 2017, Tekinalp 2013, Karasu 2015, Nomer Ertan 2015, Turan 2023). Buna karşın doktrinde bir grup yazar %10'luk oranın esas sözleşmeye indirilebileceğini fakat artırılamayacağını ileri sürmüştür (Ayan 2011, Sumer 2010, Erdem 2019). Kanımızca azlık haklarını kullanabilecek pay sahipleri oranının indirilebilmesi, TTK m. 340 gereği, kanunun buna açıkça izin vermesi durumunda mümkün olmalıdır. Nitekim çalışma konumuzu oluşturan azlık pay sahiplerinin genel kurulu toplantıya çağırmasını düzenleyen TTK m. 411 hükmünde çağrı hakkının esas sözleşmeyle daha az sayıda paya sahip pay sahiplerine tanınabileceği hüküm altına alındığı için genel kurulu toplantıya çağırma konusunda yetkili azlık esas sözleşmeyle sermayenin yüzde onundan daha azı olarak tespit edilebilir.

NOMİNAL AZLIK

Nominal azlık, azlığın payların esas sermayeye oranına göre başka bir deyişle oransal (yüzde) olarak değil; anonim şirket paylarının nominal değerine göre tespit edildiği hallerde söz konusu olur (Günay 2022, Özden 2022). Nominal azlık kavramı 6762 sayılı Mülga TTK'da mevcut olmayıp, 6102 sayılı TTK m. 439 ile hukuk sistemimize girmiştir (Ulusoy 2017). TTK m. 439 hükmüne göre genel kurulun özel denetim talebini reddetmesi halinde sermayenin en az onda birini, halka açık şirketlerde ise yirmide birini oluşturan pay sahipleri veya paylarının itibari değerlerinin toplamı en az bir milyon Türk Lirası olan pay sahipleri üç ay içinde şirket merkezinin bulunduğu yer asliye ticaret mahkemesinden özel denetçi atanmasını isteyebilir. İlgili hükmün gerekçesinde azlık kavramının şirketin halka açık olup olmamasına göre farklı şekilde tanımlandığı, sermayesi büyük olan şirketlerde hükümdeki yüzdelere ulaşılması güç olacağından sabit bir miktarın da öngörüldüğü ifade edilmiştir. Bu durumda özel denetçi atanmasını talep hakkı yalnız oransal azlığa tanınmış bir hak olmayıp, sermaye oranından bağımsız olarak paylarının itibari değeri bir milyon Türk Lirası olan pay sahiplerine de (nominal azlığa da) tanınmış bir haktır (Özden 2022). Nominal azlık somut olay için esas sermayenin ya düşük bir yüzdesini ya da bazı şirketler için çoğunluğunu veya tamamını ifade edebilir (Ulusoy 2017, Günay 2022).

FİİLİ AZLIK

Fiili azlık önceden esas sermayenin veya toplam oy sayısının belirli bir oranı olarak veya payların nominal değerine göre tespit edilemeyen, ancak fiili duruma göre genel kurulda mevcut ya da kullanılan oyların belirli bir oranı olarak belirlenen ve esas sermayedeki veya tüm oy haklarındaki oranı fiili koşullara göre değişebilen azlığı iade eder (Ulusoy 2017, Günay 2022, Baltalı 2019, Ölmez 2021). TTK m. 360 hükmüne göre esas sözleşmeyle öngörülmek şartıyla belirli pay gruplarına, özellik veya nitelikleriyle belirli grubu oluşturan pay sahiplerine ve azlığa yönetim kurulunda temsil edilme hakkı tanınabilir. Doktrinde bazı yazarlar TTK m. 360 hükmünde öngörülen azlığın dar ve teknik anlamda sermayenin en az yüzde onunu ve halka açık şirketlerde yüzde beşini temsil eden pay sahipleri olarak nitelendirilemeyeceğini; %50 + 1paya sahip çoğunluk karşısında yer alan payın veya payların sahibini kapsadığını belirtmektedir (Kırca/Şehirali-Çelik/Manavgat 2013, Güçlütürk 2018, Tekinalp 2015, Eminoğlu 2020, Baltalı 2019). TTK m. 360'da öngörülen azınlığın yönetim kurulu seçimlerine ilişkin her yapılan oylamada fiilen oluştuğunu nazara alırsak, hükümde öngörülen azınlığın fiili azlık olduğu sonucuna varılabilir (Ulusoy 2017).

AZLIĞIN GENEL KURULU TOPLANTIYA ÇAĞIRMASI

TTK m. 411 ve BTY m. 9/3 hükümlerinde olumlu bir azlık hakkı olarak genel kurulun toplantıya çağrılması ve genel kurul zaten toplanacaksa görüşülmesi istenen hususlarının gündeme ekletilmesi

düzenlenmiştir. TTK m. 411 hükmüne göre anonim şirket esas sermayesinin en az onda birini, halka açık şirketlerde ise en az yirmide birini oluşturan azlık pay sahipleri yönetim kurulundan gerektirici sebeplerini ve gündemi belirterek genel kurulun toplantıya çağrılmasını isteyebilecekleri gibi, genel kurul zaten toplanacaksa karara bağlanmasını istedikleri konuların gündeme konulmasını da talep edebilirler (TTK m. 411/1). TTK m. 411'de belirlenen sermayenin onda biri ve halka açık şirketler için yirmide biri oranı asgari oranlar olup, bu oranların çok üstündeki pay sahipleri de kuşkusuz bu hakka sahiptir. Genel kurulu toplantıya davet etme yetkisine sahip azlık pay sahibi oranı esas sözleşmeye konulacak bir hükümle azaltılabilir, ancak artırılamaz. Azlığın TTK m. 411 gereğince genel kurulu toplantıya davet yetkisi hem olağan hem de olağanüstü toplantılar için kullanılabilecek bir yetkidir.

Genel kurulun TTK m. 411 gereğince azınlığın talebiyle toplanması halka açık anonim şirketler açısından da geçerlidir. Ancak SerPK'da azınlığın gündeme madde konulmasını talep etme yetkisi TTK'dan daha ayrıntılı düzenlenmiştir. SerPK m. 29/5 hükmünde, azlığa TTK m. 411 hükmünde tanınmış olan gündeme madde ekletme hakkının halka açık şirketlerde gündem maddelerine ilişkin karar taslaklarının görüşülmeye sunulmasını da kapsayacağı hüküm altına alınmıştır. Bu durumda halka açık anonim şirketlerde azlık pay sahipleri önceden hazırladıkları karar taslaklarının genel kurulda müzakere edilmesini de talep edebilecektir.

ÇAĞRI TALEBİ

ÇAĞRI TALEBİNİN ŞEKLİ VE KAPSAMI

Azlık pay sahiplerinin genel kurulu toplantıya davet etme veya gündeme madde ekletme konusunda yönetim kuruluna yönelteceklerı taleplerin şekli de TTK'da düzenlenmiştir. Çağrı ve gündeme madde eklenmesine yönelik talepler noter aracılığıyla yapılacaktır (TTK. m. 411/3). Azlık pay sahiplerinin yönetim kuruluna yapacakları çağrı için öngörülen bu şekil şartı ispat şartı değil, sıhhat şartıdır. Çağrı isteminde toplantıya davet için gerektirici sebeplerin ve gündemin de belirtmesi gerekir. Pay sahiplerinin yönetim kuruluna noter aracılığıyla yaptıkları çağrıda belirttikleri toplantının yapılmasını gerektiren sebepleri ve gündemi mahkemeye başvuru aşamasında değiştirmeleri veya genişletmeleri de mümkün değildir (Albayrak Doğan 2020). Genel kurulun zaten toplanacak olması durumunda azlık pay sahiplerinin gündeme madde ekletmek amacıyla yönetim kuruluna yönelteceklerı istemin ulaşması gereken zaman da TTK'da belirtilmiştir. Buna göre istem yönetim kuruluna, çağrı ilanının Türkiye Ticaret Sicil Gazetesinde yayımlanmasına ilişkin ilan ücretinin yatırılmasından önce ulaşmalıdır. Şirket yönetim kuruluna çağrının noter vasıtasıyla yapılmadığı hallerde mahkemeler TTK m. 411 ve TTK m. 412'deki dava şartlarının yerine getirilmediği gerekçesiyle genel kurulu toplantıya çağrı taleplerini reddetmektedir (Örn. İzmir 5. Asliye Ticaret Mahkemesi, 05.07.2023, E.2023/348 K.2023/557, Lexpera – e.t. 24.06.2026)

YÖNETİM KURULUNUN ÇAĞRI TALEBİNİ KABULÜ

YÖNETİM KURULUNUN TOPLANTIYI SÜRESİ İÇİNDE YAPMASI

Genel kurulu toplantıya davet veya gündeme madde eklenmesine yönelik azlık pay sahipleri taleplerinin yönetim kurulunca kabul edilmesinin veya reddedilmesinin sonuçları kanunda ayrı ayrı düzenlenmiştir. Yönetim kurulu azlığın toplantıya çağrı veya gündeme madde eklenmesi talebini kabul etmek istiyorsa çağrı talebini aldığı günden itibaren yedi iş günü içinde bu kabulünü azlığa bildirmelidir. Yönetim kurulunun talebi kabul ettiğine yönelik bildirimi nasıl yapacağına ilişkin bir düzenleme TTK'da yer almamakla birlikte; bu bildirimin de azlık pay sahiplerine noter vasıtasıyla yapılması gerektiği ifade edilmektedir (Can 2014).

Yönetim kurulunun azlığın çağrı veya gündeme madde ekleme taleplerini kabul edebilmesi için:

- Toplantıya çağrı veya gündeme madde eklenmesine yönelik taleplerin yazılı olması,

- talepte bulunanların sermayenin en az %10'nu temsil eden veya esas sözleşmede daha az bir oran öngörülmüşse bu oranda pay veya pay senedine sahip olması,

- toplantıya çağrı veya gündeme madde eklenmesine yönelik taleplerde talebin gerekçesine yer verilmesi,

- önerilen gündem maddelerinin genel kurulun yetki alanı içinde yer alması,

- çağrı talebinin emredici hükümlere, ahlaka ve adaba aykırı olmaması,

- daha önce aynı gündeme ilişkin genel kurul kararının alınmamış olması gerekir (Can 2014).

Yönetim kurulunun çağrı talebini kabul etmesinin sonuçları TTK m. 411/4 hükmünde: *"Yönetim kurulu çağrı talebini kabul ettiği taktirde, genel kurul en geç kırkbeş gün içinde yapılacak şekilde toplantıya çağrılır; aksi halde çağrı istem sahiplerince yapılır*" şeklinde düzenlenmiştir. Anonim Şirketlerin Genel Kurul Toplantılarının Usul ve Esasları ile Bu Toplantıda Bulunacak Bakanlık Temsilcileri Hakkında Yönetmelik m. 9/4 ise: "*Azlık pay sahiplerinin genel kurulun toplantıya çağrılmasına ilişkin yönetim kuruluna yaptıkları başvurunun kabul edilmesine rağmen kırk beş gün içinde toplantı çağrısının yönetim kurulu tarafından yapılmaması halinde azlık pay sahipleri genel kurulu toplantıya çağırabilir"* hükmünü içermektedir. Bu durumda azlık pay sahiplerinin çağrı talebinin kabul edilmesi halinde genel kurulun en kırk beş gün içinde yapılacak şekilde toplantıya çağrılacağını düzenleyen TTK m. 411/4 hükmü ile kırk beş gün içinde toplantıya çağrının yapılması gerektiğini belirten Yönetmelik m. 9/4 hükmü arasında çelişki olduğu açıktır. Yasa hükmüne öncelik tanınarak en geç kırk beş gün içinde genel kurul toplantısı yapılacak şekilde çağrı yapılması gereklidir. TTK m. 411 düzenlemesinde kırk beş günlük sürenin başlangıç tarihi hakkında açıklık yoktur. Ancak hükmün gerekçesinde kırk beş günlük sürenin yönetim kurulunun karar tarihinden itibaren başlayacağı belirtilmiştir (Gerekçe m. 411/4).

YÖNETİM KURULUNUN TOPLANTIYI SÜRESİ İÇİNDE YAPMAMASI

Uygulamada yönetim kurulunun çağrı talebini kabul etmesine rağmen kırk beş gün içinde genel kurulu toplamadığı görülmektedir. TTK m. 411/4'te yönetim kurulunun çağrı talebini kabul edip kırk beş gün içinde genel kurulu toplamaması durumunda çağrı yetkisinin azlığa geçeceği hüküm altına alınmış olmakla birlikte; azlığın bu yetkiyi nasıl kullanacağına yönelik bir düzenleme yoktur. Doktrinde bir görüş Türk hukukuna özgü olan bu düzenlemenin pratik olarak uygulanması aşamasında sorunlarla karşılaşmanın kaçınılmaz olduğunu; mahkemece verilen bir yetkilendirme kararına dayalı olmayan çağrının diğer pay sahipleri ve özellikle toplantıya katılması gerekiyorsa Bakanlık temsilcisi tarafından dikkate alınmama ihtimalinin bulunduğunu; ayrıca azlık pay sahiplerinin toplantının yapılabilmesi için gerekli hazırlıkları yapma imkanından çoğunlukla mahrum olduklarını; bu durumda TTK m. 412 gereğince atanacak bir kayyım aracılığıyla tüm sorunların rahatlıkla aşılmasının mümkün olduğu ifade etmiştir (Kendigelen 2011). Bir diğer yazar ise burada çağrı yetkisi mahkeme kararına dayanmadığını, azlığın Bakanlık temsilcisi için başvururken ve ayrıca şirketin internet sitesi ile Ticaret Sicil Gazetesinde ilanları yaparken yasal süreci gösterip çağrı yetkisine sahip olduğunu belirtmesinin yeterli olduğu görüşündedir (Albayrak Doğan 2020). Kanımızca TTK m. 411/4 uyarınca çağrı yetkisinin azlık pay sahiplerine geçtiği ve fakat yönetim kurulunun azlığa çağrı işlemlerini yapma konusunda yardımcı olmadığı hallerde ilgili pay sahipleri çağrı işlemlerini yapma konusunda ciddi zorlukla karşılaşacaktır. Azlık özellikle Bakanlık temsilcisi için veya Ticaret Sicil Gazetesine ilan için başvururken toplantıya davet yetkisine sahip olduğunu ispat konusunda problem yaşayacaktır. Bu durumda azlık TTK m. 412 gereğince mahkemeye başvurup toplantıya çağrı işlemlerini yapmak üzere şirkete temsil kayyımı atanmasını talep edebilmelidir.

YÖNETİM KURULUNUN ÇAĞRI TALEBİNİ REDDETMESİ VE MAHKEMEYE BAŞVURU

Azlık pay sahiplerinin genel kurulu toplantıya çağrı veya gündeme madde eklenmesine yönelik talepleri yönetim kurulunca reddedilir ya da isteme yedi iş günü içinde olumlu cevap verilmez ise aynı pay sahiplerinin başvurusuyla genel kurulun toplantıya çağrılmasına şirket merkezinin bulunduğu yer asliye ticaret mahkemesince karar verilebilir (TTK m. 412). TTK m. 412 hükmünde "aynı pay sahipleri" ifadesi kullanılmasına rağmen öğretide "azınlığın başvurusu üzerine" ifadesinin kullanılmasının uygun olacağı, azlık hakkının kullanılmasının belirli kişilere değil, tüm azlığa tanınması gerektiği ifade edilmiştir (Can 2014, Yılmaz 2020). Azlığın mahkeme kararıyla genel kurul toplanması yönünde talepte bulunabilmesi için öncelikle TTK m. 411'de öngörülen yönetim kurulundan yazılı talep, talebin noter vasıtasıyla yapılması ve gündemi belirtme şartlarını yerine getirmesi gerekir. Nitekim mahkemeye başvurulduğunda da mahkeme öncelikle bu şartların yerine getirilip getirilmediğini inceler. Dolayısıyla bu hakkın, tüm azlık pay sahiplerine değil, daha önce TTK m.411'deki şartları yerine getiren pay sahiplerine verilmesinin doğru bir yaklaşım olduğu kanaatindeyiz.

TTK m. 412 gereğince açılan davanın çekişmesiz yargı işi olduğu yönünde görüşler olmakla birlikte; kanımızca HMK m. 382/e hükmünde ticaret hukuku alanındaki çekişmesiz yargı işleri arasında sayılmayan TTK m. 412'den kaynaklanan davanın şirket tüzel kişiliğine yöneltilmesi gerekir (Günay 2022). Nitekim uygulamada da bu davanın şirket tüzel kişiliğine karşı ikame edildiği görülmektedir (Örn. İstanbul 9. Asliye Ticaret Mahkemesi, 24.10.2025, E.2026/65 K.2026/190, Ankara Batı 2. Asliye Ticaret Mahkemesi E.2025/1115 K.2026/26, Lexpera – e.t. 26.06.2026)

Davacı azlık pay sahipleri toplantı yapılmasını gerektiren sebepleri ve genel kurulun hangi gündemle toplanması gerektiğini açıkça belirtmeli, TTK m. 411'de öngörülen şekli şartların yerine getirildiğine ilişkin belgeleri (sermayenin en az onda biri veya halka açık şirketlerde yirmide birine sahip olunduğuna ilişkin belgeyi, yönetim kuruluna yazılı olarak noter vasıtasıyla yapılan talebe ilişkin belgeyi, yönetim kurulunun ret kararına ilişkin belgeyi) dava dilekçesine eklemelidir. Azlık pay sahiplerinin taleplerini inceleyen mahkeme öncelikle toplantıya çağrı için kanunun öngördüğü şekli şartların yerine getirilip getirilmediğini, sonra da azlık tarafından toplantıya çağrı için gösterilen sebeplerin haklı olup olmadığını inceleyecektir. Mahkeme şekli şartlar açısından yapacağı incelemede:

- Davacıların esas sermayenin onda birine, halka açık şirketlerde yirmide birine veya esas sözleşmeyle öngörülen daha az oranda paya sahip olup olmadıklarını,

- azlığın yönetim kuruluna yaptıkları çağrı bildiriminin yazılı olarak noter aracılığıyla yapılıp yapılmadığını,

- çağrı talebinde toplantı yapılması için gerektirici sebeplerin ve gündemin bildirilip bildirilmediğini,

- yönetim kurulunun toplantıya çağrı veya gündeme madde konulmasına ilişkin istemleri reddedip etmediğini veya isteme yedi gün içinde olumlu cevap verip vermediğini incelemelidir. Şekli şartlar açısından inceleme yapan mahkeme, azlığın toplantıya davet için ileri sürdüğü sebeplerin haklılığı açısından da inceleme yapar. Yargı kararları incelendiğinde davalı şirketin genel kurulun yapılacağının belirtilmesine rağmen davacı tarafın görüşülmesini istediği hususlara gündemde yer verilmemesi gerekçesine dayanarak davacının belirttiği gündem maddeleri doğrultusunda genel kurulun toplanması yönünde karar verildiği görülmektedir (İstanbul Anadolu 8. Asliye Ticaret Mahkemesi, 13.09.2024, E.2024/554 K.2024/642, Lexpera – e.t. 27.06.2026). Yine, davalı şirketin 2019, 2020 ve 2021 yılı olağan genel kurullarını toplamadığı gerekçesiyle azınlığın TTK m. 412 uyarınca genel kurulu toplantıya çağrı talebi kabul edilmiştir (İstanbul 20. Asliye Ticaret Mahkemesi, 25.04.2023, E.2023/194 K.2023/317, Lexpera – e.t. 27.06.2026).

TTK m. 412 azınlığın genel kurulun toplanması istemiyle açtığı davada zorunluluk olmadıkça mahkemenin dosya üzerinden inceleme yapıp karar vermesi gerektiğini belirtmektedir. Bu durumda mahkeme dosya içeriğine ve somut olayın koşullara göre duruşma açıp şirket yetkililerini dinleme ihtiyacı duyarsa duruşma açabilecektir (Poroy/Tekinalp /Çamoğlu 2021). Söz konusu düzenleme "taraf oluşturulması" gereğine yer vermediği için eleştirilmiş; hukuki dinlenilme hakkının gereği olarak davalı şirkete cevap hakkının tanınması gerektiği ifade edilmiştir (Moroğlu 2012, Albayrak Doğan 2020). Mülga TTK döneminde söz konusu davalarda mahkemenin duruşma açtığı, dosyayı bilirkişiye gönderdiği ve bu nedenle davaların uzadığı, azlık pay sahiplerinin hızlı şekilde karar alamadıkları görülmüştür. Kanımızca TTK m. 412 de öngörülen azlık hakkının etkin şekilde kullanılmasını sağlamak için mahkeme kural olarak dosya üzerinden duruşma açmadan karar vermelidir. Şirkete tebligat yapmaya ve duruşma açmaya karar veren mahkeme de bu kararın gerekçesini, yani duruşma açmanın neden zorunlu olduğunu açıklamalıdır. Mahkeme kararı kesindir.

MAHKEME KARARI VE ŞİRKETE KAYYIM ATANMASI

Azlık pay sahibinin başvurusu üzerine şirket merkezinin bulunduğu yer Asliye Ticaret Mahkemesi genel kurulun toplantıya çağrılmasına karar verebilir (TTK m.412) Bu durumda mahkeme toplantıya çağrı için öngörülen şekli şartların yerine getirildiği ve davacının toplantıya davet için öngördüğü sebeplerin haklı olduğuna kanaat getirirse çağrı kararı verecek, aksi halde azlığın talebini reddedecektir. Mahkeme davacı azlığı haklı bulup genel kurulun toplantıya çağrılmasına karar verirse, gündemi düzenlemek ve kanun hükümleri uyarınca çağrıyı yapmak üzere bir kayyım atar. Mahkeme kararında kayyımın görevleri ve toplantı için gerekli belgeleri hazırlamaya ilişkin yetkileri gösterilir. Uygulamada

mahkemeler TTK m. 412 gereğince genel kurulun toplanmasına karar verdiğinde genel kurul gündemini karara ayrıntılı şekilde yazmakta ve kayyımı mahkeme kararında belirtilen gündemi düzenlemek ve bu konuda gerekli tüm yasal işlemleri yapmak üzere görevlendirmektedir (Örn. İstanbul 7. Asliye Ticaret Mahkemesi, 17.07.2024, E.2024/365, K.2024/443, Lexpera – e.t. 27.06.2026).

Azlık pay sahibinin genel kurulun toplanması veya gündeme madde eklenmesine yönelik talebi üzerine asliye ticaret mahkemesinin toplantıya gerek görürse gündemi düzenlemek ve çağrıyı yapmak üzere atadığı kayyımın yönetim kayyımı mı, temsil kayyımı mı olduğu hususu doktrinde tartışılmıştır. Doktrinde bir görüş TTK m. 412'de düzenlenen ve yönetim kayyımlığı içinde değerlendirilen kayyımın şirketin organsız kaldığı durumlarda gündeme geldiğini; mahkemenin azınlığın genel kurul toplanma talebini haklı görmesi ve fakat şirketin de yönetim organından mahrum olması durumunda gündemi düzenlemek ve çağrıyı yapmak üzere yönetim kayyımlığı tesis edeceğini, bu yönetim kayyımının da mahkemenin istediği işlemleri gerçekleştireceğini belirtmektedir. Bu görüşte olan yazara göre TTK m. 412 uyarınca kayyıma verilecek görevler temsil kayyımının amaç ve yetki sınırını aşmaktadır. TTK m. 412 kapsamındaki kayyım temsil kayyımlığındaki gibi anonim şirketi bir dava kapsamında temsil etmeyecek, başta çağrı olmak üzere ilgili işlemleri yapacaktır. Yazara göre söz konusu işlemler yönetim kayyımlığı kümesi içinde değerlendirilmelidir (Keçecioğlu 2024). Kanımızca TTK m. 412 gereğince atanan kayyım temsil kayyımı niteliğindedir. TTK m. 412'de öngörülen halde TMK m. 427/4 gereğince şirkete yönetim kayyımı atanmasını gerektirecek "gerekli organlardan yoksun olma ve yönetimin başka yoldan sağlanamaması" durumu söz konusu değildir. Şirkette yönetim organı mevcuttur ve göreve devam etmektedir. Ancak azınlığın genel kurulun toplantıya çağrılma veya gündeme madde eklenmesi talebine 7 iş günü içinde cevap vermemiştir veya bu talebi reddetmiştir. Ayrıca TTK m. 412 hükmünde mahkemenin gündemi düzenlemek ve çağrıyı yapmak üzere kayyım atayacağı hüküm altına alınarak kayyımın hangi iş ve işlemleri yapabileceğinin sınırı da belirlenmiştir. Bu nedenle TTK m. 412 gereği atanan kayyım belirli bir iş için atanan ve yetki kapsamı da kanunla belirlenen bir temsil kayyımı olarak kabul edilmelidir (Yıldız 2018, Türkoğlu 2008, Kayıklık 2024, Kuru 2022).

AZLIĞIN GÜNDEMİ BELİRLEME YETKİSİ

Anonim şirket genel kurulunun zaten toplanacak olması durumunda azlık pay sahipleri gündeme madde konulması için de yönetim kuruluna başvurabilirler. TTK azlık pay sahiplerinin hangi süre içinde bu haklarını kullanabileceğini de düzenlemektedir. Azınlığın gündeme madde konulması istemi çağrı ilanının Türkiye Ticaret Sicil Gazetesinde yayımlanmasına ilişkin ilan ücretinin yatırılması tarihinden önce yönetim kuruluna ulaşmış olmalıdır (TTK m. 411/2). Çağrı ilanına ilişkin ücretin yatırılmasından sonra yönetim kuruluna ulaşan gündeme madde eklenmesi talepleri dikkate alınmaz.

Azlık pay sahiplerinin gündeme madde eklenmesine yönelik talepleri noter aracılığıyla yapılır. Yönetim kurulu gündeme madde eklenmesine yönelik talebe 7 iş günü içinde cevap vermez veya talebi reddederse azlık pay sahipleri gündeme madde eklenmesi için mahkemeye başvurabilir (TTK m. 412). Yönetim kurulu azlığın gündeme madde konulması yönündeki talebini kabul etmiş, fakat istenilen konuları gündeme koymamış ise azlık belirttiği hususların gündeme konulması için de mahkemeye başvurabilir.

SONUÇ

Anonim şirketlere egemen olan çoğunluk ilkesi gereği şirket genel kurulunda alınan kararlar olumlu oy versin veya vermesin tüm pay sahiplerini bağlar. Çoğunluk ilkesinin uygulanmasının olumsuzluklarını gidermek ve şirkette hâkim pay sahipleri ile azlık pay sahipleri arasındaki menfaat dengesini korumak amacıyla azlık pay sahiplerine birtakım haklar verilmiştir ki, bunlar azlık hakları olarak ifade edilir. Biz bu çalışmamızda azlığın genel kurulu toplantıya davet ve genel kurul zaten toplanacaksa görüşülmesini istedikleri hususları gündeme ekletme yetkisini inceledik. TTK m. 411'de bu hak sermayenin onda biri, halka açık şirketlerde ise yirmide birini temsil eden pay sahiplerine tanınmıştır. TTK m. 411'deki açık düzenleme göre esas sözleşmeye hüküm konularak bu hak daha az sayıda paya sahip pay sahibine de tanınabilir. Azlık pay sahiplerinin kendilerine tanınan bu hakkı nasıl kullanacakları da kanunda ayrıntıları ile düzenlenmiştir. Azlık pay sahiplerinin çağrı talebi yazılı olarak noter vasıtasıyla yapılmalıdır. Azlık pay sahiplerinin yönetim kuruluna yapacakları bu çağrı için kanunda öngörülen şekil şartı, ispat şartı değil, sıhhat şartı olarak öngörülmüştür. Azlık pay sahiplerinin genel kurulun toplantıya

çağrılması veya gündeme madde eklenmesi için yapacakları ihtarın şirket tüzel kişiliğine değil, doğrudan şirket yönetim kuruluna yapılması gerekir. Azlık pay sahiplerinin yönetim kuruluna noter vasıtasıyla bildirimde genel kurul toplantısı yapılmasını gerektiren sebepleri ve gündemi de belirtmeleri gerekir. Bu bildirimde belirttikleri gerektirici sebepleri ve gündemi dava aşamasında değiştirmeleri ve geliştirmeleri mümkün değildir. Şirket yönetim kurulu azlığın toplantıya çağrı veya gündeme madde ekleme talebini kabul etmek istediği taktirde çağrı talebini aldığı günden itibaren yedi iş günü içinde kabul ettiğini azlığa bildirmelidir. Yönetim kurulunun talebi kabul ettiğine yönelik bildirimi nasıl yapacağına ilişkin bir düzenleme TTK'da yer almamakla birlikte bu bildirimin de, çağrı bildirimi gibi, azlık pay sahiplerine noter vasıtasıyla yapılması gerektiği kanaatindeyiz. TTK m. 411/4 hükmünde yönetim kurulunun azlık pay sahiplerinin talebini kabul etmesi durumunda en geç kırk beş gün içinde yapılacak şekilde genel kurulun toplantıya davet edileceğini belirtilmiştir. Genel Kurul Toplantıları Hakkında Yönetmelik m. 9/4 hükmünde ise genel kurulun toplantıya çağrısının kırk beş gün içinde yapılacağı düzenlenmiştir. Kanun hükmü ile ilgili yönetmelik hükmü arasındaki bu çelişki karşısında; TTK m.411/4 hükmüne üstünlük tanınarak genel kurulun kırk beş gün içinde toplanacak şekilde toplantıya davet edilmesi gerektiği kanaatindeyiz.

TTK m. 411/4 hükmünde yönetim kurulunun çağrı talebini kabul etmesi, fakat kırk beş gün içinde genel kurulu toplamaması durumunda çağrı yetkisinin azlığa geçeceği düzenlenmiştir. Çağrı yetkisinin azlık pay sahiplerine geçtiği, fakat yönetim kurulunun azlığa çağrı işlemlerini yapma konusunda yardımcı olmadığı hallerde ilgili pay sahipleri çağrı işlemlerini yapma konusunda ciddi zorluklarla karşılaşacaktır. Azlık özellikle Bakanlık temsilcisi için veya Ticaret Sicil Gazetesine ilan için başvururken toplantıya davet yetkisine sahip olduğunu ispat konusunda problemler yaşayacaktır. Bu durumda azlığın TTK m. 412 uyarınca mahkemeye başvurup toplantıya çağrı işlemlerini yapmak üzere şirkete temsil kayyımı atanmasını talep edebileceği kanaatindeyiz.

TTK m.412 hükmüne göre azlık pay sahiplerinin genel kurulu toplantıya çağrı veya gündeme madde eklenmesine yönelik talepleri yönetim kurulu tarafından reddedilir ya da isteme yedi iş günü içinde olumlu cevap verilmez ise, genel kurulun toplantıya çağrılmasına aynı pay sahiplerinin başvurusuyla şirket merkezinin bulunduğu yerdeki asliye ticaret mahkemesince karar verilebilecektir (TTK m. 412). Zorunluluk olmadıkça mahkeme dosya üzerinden inceleme yaparak karar verecektir (TTK m. 412). 6762 sayılı Mülga TTK döneminde azlık pay sahiplerinin genel kurulu toplantıya çağrılması veya gündeme madde eklenmesi talebiyle açtıkları davalarda mahkemelerin duruşma açtığı ve dosyayı bilirkişiye gönderdiği görüldüğünden; azlığın söz konusu hakkı etkin şekilde kullanılmasını sağlamak amacıyla, mahkemenin zorunluluk olmadıkça dosya üzerinden inceleme yapıp karar vermesi gerektiğine ilişkin düzenlemeye kanunda yer verilmesinin isabetli bir tercih olduğu kanaatindeyiz. Azlık pay sahiplerinin talepleri üzerine mahkeme genel kurulun toplanması veya gündeme madde eklenmesi gerektiğine karar verirse gündemi düzenlemek ve çağrı yapmak üzere kayyım atar. Mahkemenin atadığı bu kayyımım yönetim kayyımı mı, temsil kayyımı mı olduğu doktrinde tartışılmıştır. Kanımızca bu halde şirkette yönetim kayyımı atanmasını gerektirecek organ boşluğu mevcut değildir; zira şirkette yönetim organı var ve görevine devam etmekte olup, sadece, azlığın genel kurulu toplantıya davet ve gündeme madde eklenmesi talebini reddetmektedir. Bu nedenle, mahkemenin genel kurul toplantısına çağrı işlemlerini yapmak üzere görevlendirdiği kayyım temsil kayyımı niteliğinde görülmelidir.

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BURDEN OF COVID-19 AND MENTAL DISORDERS IN ALBANIA DURING 2020-2021

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ABSTRACT

Introduction: The COVID-19 pandemic posed unprecedented challenges to Albania's health system, intensifying the burden of mental disorders, like in all countries worldwide. Between 2020 and 2021, intertwined effects of infection, social disruption, and psychological distress highlighted urgent needs for integrated public health and mental health responses.

Objective: To describe the burden of COVID-19 and mental disorders in Albania during 2020-2021.

Methods: This analysis is based on the crude and age-standardized Disability-Adjusted Life Years (DALYs) from COVID-19 and mental disorders in Albania for the years 2020-2021, according to the estimates of the Global Burden of Disease (GBD) Study (https://vizhub.healthdata.org/gbd-results/).

Results: Crude burden of COVID-19 in the Albanian population was estimated at about 4,382 (95%CI=3,769-4,994) DALYs per 100,000 population in 2020, and 6,370 (95%CI=5,468-7,477) DALYs per 100,000 population in 2021. The age-standardized burden of COVID-19 was estimated at around 2,688 (95%CI=2,257-3,172) DALYs per 100,000 in 2020, and 3,925 (95%CI=3,276-4,849) DALYs per 100,000 in 2021. Conversely, crude burden of mental disorders was estimated at approximately 1,854 (95%CI=1,376-2,432) DALYs per 100,000 in 2020, and 1,866 (95%CI=1,376-2,442) DALYs in 2021. The age-standardized burden of mental disorders was about 1,737 (95%CI=1,245-2,263) DALYs per 100,000 in 2020, and 1,747 (95%CI=1,252-2,282) DALYs in 2021.

Conclusion: The increasing COVID-19 burden in Albania during the period 2020-2021 coincided with a persistently high burden of mental disorders, reflecting their interconnected nature. Similar to the situation in other countries, pandemic-related infection, mortality, and social disruption likely exacerbated psychological distress in Albania, highlighting the need for integrated strategies addressing both COVID-19 and mental health.

Keywords: COVID-19, Disability-Adjusted Life Years (DALYs), Global Burden of Disease (GBD) Study, mental disorders.

ASSESSMENT OF STUDIES ON SOCIAL MOBILITY IN ALBANIA: THE NEED FOR CONSIDERATION OF INTERGENERATIONAL SOCIAL MOBILITY

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ABSTRACT

The Albanian society has developed along a dynamic and multilinear trajectory after the 1990s. In a similar way to countries of the Western Balkans, but often also in a unique way, profound transformations have made the journey toward the consolidation of democratic social structures a prolonged process of transition. During these 3 decades, significant research and statistical data have continuously been produced on indicators of social development both at national and international level. Among the indicators of high sociological importance and interest that should be considered are interdisciplinary discussions on the potential for social mobility. In this context, this article aims to assess the current situation of studies on social mobility with a focus on Albanian society and the consideration in these studies of comparative evidence of intergenerational mobility. The method used for this article is qualitative and aims at the assessment of existing research literature on social mobility in Albania and the incorporation of intergenerational social mobility. The selection of literature is conducted through online sources in Google Scholar and Jstor, using keywords such as "Social mobility", "Intergenerational social mobility", "Albania", "Western Balkans". This research concludes that studies on social mobility in Albania are interdisciplinary, mainly economic and political, and are very rarely sociological in nature and with a focus on intergenerational social mobility. The studies analyzed for this literature review consider migration, social inequalities, transition and education as factors that affect mobility, but have not comparatively considered intergenerational mobility. This article identifies the need for sociological studies on intergenerational mobility in Albania.

Keywords: Social mobility, Intergenerational mobility, Albania, transition, Western Balkans

INTRODUCTION

Albania, like the other countries of the Western Balkans, has experienced profound political, economic, and social transformations after the fall of the communist regime in the early 1990s. The transition from a centrally planned economy to a market economy and from the one-party political system to democratic pluralism marked the beginning of a complex transition process, which continues to affect the country's social, economic, and institutional structures. Studies on post-communist transformation argue that these changes represent not only political and economic reforms, but broad processes of social restructuring that affect the way resources, opportunities, and social positions are distributed (Kume & Llaci, 2000; Elbasani, 2004). In this sense, the Albanian transition can be seen as a process of reconfiguring the structure of social stratification and creating new mechanisms of social mobility. In the existing literature, the development of Albanian society after the 1990s is generally characterised in three main phases. The first phase (1990–1996) is characterised by the transformation of the form of the political regime and the country's economic base. This period marked the beginning of reforms, the privatisation of state property, economic liberalisation, and the building of the first democratic institutions. It represents an intensive phase of institutional transformation and economic restructuring, accompanied by considerable social and economic uncertainty, but also by the creation of new opportunities for individual initiative and private enterprise (Kume & Llaci, 2000). The changes of this period transformed the traditional mechanisms of social positioning and created the conditions for the formation of new structures of social stratification, reconfiguring the opportunities for social mobility in post-communist Albania.

The second phase (1997–2009) is characterised by the interplay of internal crises with the challenges of the global economy. The crisis of 1997 constitutes a turning point in the country's political and economic development, while the intensive processes of migration, urbanisation, and labour market transformation significantly affected the Albanian social structure. Studies on migration highlight that international emigration and internal migration were transformed into important mechanisms for improving the well-being of Albanian families and expanding economic opportunities (King & Vullnetari, 2012; King, Mata-Codesal & Vullnetari, 2013). However, analyses on poverty and regional inequalities show that the benefits of the transition were not distributed equally. Betti et al. (2018) and Dumani et al. (2020) identify considerable territorial differences in the level of well-being, education, and socio-economic development, emphasising that social opportunities continued to be distributed unequally between regions and different social groups.

The third phase (2009–present) is linked to efforts to consolidate democratic institutions, strengthen the economic base, and advance the processes of Euro-Atlantic integration. Membership in NATO and progress in the process of European integration were accompanied by a greater focus on sustainable development, human capital, and improving the quality of institutions. Studies from this period emphasize the importance of education, innovation, human capital, and social capital for economic and social development. In this regard, Prašnikar, Redek and Memaj (2012) argue that intangible capital, especially human capital, constitutes an important component of long-term economic development in Albania. Along the same lines, Deda et al. (2021) emphasize that investment in education and the development of human capital remain key factors for improving well-being and economic development. However, studies continue to highlight considerable differences in access to education, employment, and economic resources between regions and different social categories (Dumani et al., 2020). The transformations experienced during these three decades have affected not only political and economic institutions, but also the way social opportunities are distributed among individuals and social groups. In this context, social mobility is considered one of the most important indicators of social development, as it reflects the extent to which individuals can change their socio-economic position throughout life. Important authors in the sociology of stratification argue that high levels of social mobility are linked to the expansion of equality of opportunity, the reduction of inequalities, and the more meritocratic functioning of the social structure (Breen, 2004; Goldthorpe, 2013).

A particularly important dimension of this phenomenon is intergenerational social mobility, which analyses the relationship between the socio-economic status of parents and that of children. Classic studies on social mobility show that social origin remains an important factor in determining individuals' educational and professional achievements (Blau & Duncan, 1967; Erikson & Goldthorpe, 1992). In recent decades, studies on social mobility have expanded their focus beyond the traditional parent–child relationship, analysing the processes of transmission of social advantages and disadvantages across several generations of the family. Pfeffer (2014) argues that the processes of transmission of social advantages and disadvantages are not limited only to the parent–child relationship, while Song (2021) emphasises the importance of analysing the influence of grandparents and earlier generations in shaping individuals' social opportunities.

The importance of studying intergenerational mobility becomes even greater in the context of post-communist societies. Gugushvili (2018), in his comparative analysis in more than 24 post-communist societies, argues that social origin continues to significantly influence individuals' educational and professional achievements even after the transformations of the transition. His findings show that parents' education remains an important factor in determining the life opportunities of subsequent generations, suggesting that political and economic changes do not automatically eliminate intergenerational inequalities. In the case of Albania, existing research has extensively addressed the political and economic transition, migration, education, regional development, poverty, and social inequalities. However, studies that directly analyse social mobility remain limited and, even more rarely, focus on intergenerational social mobility from a sociological perspective. Consequently, it remains unclear to what extent the transformations of the last three decades have affected the intergenerational transmission of social advantages and disadvantages. This lack of evidence limits the understanding of the degree of equality of opportunity in Albanian society and of the role that social origin continues to play in shaping individuals' life trajectories. In this context, the aim of this study is to assess the current

state of studies on social mobility in Albania and to analyse to what extent existing research has considered intergenerational social mobility. The main research question for this study is: To what extent have studies on social mobility in Albania included the analysis of intergenerational social mobility and what research gaps are identified in the existing literature?

MATERIALS AND METHODS

This study uses a qualitative approach and is based on the analysis of existing studies on social mobility in Albania, with a particular focus on intergenerational social mobility. This approach has been selected because it enables the systematic review of existing scientific knowledge, the identification of the main research trends, and the highlighting of research gaps in this field.

The studies included in the analysis were identified through Google Scholar and JSTOR, which provide access to a wide range of scientific publications in the fields of sociology, social development, political science and economics, as well as studies dealing with Albania, the Western Balkans and post-communist societies. For the identification of the studies, combinations of keywords such as: "social mobility", "intergenerational social mobility", "Albania" and "the Western Balkans" were used.

The analysis included scientific articles published in peer-reviewed scientific journals, academic books, and research reports of national and international institutions. The selected studies were assessed on the basis of three main criteria. First, they had to address directly social mobility, intergenerational mobility, or processes related to them, such as education, migration, social inequalities, and post-communist transformations. Second, priority was given to studies focused on Albania and the Western Balkans, while in their absence comparative analyses on the post-communist countries of Central and Eastern Europe were also considered. Third, studies of theoretical and empirical importance for understanding the mechanisms of social mobility and the intergenerational transmission of social advantages and disadvantages were included.

After reviewing the titles, abstracts and full content of the identified publications, studies that were not directly related to the subject matter of the research or that addressed only the economic aspects of the transition, without analysing the dimensions of social mobility and, in particular, intergenerational social mobility, were excluded. The selected studies were organised according to the main themes of the analysis, including the transformations of the post-communist transition, migration, education, social and regional inequalities, human capital, as well as studies on social mobility and intergenerational mobility.

The analysis was carried out through a thematic analysis, which made it possible to identify the main concepts, the most important findings, and research gaps. Particular attention was paid to the way the authors conceptualize social mobility, the factors that are considered to affect it, and the extent to which intergenerational social mobility has been addressed in the case of Albania. This process made it possible to assess the current state of research and identify the need for more in-depth sociological studies on intergenerational social mobility in the Albanian context.

RESULTS

Studies on the post-communist transition and social transformation

The literature on Albania's development after the 1990s has focused mainly on the analysis of the political, economic, and social transformations of the transition period. A considerable part of the studies focuses on the shift from the socialist system toward the market economy, the processes of democratisation, and the restructuring of state institutions. In this context, Elbasani (2004) argues that the Albanian transition brought profound changes to the organisation of economic and social life, while simultaneously creating new opportunities and forms of social inequality. Although this research provides important knowledge on the transformation of the Albanian social structure, its attention has been focused mainly on macro-social and institutional processes. As a result, issues related to social mobility and, especially, to the intergenerational transmission of social advantages and disadvantages remain addressed in a limited manner.

Migration as a mechanism of social mobility

Migration constitutes one of the most widely addressed topics in research on social development in Albania. After the 1990s, the processes of internal and international migration have significantly influenced the transformation of the country's demographic and social structure. King and Vullnetari (2012) argue that migration has affected not only population movement, but also family relationships, gender roles, and the economic opportunities of individuals and families. Another aspect emphasized in the literature is related to the role of remittances in improving the economic well-being of Albanian families. In this regard, King, Mata-Codesal and Vullnetari (2013) highlight the importance of remittances as a mechanism that has favored investments in education, the improvement of living conditions, and the expansion of economic opportunities. These findings suggest that migration has played an important role in creating opportunities for social mobility. However, existing studies focus mainly on the economic and social consequences of migration, while its impact on intergenerational social mobility processes remains largely unexplored.

Education, social inequalities and opportunities for social mobility

Education, social inequalities and the unequal distribution of economic opportunities constitute some of the most important topics in the literature on social development in Albania. The studies included in this review suggest that, although the country has recorded economic progress during the transition period, the benefits of this development have not been distributed equally among individuals, social groups and different regions. In this regard, Pere and Bartlett (2018) argue that levels of poverty and social inequalities continue to affect individuals' opportunities for development and improvement of their social position. Similarly, Betti et al. (2018) identify considerable differences in the level of well-being among Albanian regions, showing that economic and social opportunities remain unevenly distributed. Similar findings are also reported by Dumani et al. (2020), who argue that regional differences in economic and social development are associated with different levels of educational participation and achievement. Despite differences in the focus and methodological approach of these studies, they reach a common conclusion: education and human capital constitute central mechanisms for expanding social opportunities and reducing inequalities. This argument is also supported by Deda et al. (2021), who emphasize that investment in education and the development of human capital remain key factors for improving well-being and promoting economic development. However, although these studies provide important insights into the factors that affect social opportunities and individual development, they do not directly analyze the relationship between the family's social origin and the educational or professional achievements of subsequent generations. Consequently, the intergenerational dimension of social mobility remains still underexamined in the existing literature.

Intergenerational social mobility in the existing literature

Compared with the literature on the post-communist transition, migration, education, and social inequalities, studies that directly address social mobility and, in particular, intergenerational social mobility remain limited. The international literature highlights that social origin continues to play an important role in shaping individuals' life chances. In this regard, Gugushvili (2018) argues that parents' educational level and socio-economic status significantly affect children's educational and professional achievements in post-communist societies. Similarly, Pfeffer (2014) and Song (2021) emphasize that the transmission of social advantages and disadvantages is not limited only to the parent-child relationship, but may also extend across several generations of the family. As a result, it remains unclear to what extent the transformations of the post-communist period have affected the relationship between the family's social origin and the educational, professional, or economic achievements of subsequent generations. Overall, the existing literature provides important knowledge on the factors that affect social opportunities in Albania, but does not provide sufficient evidence on how these opportunities are transmitted between generations. This constitutes the main research gap identified by this study and at the same time highlights the need for more in-depth sociological research on intergenerational social mobility in the Albanian context. However, the findings of this review show that the Albanian literature has not addressed intergenerational social mobility as a consolidated field of research. Although there is a considerable number of studies that analyse factors such as migration, education, economic development, and social inequalities, this research focuses mainly on the structural conditions that affect

social opportunities and rarely examines the processes of intergenerational transmission of social advantages and disadvantages.

DISCUSSION

This study aimed to assess the current state of the literature on social mobility in Albania and to analyse the extent to which existing studies have considered intergenerational social mobility. The literature analysis showed that, although over the last three decades a considerable number of studies have been produced on the political, economic, and social transformations of Albanian society, social mobility has not been addressed directly as a consolidated field of sociological research. Instead, most studies have focused on phenomena related to it, such as migration, education, economic development, social inequalities, and the transformations of the transition. One of the main findings of this review is that social mobility appears mainly as a secondary dimension of analysis and not as a distinct object of research in the Albanian literature. Studies on migration have highlighted the importance of remittances, internal migration, and international migration in improving the economic conditions of Albanian families. Similarly, research on education, regional development, and social inequalities has shown that opportunities for education, employment, and well-being are not distributed equally among different groups and regions. However, these studies focus mainly on the structural factors that affect social opportunities and not on the way these opportunities are translated into social mobility between generations. The lack of studies on intergenerational social mobility can be explained partly by the complex nature of the post-communist transition processes in Albania. During the first decades after the fall of the communist system, the attention of researchers and policymakers focused mainly on the emerging challenges of economic transformation, democratisation, mass migration, and institution-building. As a result, scientific research focused more on the immediate problems of social development than on the long-term processes of stratification and social reproduction. In this context, questions related to the influence of family background on individuals' life opportunities remained at the periphery of research interest.

Another factor that may have influenced this gap is related to the lack of data on the social and economic status of different family generations. Unlike many European countries, where consolidated databases exist that make it possible to track individuals and families across several generations, in Albania such data sources are lacking. This makes it more difficult to carry out empirical analyses on intergenerational mobility and may have influenced the dominance of descriptive studies on social development, instead of research focused directly on social mobility. Comparative studies have shown that, despite profound political and economic transformations, social origin continues to significantly influence individuals' educational and professional achievements (Gugushvili, 2018). This suggests that institutional and economic changes do not automatically produce greater equality of opportunity. In the case of Albania, the lack of empirical evidence on intergenerational mobility makes it difficult to assess whether the opportunities created during the transition have been equally accessible to all social groups or whether existing inequalities continue to be reproduced between generations. Likewise, the most recent theoretical developments in the field of social mobility have begun to emphasise the importance of multigenerational perspectives. These approaches argue that social advantages and disadvantages are not transmitted only from parents to children, but may also extend to grandparents and other family generations (Pfeffer, 2014; Song, 2021). Compared to these theoretical developments, Albanian literature still remains at an early stage, as not only multigenerational studies are lacking, but also basic analyses on intergenerational mobility. The lack of research on intergenerational social mobility does not constitute only an academic gap. It also has important implications for policymaking and social development. Without clear knowledge of the relationship between family origin and individuals' educational, professional or economic outcomes, it becomes difficult to assess whether the education system, the labour market and social policies genuinely promote equality of opportunity or contribute to the reproduction of existing inequalities. This study suggests that the lack of studies on intergenerational social mobility limits the sociological understanding of the way social advantages and disadvantages are distributed and reproduced in contemporary Albania. Overall, the focus of Albanian literature has been mainly on the political, economic and social transformations of the transition, while the dimension of intergenerational social mobility has remained almost unexplored. The development of research on intergenerational social mobility would contribute to filling an important gap in Albanian

literature and to a better understanding of the relationship between social origin and equality of opportunity in contemporary Albania.

CONCLUSION

This study aimed to assess the current state of studies on social mobility in Albania, with a special focus on the treatment of intergenerational social mobility. Through the analysis of the existing literature, it was highlighted that, although during the last three decades a considerable number of studies have been developed on the post-communist transition, migration, education, economic development, and social inequalities, social mobility has not been treated as a consolidated field of sociological research. The findings of this study show that Albanian studies have analyzed important factors that affect individuals' social opportunities, such as migration, human capital, regional development, and education. However, these studies have focused mainly on the structural conditions of development and not on the analysis of the relationship between social origin and the socio-economic achievements of subsequent generations. As a result, there is a lack of empirical evidence that would make it possible to assess the degree of intergenerational social mobility in Albania. From the comparison with international studies, it results that contemporary research on social mobility is paying increasing attention to the processes of intergenerational and multigenerational transmission of social advantages and disadvantages. In this aspect, Albanian studies present an important research gap, as there is a lack of systematic sociological analyses that examine the impact of family origin on individuals' educational, professional, and economic achievements.

In conclusion, this study argues that intergenerational social mobility constitutes an important dimension for understanding social development in Albania and that further empirical research is needed to analyze the relationship between social origin and individuals' life chances. Such studies would contribute to deepening knowledge of social stratification in Albania and to a better understanding of the mechanisms through which social advantages and disadvantages are transmitted between generations.

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THE ROLE OF WESTERN EUROPEAN LITERATURE IN THE FORMATION OF THE HISTORICAL TURKISH NOVEL GENRE

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ABSTRACT

This article examines the formation and development of the historical Turkish novel genre in the context of the influence of Western European literature. The social and cultural transformations that took place in the Ottoman Empire during the nineteenth century created favorable conditions for the emergence of new literary forms and artistic approaches. Through translations from French and English literature, Turkish readers became acquainted with the novel genre, which gradually began to replace traditional narrative forms. The study highlights that literary movements such as Romanticism and Realism played a significant role in shaping the thematic structure, character development, and narrative style of early Turkish novels. Writers including Namık Kemal, Ahmet Mithat Efendi, and Halid Ziya Uşaklıgil reflected many features of Western literary traditions while also adapting them to the social realities of Turkish society.

The article further emphasizes that the impact of Western European literature was not limited to stylistic changes alone, but also contributed to a transformation in the understanding of the individual and society within Turkish literature. Idealized heroes commonly found in classical Eastern literature were gradually replaced by more realistic characters struggling with social and psychological conflicts. At the same time, Turkish authors did not merely imitate Western models; instead, they combined European literary techniques with national and cultural values to create a unique literary synthesis. As a result, the formation of the historical Turkish novel genre emerged as a complex process shaped by the interaction of Eastern and Western literary traditions. This development became an important stage in the modernization of Turkish literature and significantly influenced the evolution of national literary thought.

Keywords: Historical Turkish novel, Western European literature, literary influence, modernization, Turkish literature

INTRODUCTION

The nineteenth century occupies a special place in the history of Turkish literature. During this period, profound political, social, and cultural transformations affected almost every aspect of life within the Ottoman Empire. Efforts to modernize state institutions, educational systems, and cultural practices created an environment in which new literary forms could emerge and develop (Değirmenci, 2020). Among these forms, the novel became one of the most influential genres, eventually replacing many traditional narrative structures that had dominated Ottoman literary culture for centuries. The emergence of the Turkish novel was closely connected with the broader process of modernization and with increasing contact between the Ottoman world and Western Europe.

Before the introduction of the novel, Ottoman literary traditions were largely shaped by classical Divan literature and folk narratives. These literary forms possessed their own rich artistic conventions and cultural significance; however, they differed substantially from the European novel in terms of narrative structure, characterization, and representation of social reality. Classical literary works often emphasized symbolic expression, idealized characters, and moral instruction rather than realistic depictions of everyday life. As a result, the transition from traditional literary forms to the novel represented not only a change in genre but also a transformation in literary mentality (Akman, 2018).

The growing influence of Western Europe during the nineteenth century accelerated this transformation. Through diplomatic relations, educational reforms, and translation activities, Ottoman intellectuals gained access to European literary traditions. French literature, in particular, played a decisive role in introducing Turkish readers and writers to the novel as a literary form. The works of authors such as Victor Hugo, Alexandre Dumas, Honoré de Balzac, and later Gustave Flaubert provided new models of storytelling that differed significantly from established Ottoman literary conventions (Watt, 1957). These works demonstrated how fiction could be used to explore historical events, social problems, individual psychology, and national identity.

Translation activities became one of the most important channels through which Western literary ideas entered the Ottoman cultural sphere. During the Tanzimat period, intellectuals viewed translation not merely as a literary exercise but also as a means of cultural and intellectual development (Lukács, 1962). Through translated novels, readers encountered unfamiliar narrative techniques, complex plot structures, and multidimensional characters. These innovations encouraged Turkish writers to experiment with new literary approaches and to adapt European models to local cultural realities.

The development of the historical novel was particularly significant within this context. Historical fiction offered authors an opportunity to examine the past while simultaneously addressing contemporary social and political concerns. European historical novels, especially those written by Walter Scott, demonstrated how national history could be transformed into literary narrative. Scott's works combined historical accuracy with imaginative storytelling, creating a model that influenced writers across Europe and beyond. Ottoman intellectuals recognized the potential of this genre for strengthening historical consciousness and promoting cultural identity during a period of rapid change (Arif, 2019).

The adoption of the historical novel in Turkish literature did not occur through simple imitation. Turkish writers selectively borrowed elements from Western literary traditions while preserving aspects of their own cultural heritage. Consequently, early historical novels reflected both European narrative techniques and local social realities. This process resulted in a unique literary synthesis that distinguished Turkish historical fiction from its European counterparts.

One of the most important consequences of Western literary influence was the emergence of a new understanding of the individual. Traditional literary narratives frequently portrayed idealized heroes whose actions reflected moral or religious values. In contrast, Western novels often focused on ordinary individuals facing social, political, and psychological challenges. Turkish novelists gradually adopted this perspective, creating characters whose experiences reflected the complexities of modern life. Such developments contributed to a broader transformation in literary representation and helped establish realism as an important component of Turkish fiction.

The relationship between literature and society also changed during this period. Writers increasingly viewed literature as a tool for social criticism, public education, and cultural reform (Yıkık, 2022). Inspired by European intellectual movements, many Turkish authors sought to address issues such as modernization, education, social justice, and national identity through their works. Historical novels became especially effective in this regard because they allowed writers to discuss contemporary concerns indirectly through representations of the past.

The influence of Romanticism and Realism further shaped the development of the historical Turkish novel. Romanticism encouraged interest in national history, heroic figures, and emotional expression, while Realism emphasized social observation and psychological depth. Together, these literary movements provided Turkish authors with new artistic possibilities that expanded the scope of literary expression. Their combined impact can be observed in the thematic concerns, narrative structures, and characterization techniques of many early Turkish historical novels.

This study aims to examine the role of Western European literature in the formation of the historical Turkish novel genre (Sağlık, 2002). Particular attention is given to the cultural conditions that facilitated literary transformation, the influence of European literary movements, and the contributions of major Turkish authors who adapted Western models to local contexts. By analyzing these interconnected developments, the article seeks to demonstrate that the historical Turkish novel emerged through a

dynamic process of cultural exchange rather than through simple imitation. The interaction between Eastern and Western literary traditions ultimately contributed to the creation of a distinctive national literary form that played a significant role in the modernization of Turkish literature.

RESULTS

The analysis of the historical development of Turkish literature demonstrates that Western European literary traditions played a decisive role in the emergence and consolidation of the historical Turkish novel genre. The findings reveal that this influence operated through several interconnected channels, including translation activities, educational reforms, literary criticism, and direct contact between Ottoman intellectuals and European cultural institutions. These factors collectively contributed to the transformation of literary expression and encouraged the adoption of new narrative models.

One of the most significant outcomes of Western influence was the introduction of the novel as a distinct literary genre. Prior to the nineteenth century, Ottoman literature relied primarily on poetic forms and traditional prose narratives. Although these forms possessed considerable artistic value, they differed fundamentally from the European novel in their treatment of plot, characterization, and social reality. The spread of translated European novels familiarized Turkish readers with a new type of literary experience that emphasized narrative coherence, historical context, and psychological development (Dadashova, 2022).

The examination of early Turkish novels indicates that French literature exercised a particularly strong influence on literary production. French cultural prestige during the Tanzimat period encouraged Ottoman intellectuals to regard French literary works as models of artistic achievement and social progress. Consequently, many translated novels originated from French authors whose works introduced themes related to freedom, patriotism, social justice, and individual responsibility. These themes resonated with Ottoman reformers who sought to reconcile traditional values with the demands of modernization.

The findings further reveal that the historical novel emerged as one of the most effective literary forms for addressing questions of national identity and historical memory. Turkish authors recognized that historical fiction could serve both educational and artistic purposes (Yalçın Çelik, 2007). By revisiting significant moments from the national past, writers sought to strengthen collective consciousness while also providing readers with engaging narratives. In this respect, the influence of European historical fiction, particularly the novels of Walter Scott, proved especially important.

Scott's approach to historical narration offered a model that combined factual historical events with fictional characters and dramatic storytelling (Dadashova, 2022). Turkish authors adapted this technique to their own cultural and historical circumstances. Rather than merely reproducing European historical themes, they focused on events drawn from Ottoman and Turkish history. This adaptation allowed writers to explore national experiences while benefiting from narrative methods developed within European literary traditions.

The study also demonstrates that Romanticism significantly shaped the thematic orientation of early historical Turkish novels. Romantic literary ideals encouraged writers to emphasize heroism, patriotism, emotional intensity, and devotion to the nation. Historical figures were frequently portrayed as symbols of moral courage and collective identity. Such representations reflected both the influence of European Romanticism and the broader intellectual climate of the Ottoman Empire during a period of political and social transformation.

Namık Kemal occupies a particularly important position in this process. His literary works illustrate how European Romantic ideals could be integrated into Turkish cultural contexts. Through his emphasis on freedom, patriotism, and civic responsibility, he contributed to the development of a literary tradition that linked historical narrative with social and political concerns. His writings demonstrate that historical fiction was increasingly viewed not merely as entertainment but also as a vehicle for intellectual and moral education.

Another significant result concerns the growing influence of Realism on Turkish literary production. While Romanticism inspired emotional engagement with history, Realism encouraged a more detailed

examination of social conditions and individual experiences. The findings indicate that Turkish novelists gradually moved beyond idealized portrayals of historical events and began to explore the complexities of human behavior. This transition reflected broader developments within European literature, where realistic representation became a dominant artistic principle during the second half of the nineteenth century.

The adoption of realistic narrative techniques transformed character construction within Turkish novels. Earlier literary traditions often presented characters as embodiments of moral virtues or symbolic ideals (Lukács, 1962). In contrast, the new generation of novelists created individuals whose actions were shaped by social environments, personal motivations, and psychological conflicts. Such characters appeared more credible and relatable, allowing readers to engage with literary narratives on a deeper emotional and intellectual level.

The works of Ahmet Mithat Efendi provide valuable evidence of this transformation. As one of the most prolific writers of the period, he played a crucial role in familiarizing readers with the conventions of the novel. His narratives combined educational objectives with literary innovation, introducing readers to contemporary social issues while simultaneously experimenting with narrative techniques derived from European literature. His contribution helped establish the novel as an important medium for public discussion and cultural reflection (Arif, 2019).

The results additionally reveal that the influence of Western European literature extended beyond narrative form and thematic content. It also affected broader conceptions of literature itself. Ottoman intellectuals increasingly viewed literature as an instrument of social progress capable of influencing public opinion and encouraging reform. This perspective differed substantially from earlier literary traditions, which often prioritized aesthetic refinement and rhetorical elegance over social engagement.

Another notable finding concerns the development of historical consciousness within Turkish literary culture. Exposure to European historiography and historical fiction encouraged writers to reconsider the relationship between literature and history. Historical novels began to function as spaces in which the past could be interpreted, questioned, and reimagined. Through literary representation, authors sought to establish connections between historical experience and contemporary concerns, thereby making history relevant to modern readers.

The influence of Western literary criticism also contributed to the emergence of more sophisticated approaches to narrative construction. Turkish writers became increasingly attentive to issues such as plot organization, narrative perspective, temporal structure, and character development (Dadashova, 2022). These elements, which had received limited attention within traditional literary forms, became essential components of novelistic practice. As a result, Turkish fiction achieved greater structural complexity and artistic diversity.

The findings indicate that Halid Ziya Uşaklıgil represented a later stage in the process of literary modernization. His works demonstrate a more advanced integration of European literary techniques, particularly in relation to psychological analysis and realistic description. Through detailed character portrayals and carefully constructed narratives, he contributed to the maturation of the Turkish novel and expanded its artistic possibilities.

Despite the extensive influence of Western European literature, the analysis reveals that Turkish authors maintained a strong commitment to cultural authenticity. They did not abandon local traditions or national values in favor of complete Westernization. Instead, they selectively adopted foreign literary techniques while preserving elements of their own historical and cultural heritage. This selective adaptation enabled the creation of a distinctive literary identity that reflected both international influences and local realities.

The evidence suggests that the formation of the historical Turkish novel should be understood as a process of cultural interaction rather than unilateral influence. European literary traditions provided important models and inspirations, but Turkish writers actively transformed these influences according to their own intellectual priorities and artistic objectives. The resulting literary works therefore represent original cultural productions rather than simple imitations of foreign examples.

Overall, the findings demonstrate that Western European literature played a fundamental role in shaping the historical Turkish novel genre. Through the introduction of new narrative techniques, thematic concerns, and literary perspectives, European influences contributed significantly to the modernization of Turkish literature. At the same time, the creative adaptation of these influences by Turkish authors produced a unique literary tradition that continues to occupy an important place within the history of world literature.

DISCUSSION

The findings of this study confirm that the emergence of the historical Turkish novel was closely associated with the broader cultural transformation that took place within the Ottoman Empire during the nineteenth century. The influence of Western European literature was neither accidental nor superficial; rather, it formed part of a wider process of intellectual modernization that affected literature, education, politics, and social life. In this context, the historical novel became one of the most significant literary forms through which Ottoman and later Turkish writers sought to understand the relationship between tradition and modernity.

One of the most important issues revealed by the analysis is that literary modernization did not involve a complete rejection of existing cultural traditions. Although Western European literature introduced new genres, themes, and artistic techniques, Turkish writers approached these innovations selectively (Değirmenci, 2020). The process was characterized by adaptation rather than imitation. This distinction is particularly important because discussions of literary influence often assume a passive transfer of ideas from one culture to another. The development of the historical Turkish novel demonstrates a far more dynamic interaction in which foreign models were transformed according to local cultural needs and historical circumstances.

The role of translation deserves special attention within this discussion. Translation functioned as a bridge between different literary worlds and enabled Ottoman intellectuals to engage directly with European literary thought. Through translated works, writers encountered alternative approaches to narrative construction, characterization, and historical representation. However, the influence of translation extended beyond technical literary matters. It also encouraged new ways of thinking about society, the individual, and the function of literature itself. In many respects, translated novels became instruments of cultural dialogue through which Western concepts were interpreted and reassessed within a Turkish context.

The influence of Romanticism appears particularly significant in explaining the early development of historical fiction in Turkish literature. Romantic writers throughout Europe frequently turned to the past in search of national origins, heroic figures, and collective memory. Similar tendencies emerged among Turkish authors, who increasingly viewed history as a source of cultural identity and moral inspiration (Yıkık, 2022). Historical novels provided a literary space in which national values could be explored and reaffirmed during a period marked by uncertainty and change. The popularity of such narratives suggests that readers were also seeking ways to understand their historical heritage within an evolving social environment.

At the same time, the gradual incorporation of realist principles altered the nature of historical representation. Rather than presenting history solely as a collection of heroic events, Turkish novelists began to examine the social conditions, personal motivations, and everyday experiences that shaped historical developments. This shift contributed to a more complex understanding of the past and encouraged readers to recognize the human dimensions of historical processes. The combination of Romantic and Realist elements therefore became one of the defining characteristics of the historical Turkish novel.

Another noteworthy aspect concerns the changing portrayal of the individual. Traditional literary narratives often emphasized idealized figures whose actions reflected established moral or religious values. Under the influence of Western European fiction, however, literary characters gradually acquired greater psychological depth and individuality. Historical protagonists were no longer depicted exclusively as symbols of collective ideals; they also emerged as individuals confronting personal dilemmas, emotional conflicts, and social pressures. This transformation reflected broader cultural

changes associated with modernization and the growing importance of individual experience within literary discourse.

The discussion also highlights the significance of authors such as Namık Kemal, Ahmet Mithat Efendi, and Halid Ziya Uşaklıgil in shaping the direction of Turkish literary development. Although each writer adopted different artistic strategies, all contributed to the process through which the novel became an established literary genre. Their works illustrate how European literary influences could be integrated into Turkish cultural life without sacrificing national identity. By combining foreign techniques with local themes, these authors helped create a literary tradition capable of addressing both universal human concerns and specifically Turkish historical experiences.

Furthermore, the emergence of the historical Turkish novel demonstrates the close relationship between literature and nation-building. During periods of political and social transformation, literature often serves as a means of constructing collective memory and cultural identity. Historical fiction fulfilled this function by presenting narratives that connected contemporary readers with their historical past (Sağlık, 2002). Through these narratives, writers contributed to ongoing discussions concerning cultural continuity, national consciousness, and social progress. The genre therefore possessed significance beyond purely literary considerations.

The findings additionally suggest that Western European literature influenced not only what Turkish writers wrote about but also how they understood the purpose of literature. The novel increasingly became a medium through which social issues could be examined and debated. Questions concerning modernization, education, freedom, morality, and identity entered literary discourse with greater intensity than before. Historical fiction proved especially effective in addressing such issues because it allowed authors to explore contemporary concerns through the lens of past events. In this sense, historical novels functioned simultaneously as literary works and as reflections on social change.

Despite the undeniable influence of Western literary traditions, the analysis indicates that the historical Turkish novel ultimately developed its own distinctive characteristics. Local historical experiences, cultural values, and narrative preferences continued to shape literary production throughout the modernization process. The resulting synthesis produced works that cannot be fully understood either as purely Western or purely Eastern. Instead, they represent a unique form of cultural creativity emerging from the interaction of multiple intellectual traditions.

This observation has broader implications for the study of comparative literature. The formation of the historical Turkish novel illustrates how literary genres evolve through processes of cultural exchange rather than through isolated national development. Literary traditions are rarely static; they are continually enriched through contact with other cultures. The Turkish example demonstrates that such exchanges can generate innovative forms of artistic expression while simultaneously strengthening rather than weakening cultural identity.

Overall, the discussion reinforces the argument that Western European literature played a fundamental role in the formation of the historical Turkish novel genre. Nevertheless, its influence should be understood as part of a reciprocal process in which Turkish writers actively interpreted, modified, and redefined imported literary models. Through this creative engagement, they established a distinctive literary tradition that contributed significantly to the modernization of Turkish literature and to the broader development of national literary consciousness.

CONCLUSION

The formation of the historical Turkish novel genre was one of the most significant developments in the modernization of Turkish literature during the nineteenth century. As demonstrated throughout this study, Western European literature played a crucial role in this process by introducing new literary forms, narrative techniques, and artistic perspectives that transformed traditional approaches to storytelling. Through translations, educational reforms, and increasing cultural interaction with Europe, Ottoman intellectuals gained access to literary models that contributed to the emergence of the novel as a major genre within Turkish literary culture.

The findings indicate that the influence of Western European literature extended beyond the adoption of formal literary elements. Romanticism and Realism introduced new ways of interpreting history, society, and the individual, allowing Turkish writers to explore historical events through more complex and multidimensional narratives. Historical fiction became an important means of examining national identity, collective memory, and social transformation during a period characterized by profound political and cultural change.

The study further demonstrates that Turkish authors did not simply imitate European literary traditions. Instead, they adapted foreign models to local historical realities and cultural values, creating original works that reflected both Western influences and national characteristics. Writers such as Namık Kemal, Ahmet Mithat Efendi, and Halid Ziya Uşaklıgil successfully combined European narrative methods with Turkish themes, thereby contributing to the establishment of a distinctive literary tradition.

Another important conclusion is that the historical Turkish novel emerged as a product of cultural interaction between Eastern and Western literary traditions. This interaction encouraged innovation while preserving essential elements of national identity. The genre thus became a literary space where questions of history, modernization, culture, and society could be examined from multiple perspectives.

In conclusion, the development of the historical Turkish novel genre cannot be understood without considering the influence of Western European literature. The encounter between different literary traditions created opportunities for artistic experimentation and intellectual renewal, ultimately leading to the formation of a unique and influential genre. This process not only contributed to the modernization of Turkish literature but also played an important role in shaping the evolution of modern Turkish literary thought and cultural consciousness.

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THE IMPACT OF RETURNED MIGRANTS ON AN UNEMPLOYMENT MODEL

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ABSTRACT

In this study, we develop an extended nonlinear differential equation model of unemployment that incorporates unemployed returned migrants as an additional inflow into the unemployed population. The model consists of a system of nonlinear differential equations describing the relationship and influence between employment, unemployment, and job vacancies. We also analyze how the equilibrium points and local stability of the system change with the introduction of the term $R_u(t)$. The results show that the introduction of this term influences the equilibrium structure of the system as well as labor market dynamics.

Keywords: unemployment model, returned migrants, labour market

1. Introduction

Unemployment is now a major socioeconomic problem in both developed and developing countries. Modeling unemployment, modeling it, and studying it from a mathematical and economic perspective have become crucial. Many researchers from around the world have proposed their own unemployment models, studying them from both a mathematical and economic perspective. Among the most important contributions are nonlinear models based on systems of differential equations, which allow for the study of equilibrium states, stability properties, and the behavior of labor market variables. Examples include the work of MISRA and SING [3], MUNOLI and GANI [1], PETERATIP and NIAMSAP [2]. In this study, we have based our work on the differential equation model of MUNOLI and GANI [1] and modified it. Many classical differential equation models of unemployment do not take into account the effect that returning unemployed migrants may have. Since we noted the presence of unemployed return migrants in Albania, we proposed introducing the number of unemployed return migrants as an additional input to the unemployed population in the MUNOLI and GANI model [1] and analyzing its effect on stability and equilibrium. Our main contribution in this article is the formulation and theoretical analysis of the new unemployment model. We show that the R_u parameter acts through the effective unemployment flow.

$$\Lambda_{eff} = \Lambda + R_u.$$

We will observe that returning unemployed migrants do not alter the internal interaction mechanisms between unemployment, employment, and vacancies, but will influence the shift in labor market equilibrium.

In Section 2, we present our proposed mathematical model, as well as the interpretation of the model's variables and parameters. In Section 3, we study the positivity of the system's solutions and the positive invariance of the feasible region [6]. In Section 4, we derive the positive equilibrium point. In Section 5, we analyze local stability using the Jacobian matrix and the Routh-Hurwitz criterion. Finally, in Section 6, we provide the main conclusions and possible directions for future research.

2. Mathematical Model

In this section, we will examine the nonlinear differential equation model we rely on, primarily that of MUNOLI and GANI [1], which describes the interactions between job vacancies, unemployed

individuals, and employed individuals. We assume that all unemployed individuals are qualified and competent to perform any job.

The model proposed by [1] is reported below.

$$\begin{cases} \frac{dU}{dt} = \Lambda - kUV - \alpha_1 U + \gamma E, \\ \frac{dE}{dt} = kUV - \alpha_2 E - \gamma E, \\ \frac{dV}{dt} = \alpha_2 E + \gamma E - \delta V + \phi U. \end{cases} \quad (1)$$

In the table below we have provided the relative explanation of the variables and parameters used in model 1 and also in model 2.

Variables and parameters	**Meaning**
U(t)	Number of unemployed individuals [3]
E(t)	Number of employed individuals [3]
V(t)	Number of job vacancies [3]
Λ	The constant inflow into unemployment
k	The employment matching coefficient
α_1	The removal rate from unemployment
α_2	The retirement or withdrawal rate from employment
γ	The job-loss rate
ϕ	The vacancy creation rate
δ	The vacancy disappearance rate
R_u	Inflow of unemployed returned migrants into the unemployed population

Table 1. Unified parameter interpretation

As can be seen from the model proposed by MUNOLI and GANI [1], it is a nonlinear differential equation model that better describes the main interactions in the labor market, but it does not take into account unemployed migrants who have returned to their country of origin. For countries with developing economies, in this case Albania, the return of unemployed migrants represents an important phenomenon that influences labor market dynamics. Many returning unemployed migrants enter the labor market without immediate employment, with a direct impact on unemployment.

Considering this aspect, we propose introducing a new parameter R_u into the model, which will represent the flow of returning unemployed migrants and, as such, will be introduced in the first equation, with a positive sign.

The new unemployment model we propose will be:

$$\begin{cases} \frac{dU}{dt} = \Lambda + R_u - kUV - \alpha_1 U + \gamma E, \\ \frac{dE}{dt} = kUV - \alpha_2 E - \gamma E, \\ \frac{dV}{dt} = \alpha_2 E + \gamma E - \delta V + \phi U. \end{cases} \quad (2)$$

where

$$R_u \geq 0$$

The variables and parameters of the proposed model are the same as those of MUNOLI and GANI [1], with the only difference being the variable $\boldsymbol{R_u}$ which indicates the rate of unemployed return migrants entering the labor market and constituting an additional flow to the unemployed population.

The term $\boldsymbol{R_u}$ modifies only the first equation of the system, influencing the increase in the flow to the unemployed population and thus reflecting the pressure on the labor market generated by return migration. It does not appear in the second and third equations, that of E(t) and V(t), therefore the differential structure of these two equations remains unchanged.

Note that the first equation [2] indicates that the change in unemployment is determined by the difference between entries and exits:

$$\frac{dU}{dt} = \underbrace{\Lambda + R_u + \gamma E}_{\text{Total inflow into the unemployed class}} - \underbrace{(kUV + \alpha_1 U)}_{\text{Total outflow from the unemployed class}}$$

While the second equation can be written as an increase and decrease in employment

$$\frac{dE}{dt} = \underbrace{kUV}_{\text{Inflow into the employed class}} - \underbrace{(\alpha_2 + \gamma)E}_{\text{Outflow from the employed class}}$$

the third equation is given by the change in jobs:

$$\frac{dV}{dt} = \underbrace{(\alpha_2 + \gamma)E + \phi U}_{\text{Inflow into the vacancy class}} - \underbrace{\delta V}_{\text{Outflow from the vacancy class}}$$

Therefore, the introduction of the $\boldsymbol{R_u}$ coefficient in model (2) influences the unemployment item, replacing the classical item Λ with the effective item:

$$\Lambda_{\text{eff}} = \Lambda + R_u. \quad (3)$$

This means that unemployed migrants returning to the country increase the overall flow of unemployed people and, consequently, shift the equilibrium point of the system.

3. Feasible Region and Positivity of Solutions

In this section, we will analyze the flexibility and positive solutions of the system. Since *U(t), E(t),* and *V(t)* represent the size of the active labor market population, the model makes economic sense only if these variables remain non-negative for all $t \geq 0$. For this reason, it is necessary to demonstrate the positivity of the solutions and the positive invariance of the feasible region.

Assume that the initial conditions satisfy the following:

$$U(0) > 0, E(0) > 0, V(0) > 0.$$

We analyze the boundary behavior of the system.

Theorem 1 (Positivity of solutions)**.** *Assume that all parameters of system* (1) *are non- negative and that* $\boldsymbol{R_u} \geq 0$, *[1]. If*

$$U(0) > 0, \qquad E(0) > 0, \qquad V(0) > 0,$$

then every solution of the proposed unemployment model remains nonnegative for all $t \geq 0$.

Proof. Consider the nonnegative orthant

$$\Omega = \{(U, E, V) \in \mathbb{R}^3_+ : U \geq 0, E \geq 0, V \geq 0\}$$

We examine the direction of the vector field on the boundary planes of **Ω**.

If $U = 0$, then:

$$\frac{dU}{dt}\Big|_{U=0} = \Lambda + R_u + \gamma E.$$

Hence, trajectories cannot cross the plane $U = 0$.

If $E = 0$, then:

$$\frac{dE}{dt}\Big|_{E=0} = kUV \geq 0.$$

Thus, trajectories remain nonnegative.

If $V = 0$, then:

$$\frac{dV}{dt}\Big|_{V=0} = (\alpha_2 + \gamma)E + \phi U \geq 0.$$

Therefore, the region

$$\Omega = \{(U, E, V) \in \mathbb{R}^3_+ : U, E, V \geq 0\}$$

is positively invariant.

Consequently, every solution that starts in **Ω** remains in **Ω** for all $t \geq 0$. This result shows that the introduction of the migration parameter R_u preserves the nonnegativity and economic feasibility of the model.

4. Equilibrium Points

Let us indicate with

$$A = \Lambda + R_u, \qquad b = \alpha_2 + \gamma.$$

So we write system (2) in the form

$$\begin{cases} \dfrac{dU}{dt} = A - kUV - \alpha_1 U + \gamma E, \\ \dfrac{dE}{dt} = kUV - bE, \\ \dfrac{dV}{dt} = bE - \delta V + \phi U. \end{cases} \qquad (4)$$

The equilibrium point is

$$P^* = (U^*, E^*, V^*)$$

And we will obtain it by solving the conditions

$$\frac{dU}{dt} = 0, \frac{dE}{dt} = 0, \frac{dV}{dt} = 0.$$

Equating the partial derivatives to zero, we will obtain the system

$$A - kU^*V^* - \alpha_1 U^* + \gamma E^* = 0, \quad (5)$$
$$kU^*V^* - bE^* = 0, \quad (6)$$
$$bE^* - \delta V^* + \phi U^* = 0. \quad (7)$$

From equation (6) we will have

$$kU^*V^* = bE^*. \quad (8)$$

Substituting equation (8) into (7), we will obtain

$$kU^*V^* - \delta V^* + \phi U^* = 0.$$

Therefore,

$$\delta V^* = U^*(kV^* + \phi),$$

and consequently, the value of $U^*$is

$$U^* = \frac{\delta V^*}{kV^* + \phi}. \quad (9)$$

Using relation (8) again, we will obtain

$$E^* = \frac{kU^*V^*}{b}. \quad (10)$$

Making another substitution of (9) into (10), we obtain E^*

$$E^* = \frac{k\delta(V^*)^2}{b(kV^* + \phi)}. \quad (11)$$

Now, from equation (5) and relation (8)

$$kU^*V^* = bE^*,$$

We have

$$A - bE^* - \alpha_1 U^* + \gamma E^* = 0.$$

Since

$$b = \alpha_2 + \gamma,$$

the previous equation reduces to

$$A - \alpha_1 U^* - \alpha_2 E^* = 0. \quad (12)$$

Substituting expressions (9) and (11) into (12), we obtain

$$A = \alpha_1 \frac{\delta V^*}{kV^* + \phi} + \alpha_2 \frac{k\delta(V^*)^2}{b(kV^* + \phi)}.$$

If we multiply both sides by $kV^* + \phi$, we obtain

$$A(kV^* + \phi) = \alpha_1 \delta V^* + \frac{\alpha_2 k\delta}{b}(V^*)^2.$$

Therefore V^* must satisfy the quadratic equation

$$\frac{\alpha_2 k\delta}{\alpha_2 + \gamma}(V^*)^2 + (\alpha_1\delta - k(\Lambda + R_u))V^* - (\Lambda + R_u)\phi = 0. \quad (13)$$

Since

$$\frac{\alpha_2 k\delta}{\alpha_2 + \gamma} > 0,$$

and the constant term is negative when

$$\Lambda + R_u > 0, \phi > 0,$$

equation (13) has exactly one root positive. Therefore, the positive value of V^* is given by

$$V^* = \frac{k(\Lambda + R_u) - \alpha_1\delta + \sqrt{[\alpha_1\delta - k(\Lambda + R_u)]^2 + 4\frac{\alpha_2 k\delta}{\alpha_2 + \gamma}(\Lambda + R_u)\phi}}{2\frac{\alpha_2 k\delta}{\alpha_2 + \gamma}}. \qquad (14)$$

After determining V^*, the other two equilibrium components are

$$U^* = \frac{\delta V^*}{kV^* + \phi}, \qquad (15)$$

and

$$E^* = \frac{k\delta(V^*)^2}{(\alpha_2 + \gamma)(kV^* + \phi)}. \qquad (16)$$

We conclude that the model we propose has only one positive equilibrium point.

$$P^* = (U^*, E^*, V^*),$$

where

$$U^* > 0, E^* > 0, V^* > 0.$$

The parameter R_u influences the equilibrium point through the actual input flow.

$$\Lambda_{\text{eff}} = \Lambda + R_u.$$

If $R_u = 0$, the equilibrium point will be the equilibrium point of the original model proposed by MUNOLI and GANI [1].

5. Local Stability Analysis

To study the local stability properties of the new model (2), we linearize the system around the equilibrium point using the Jacobian matrix.

$$P^* = (U^*, E^*, V^*),$$

Let's define the functions

$$f_1(U, E, V) = \Lambda + R_u - kUV - \alpha_1 U + \gamma E,$$
$$f_2(U, E, V) = kUV - (\alpha_2 + \gamma)E,$$

and

$$f_3(U, E, V) = (\alpha_2 + \gamma)E - \delta V + \phi U.$$

The Jacobian matrix of the system we obtain is

$$J(U, E, V) = \begin{pmatrix} -\alpha_1 - kV & \gamma & -kU \\ kV & -(\alpha_2 + \gamma) & kU \\ \phi & \alpha_2 + \gamma & -\delta \end{pmatrix}. \qquad (17)$$

By evaluating the Jacobian matrix at the equilibrium point

$$P^* = (U^*, E^*, V^*),$$

we have

$$J(P^*) = \begin{pmatrix} -\alpha_1 - kV^* & \gamma & -kU^* \\ kV^* & -(\alpha_2 + \gamma) & kU^* \\ \phi & \alpha_2 + \gamma & -\delta \end{pmatrix}. \qquad (18)$$

From (18), we obtain the characteristic equation from the condition

$$\det(\lambda I - J(P^*)) = 0.$$

and by solving the determinant, we obtain the cubic polynomial

$$\lambda^3 + c_1\lambda^2 + c_2\lambda + c_3 = 0, \qquad (19)$$

where

$$c_1 = \alpha_1 + \alpha_2 + \gamma + \delta + kV^*, \qquad (20)$$
$$c_2 = \alpha_1(\alpha_2 + \gamma) + \alpha_1\delta + (\alpha_2 + \gamma)\delta + kV^*(\alpha_2 + \gamma + \delta) + kU^*(\phi - \alpha_2 - \gamma), \qquad (21)$$

and

$$c_3 = \alpha_1(\alpha_2 + \gamma)\delta - \alpha_1(\alpha_2 + \gamma)kU^* + \alpha_2 k\phi U^* + \alpha_2 k\delta V^*. \qquad (22)$$

According to the Routh-Hurwitz criterion for a cubic polynomial (19), the positive equilibrium point P^* is locally asymptotically stable if the conditions are satisfied [4].

$$c_1 > 0, c_2 > 0, c_3 > 0, \qquad (23)$$

and

$$c_1 c_2 > c_3. \qquad (24)$$

5.1 The Effect of Returned Migrants on the Stability of an Unemployment Model

The introduction of the R_u parameter constitutes the main extension of the model (1). This parameter enters the system as a constant additional flow into the unemployed population:

$$\frac{dU}{dt} = \Lambda + R_u - kUV - \alpha_1 U + \gamma E. \qquad (25)$$

Since R_u is constant and does not depend on the state variables U and V, its partial derivatives are zero:

$$\frac{\partial R_u}{\partial U} = 0, \frac{\partial R_u}{\partial E} = 0, \frac{\partial R_u}{\partial V} = 0. \qquad (26)$$

Therefore, this parameter R_u does not appears explicitly in the Jacobian matrix (17).

However, this does not mean that unemployed return migrants have no impact on stability. The parameter R_u influences the equilibrium point through the effective inflow:

$$\Lambda_{\text{eff}} = \Lambda + R_u. \qquad (27)$$

Since the equilibrium values

$$U^*, E^*, V^*$$

depend on Λ_{eff},, they also depend on R_u. Consequently, the Jacobian matrix estimated at the equilibrium point depends indirectly on R_u through the elements

$$-\alpha_1 - kV^*, -kU^*, kV^*, kU^*. \qquad (28)$$

Therefore, the impact of unemployed returning migrants on local stability is indirect and is described by the chain

$$R_u \longrightarrow \Lambda_{\text{eff}} \longrightarrow P^*(U^*, E^*, V^*) \longrightarrow J(P^*) \longrightarrow \text{Routh} - \text{Hurwitz Conditions}. \qquad (29)$$

Based on the previous analysis, we conclude that the parameter R_u, representing the number of unemployed workers returning to the labor market, does not appear explicitly in the system's Jacobian matrix. This is because R_u enters the model as an additional constant term in the unemployment equation, and consequently, its partial derivatives with respect to the state variables (U), (E), and (V) are zero.

Although R_u does not appear in the Jacobian matrix, this does not mean that this term does not influence the system's behavior; on the contrary, it directly influences the determination of the equilibrium point's location and, consequently, can affect local stability conditions. An increase in the number of workers returning to the labor market increases the effective inflow Λ_{eff}, shifting the equilibrium values (U^*, E^*, V^*) and modifying the coefficients $c_2$and c_3 of the characteristic equation. For this reason, the stability of the system must be re-evaluated for each value of R_u.

6. Analytical and Economic Interpretation

The parameter R_uu will not be interpreted simply as a demographic or statistical quantity. In our proposed dynamical system (2), it acts as a structural input parameter that increases the effective flow into unemployment:

$$\Lambda_{\text{eff}} = \Lambda + R_u.$$

We conclude that R_u nuk modifies the functional form of the original unemployment model (1). This parameter does not modify the interaction mechanisms between unemployed individuals, employed individuals, and job vacancies.

However, it modifies the equilibrium point and, through this modification, can influence the numerical stability conditions obtained from the Jacobian matrix and the Routh-Hurwitz criterion.

Therefore, unemployed returning migrants influence the model through the chain

$$R_u \longrightarrow \Lambda_{\text{eff}} \longrightarrow P^*(U^*, E^*, V^*) \longrightarrow J(P^*) \longrightarrow \text{local stability conditions.}$$

From an economic perspective, the increase in the number of unemployed returning migrants can create further pressure on the labor market, especially when employment opportunities and new job creation are insufficient to cope with this influx.

In countries like Albania, where emigration and the return of migrants are important socioeconomic phenomena, our proposed model provides a more appropriate theoretical framework for describing unemployment dynamics.

Conclusion

In this study, we propose an extended nonlinear unemployment model, based on the classic MUNOLI and GANI model [1], which includes unemployed return migrants as an additional flow into the unemployed class. Our proposed model (2) describes the interactions between unemployed individuals, employed individuals, and job vacancies through a system of nonlinear differential equations.

The main extension consists in the introduction of the parameter R_u,which represents the flow of unemployed return migrants. This term modifies the first equation of the system by increasing the effective entry into unemployment:$\Lambda_{\text{eff}} = \Lambda + R_u$.

From mathematical analysis, we demonstrate that the model preserves the positivity of the solutions and that the nonnegative region is positively invariant [5]. Therefore, model (2) is mathematically well-defined and economically meaningful. We derive the positive equilibrium point of the modified system and demonstrate that the parameter R_u influences the equilibrium through the effective flow of unemployment. In the case where $R_u = 0$,we return to the original model (1) as a special case.

We also studied the local stability of the positive equilibrium point using the Jacobian matrix and the Routh-Hurwitz criterion. Since R_u is assumed to be constant, this term does not appear directly in the Jacobian matrix, but rather influences the equilibrium point at which it is calculated. Therefore, returning unemployed migrants indirectly may influence local stability through the equilibrium-dependent coefficients of the characteristic polynomial.

From an economic perspective, the results show that returning unemployed migrants can increase labor market pressure by increasing inflows into the unemployed population. From a mathematical perspective, R_u acts as an external parameter that shifts the equilibrium configuration of the system and, consequently, can influence the stability properties of labor market dynamics.

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MORTALITY AND BURDEN OF DISEASE ATTRIBUTABLE TO HIGH LDL-CHOLESTEROL LEVEL IN ALBANIA, 1990-2023

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ABSTRACT

Introduction: High LDL-cholesterol level is strongly associated with cardiovascular diseases, which constitute the main cause of mortality and disease burden in the Albanian population.

Objective: To describe mortality and burden of disease trends attributable to high LDL-cholesterol level in Albania during the period 1990-2023.

Methods: This analysis is based on the crude and age-standardized mortality rates and Disability-Adjusted Life Years (DALYs) attributable to high LDL-cholesterol level in Albania for the period 1990-2023, according to the estimates of the Global Burden of Disease (GBD) Study provided by the Institute for Health Metrics and Evaluation (https://vizhub.healthdata.org/gbd-results/).

Results: Crude mortality rate attributable to high LDL-cholesterol level in the Albanian population was estimated at about 76 (95%CI=48-111) deaths per 100,000 population in 2023 and 41 (95%CI=25-56) deaths per 100,000 population in 1990. Total crude percentage change was 86% (95%CI=41%-135%). Conversely, the age-standardized mortality rates were estimated at 43 (95%CI=27-63) deaths per 100,000 population in 2023 and 70 (95%CI=42-97) deaths per 100,000 population in 1990. Total age-standardized percentage change was -38% (95%CI: from -53% to -20%). Crude burden of disease attributable to high LDL-cholesterol level was 1544 (95%CI=993-2190) DALYs per 100,000 in 2023 and 976 (95%CI=627-1314) DALYs per 100,000 in 1990, whereas the age-standardized burden of disease rate was 893 (95%CI=582-1261) DALYs per 100,000 in 2023 and 1478 (95%CI=940-2008) DALYs per 100,000 in 1990.

Conclusion: Crude morality and disease burden rates attributable to high LDL-cholesterol level have increased in Albania in the past three decades in line with population aging. Yet, the age-standardized rates have declined markedly, indicating real progress and effectiveness of prevention and treatment strategies in mitigating cardiovascular risk. Nevertheless, sustained efforts to strengthen health system responses, expand preventive interventions, and monitor LDL-related outcomes remain essential to further reduce the cardiovascular disease burden and improve long-term population health in Albania.

Keywords: burden of disease, Disability-Adjusted Life Years (DALYs), Global Burden of Disease (GBD) Study, Institute for Health Metrics and Evaluation, LDL-cholesterol, mortality rate.

PREVALENCE AND DEMOGRAPHIC DISTRIBUTION OF PSYCHOSOMATIC COMPLAINTS AMONG ALBANIAN ADOLESCENTS

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ABSTRACT

Introduction: Psychosomatic complaints among adolescents – such as headache, stomach-ache, or backache – are important indicators of underlying emotional and psychological stress. These symptoms often reflect difficulties in coping with academic pressure, social challenges, or family dynamics, and may serve as early warning signs of anxiety, depression, or other mental health concerns.

Objective: To assess the prevalence and demographic distribution of selected psychosomatic complaints among Albanian adolescents.

Methods: This analysis is based on the data collected in the last round of the Health Behaviour in School-aged Children (HBSC) survey conducted in Albania in 2022, which included a nationwide representative sample of 5454 schoolchildren aged 11-15 years (52% girls; overall response rate: 96%). Among other aspects, data on psychosomatic complaints and demographic characteristics were collected. Fisher's exact test was used to assess the associations between psychosomatic complaints and demographic factors.

Results: Overall, 19.4% of adolescents reported headache more than once a week (12.8% in boys vs. 25.2% in girls, P<0.001; 12.7% in 11-year-olds, 19.9% in 13-year-olds, and 24.9% in 15-year-olds, P<0.001). Furthermore, 8.7% of adolescents reported stomach-ache more than once a week (7.0% in boys vs. 10.3% in girls, P<0.001; 7.9% in 11-year-olds, 8.8% in 13-year-olds, and 9.5% in 15-year-olds, P=0.003). Additionally, 12.9% of adolescents reported backache more than once a week (10.4% in boys vs. 15.0% in girls, P<0.001; 9.5% in 11-year-olds, 12.4% in 13-year-olds, and 16.3% in 15-year-olds, P<0.001).

Conclusion: This study indicates that psychosomatic complaints are relatively common among Albanian adolescents, with clear variations across gender and age groups. Girls and older adolescents consistently reported higher prevalence of headache, stomach-ache, and backache compared to boys and younger adolescents, respectively. Targeted interventions in schools and communities are essential to promote effective coping strategies, resilience, and overall well-being of adolescents in transitional Albania.

Keywords: Albania, backache, headache, psychosomatic complaints, schoolchildren, stomach-ache.

SOCIOECONOMIC PROFILE AND FOOD SECURITY STATUS OF RURAL HOUSEHOLDS IN NIGERIA

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ABSTRACT

Nigeria as a country is endowed with immense human and natural endowments which, if efficiently utilized, could sustain her citizens plus export its abundance to neighboring countries; unfortunately, the country is enduring a recurrent food shortage with respect to both quantity and quality. This study assessed the nexus between food security status and resilience capacity among rural households in Nigeria. The study used secondary data obtained from Nigeria Living Standards Survey (NLSS) for 2018/2019. A subset of 15,305 households in rural Nigeria was used for this study. Data were analyzed using Descriptive statistics and Food Security Index. Result showed that mean age of respondents was 49, with a size of nine people per household. The finding revealed that food insecurity among the rural household was 0.39. It is recommended that young people between the ages of 21 and 49 should be gainfully and productively engaged in Nigeria, thereby improving the country's food security situation.

Keywords: Food Security, Rural Households, Rural Nigeria.

THE WASTE TRADE TRAP: MYTHS AND REALITIES OF WASTE COLONIALISM

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ABSTRACT

This study examines waste colonialism as a manifestation of global inequality within the broader framework of sustainability and environmental justice. Although sustainability has become a central paradigm for addressing interconnected ecological, social, and economic crises, persistent asymmetries in global trade and waste management continue to undermine its goals. Waste colonialism refers to the systematic export of hazardous and low-quality waste from wealthier nations in the Global North to less developed countries in the Global South, where weaker regulatory systems and economic vulnerabilities enable such practices. Rooted in colonial patterns of exploitation, waste colonialism intensified with industrialization, mass consumption, and stricter environmental regulations in developed countries, which encouraged the externalization of waste. This often occurs under the guise of recyclable materials or second-hand goods. The Khian Sea incident (1986) illustrates the legal and ethical failures in regulating transboundary waste, while China's 2018 National Sword policy exposed structural weaknesses in the global recycling system by disrupting established waste flows. Despite international efforts such as the Basel Convention, enforcement gaps, legal loopholes, and uneven state capacity limit effective regulation. As a result, recipient countries face environmental degradation, public health risks, and socio-economic challenges, disproportionately affecting vulnerable communities. The study argues that waste colonialism is a structural feature of the global economy, requiring stronger international governance and a transition to circular economies that reduce waste at its source.

Keywords: Waste colonialism; Environmental justice; Global South; Global inequality; Transboundary waste; Sustainability

REIMAGINING PUBLIC HEALTH: INTEGRATING LIFESTYLE MEDICINE INTO NEIGHBOURHOOD WELLBEING CENTRES

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ABSTRACT

The increasing global burden of chronic, lifestyle-related diseases and the current strain on hospital-centric healthcare models necessitate a radical shift towards proactive, preventative public health strategies. This paper explores the transformative potential of integrating Lifestyle Medicine within "Neighbourhoods of the Future" and Community Health and Wellbeing Hubs. Lifestyle Medicine provides an evidence-based approach to preventing and managing chronic conditions by focusing on six core pillars: physical activity, healthy eating, mental wellbeing, social connection, sleep, and the reduction of harmful substances. However, achieving sustainable behaviour change requires moving beyond traditional clinical advice to create environments that make healthy choices highly accessible.

Community wellbeing centres address this by embedding preventative healthcare directly into the local social fabric. These multigenerational hubs operate as localized ecosystems that not only provide clinical services but actively facilitate healthy living through integrated exercise facilities, green spaces, nutrition clubs, and community meeting places. This physical infrastructure is further augmented by digital health innovations, including wearable sensors, gamification, and data-driven predictive analytics, which empower individuals with personalized health insights and continuous monitoring.

By shifting care from reactive sickness services to community-led prevention, these hubs address the upstream socioeconomic determinants of health, combat social isolation, and promote independent, healthy ageing. Ultimately, integrating lifestyle medicine into community wellness centres offers a highly scalable, interdisciplinary solution that can narrow health inequalities, improve long-term population wellbeing, and ensure the financial sustainability of future health and social care systems

KeyWords: Community health, lifestyle medicine, preventative healthcare, digital health, community wellness hubs, healthy agein

MULTIVARIATE ANALYSIS AND PROBABILISTIC PREDICTION OF CRUDE OIL PRODUCTION: A CASE STUDY OF THE GORISHT OILFIELD, ALBANIA

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ABSTRACT

Predicting crude oil production accurately is crucial for improving efficiency and helping with decision-making in petroleum production. This study introduces a statistical method for predicting crude oil production using operational data from the Gorisht Oilfield in Albania, collected in 2025. The dataset includes fluid volume, free water volume, emulsion volume, bound water volume, demulsifier use, diesel use, temperature, and monthly oil production. We applied descriptive statistical analysis, least squares smoothing, correlation analysis, principal component analysis (PCA), and multiple linear regression to explore the relationships between production performance and process variables. To handle operational uncertainty, we developed a probabilistic prediction method based on the observed production distribution. We conducted all statistical analyses, simulations, and visualizations using matlab. The results show that crude oil production is influenced by the interaction of various separation process variables, not just one main factor. This method offers a clear and practical way to predict production, assess operations, and optimize processes in uncertain conditions. The framework can also be used in other petroleum production and oil treatment facilities.

Keywords: Crude oil production, probabilistic prediction, principal component analysis, multiple linear regression, matlab.

INTRODUCTION

Predicting crude oil production accurately is essential for managing reservoirs and optimizing petroleum output. Many factors, including reservoir characteristics, operational conditions, and surface processing parameters, affect production behaviour, making forecasting a challenging task (Ahmed, 2019; Craft et al., 1991). While traditional approaches often rely on trend analysis and single-variable correlations, production performance is generally controlled by the combined influence of multiple interacting variables (Johnson and Wichern, 2019; Jensen et al., 2003). The Gorisht–Kocul oilfield in southwestern Albania is one of the country's most important carbonate oil reservoirs. It is characterized by fractured carbonate rocks, low porosity, moderate permeability, and a mature production stage with increasing water production. These characteristics make fluid separation, water handling, chemical treatment, and energy consumption important operational factors affecting production performance.

This study aims to investigate the relationships between crude oil production and operational parameters recorded during the oil treatment and decantation process. A multivariate statistical framework combining descriptive statistics, correlation analysis, principal component analysis (PCA), multiple linear regression (MLR), and probabilistic prediction was applied to evaluate production behaviour and quantify uncertainty. PCA was used to identify dominant patterns within the dataset (Jolliffe, 2002), while regression analysis was applied to quantify the influence of operational variables on production performance (Cohen et al., 2003; Ma, 2011). The methodology provides a practical approach for understanding production dynamics and supporting decision-making in mature oilfields.

MATERIALS AND METHODS

Study Area

The Gorisht–Kocul oilfield is located approximately 20 km east of the city of Vlora, Albania. The field covers an area of 8.6 km² and is hosted within fractured carbonate reservoirs of Cretaceous–Paleogene age. Reservoir thickness ranges between 350 and 400 m, while production depths vary from approximately 400 to 1250 m. The reservoir is characterized by low matrix porosity (1.08%) and total porosity values ranging from 2% to 2.98%, with an average permeability of approximately 300 mD. The produced crude oil is classified as heavy oil, with an API gravity between 13° and 16° API. Initial geological reserves were estimated at 213.5 million barrels, while recoverable reserves were estimated at 102.7 million barrels. By the end of the evaluated production period, approximately 79.9 million barrels had been produced, corresponding to a recovery factor of 37.3%. Associated gas reserves were estimated at 594 × 10^6 Nm^3, of which approximately 501 × 10^6 Nm^3 had already been produced. (Gjermani, 2016).

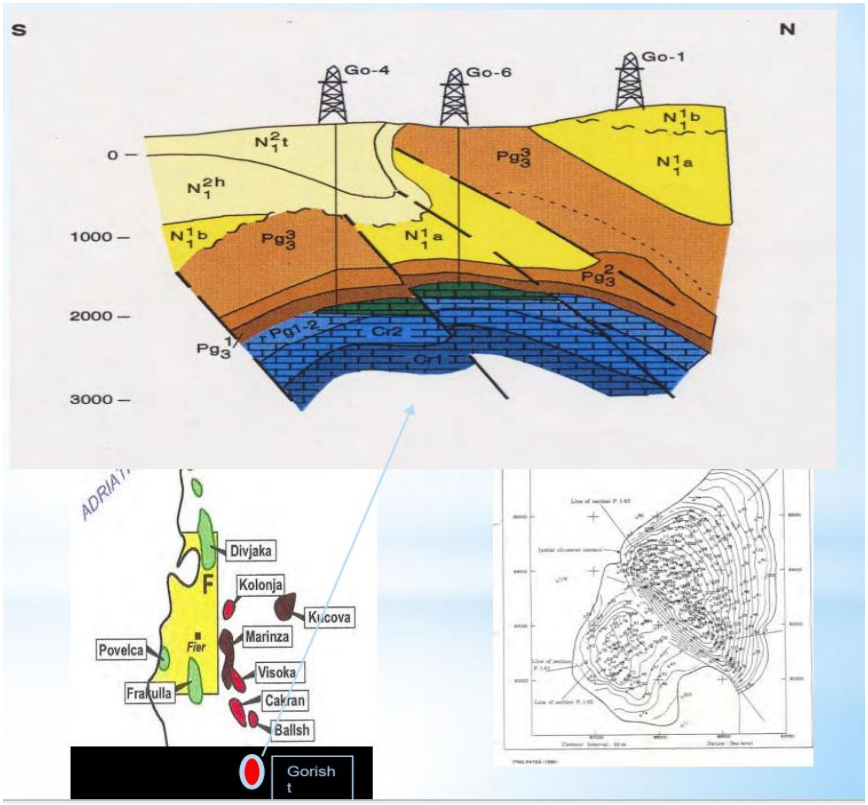


Figure 1. Geological setting and reservoir characteristics of the Gorisht–Kocul oilfield, Albania, including the structural cross-section, field location, and structural contour map of the reservoir (compiled and adapted from Gjermani, 2016).

Table 1. Annual production performance of the Gorisht–Kocul oilfield.

Year	Oil Production (ton)	Gas Production (10^3 Nm^3)	GOR (Nm^3/ton)	Water Production (m^3)	Fluid Production (m^3)
2024	32,478.0	212.978	6.56	123,921.8	164,383.6
2025	29,242.9	220.594	6.45	115,940.4	147,059.0

Table 1 provides a general overview of field performance during the study period. A moderate decline in oil and fluid production was observed in 2025 compared with 2024, reflecting the mature development

stage of the Gorisht–Kocul oilfield. These data provide operational context for the monthly production and decantation dataset analysed in this study.

Production Dataset

For this research, the monthly operational records collected from the crude oil decantation facility in the year 2025 are used. The variables monitored are: total fluid volume, free water volume, emulsion volume, bound water volume, demulsifier consumption, diesel consumption, operating temperature and crude oil production. Oil production ranged from 1,003 to 4,200 tonnes per month, total volumes of processed fluids – from 10,768 to 14,208 cubic meters. The operating temperature ranged from 62°C to 72°C. The consumption of demulsifier varied between 600 and 1,115 kg/month, and the diesel consumption varied between 11,863 and 31,215 L/month.The data collected are a representative description of the operational conditions affecting the oil separation efficiency and production performance. These variables were selected as predictors for the following multivariate and probabilistic analyses.

Table 2. Monthly operational and production data from the Gorisht decantation facility during 2025.

Month	Fluid Volume (m^3)	Free Water (m^3)	Emulsion (m^3)	Bound Water (m^3)	Demulsifier (kg)	Diesel Consumption (L)	Oil Production (ton)	Temperature (°C)
January	14208	9201	5007	2996	996	29927.56	1890	70
February	10768	6822	3946	2235	935	23635	1625	65
March	12063	4229	7834	4428	1115	31215	3208	62
April	13562	6279	7283	3831	930	26510	3259	65
May	13589	6017	7572	3063	1010	28682	4200	70
June	13437	7595	5842	2627	840	19061	3002	70
July	12445	7956	4489	2691	875	14754	1686	72
August	13929	8537	5392	2661	1100	19261	2553	70
September	13710	7944	5766	2808	1000	21327	2768	72
October	12796	10143	2653	1593	600	11863	1003	70
November	12610	7720	4890	2533	920	22212	2218	70
December	13525	7221	6304	3124	1100	30591	2980	68

Note: Diesel was used as the fuel source in the decantation process. The demulsifier applied during the study period was TF-45.

The operational and production data used in this study are summarized in Table 1. The dataset includes monthly measurements of fluid volume, water production, emulsion volume, demulsifier consumption, diesel consumption, operating temperature, and crude oil production for the year 2025.

Methodology

The methodological workflow adopted in this study consists of the following steps:

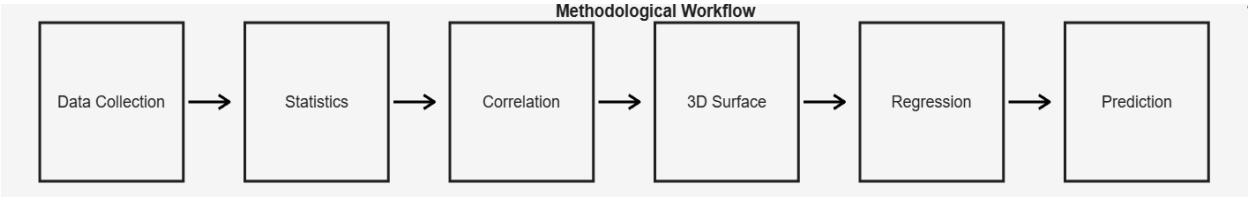


Figure 2. Methodological workflow for scenario-based crude oil production prediction using operational parameters.

Descriptive statistical analysis was initially used to summarise the central tendency and variability of the production variables. Least-squares smoothing was used to detect trends in production and to filter out short-term fluctuations.Correlation analysis was then performed to examine linear relationships between oil production and operational variables. To reduce the dimensionality of the data and identify the dominant production factors, principal component analysis (PCA) was applied. Then, a predictive model for oil production was developed based on operational parameters using multiple linear regression. Finally, a probabilistic prediction method based on the observed production distribution was applied for uncertainty quantification and prediction of production under different operational conditions. All statistical analysis, simulation, and graphical visualisation was performed in MATLAB (Chapra, 2018).

RESULTS

Descriptive Statistics

The descriptive statistical analysis provides an overview of the operational conditions and production performance during 2025. Monthly crude oil production exhibited considerable variability, ranging from 1,003 to 4,200 tons. Processed fluid volumes varied between 10,768 and 14,208 m³, indicating relatively stable field operations throughout the year. Free water represented a substantial proportion of the processed fluid, reflecting the mature stage of reservoir development. Demulsifier consumption ranged from 600 to 1,115 kg per month, while diesel consumption varied between 11,863 and 31,215 liters per month. Operating temperatures remained within a relatively narrow interval of 62–72 °C, ensuring acceptable separation conditions during the decantation process. Basic statistical indicators, including the mean, standard deviation, minimum, maximum, and coefficient of variation, were calculated for all variables. The average monthly crude oil production was 2,533 tons per month, with a standard deviation of 907 tons per month, indicating moderate-to-high production variability during the study period.

Production Trends

Oil production fluctuated considerably throughout 2025, reaching a maximum of 4,200 tons in May and a minimum of 1,003 tons in October. These variations reflect the combined influence of operational conditions on production performance.

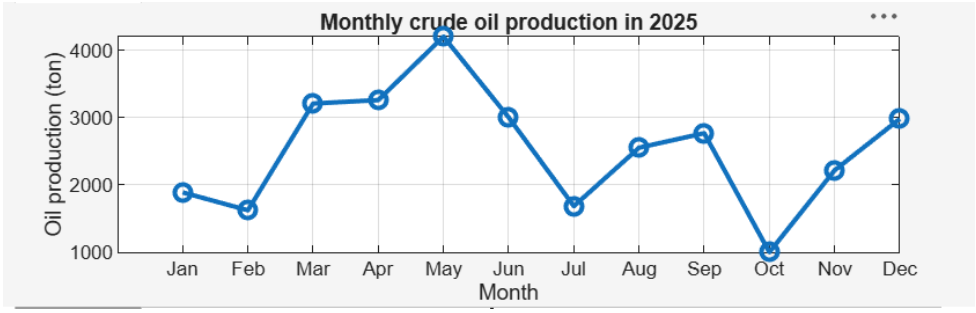


Figure 3. Monthly crude oil production in 2025.

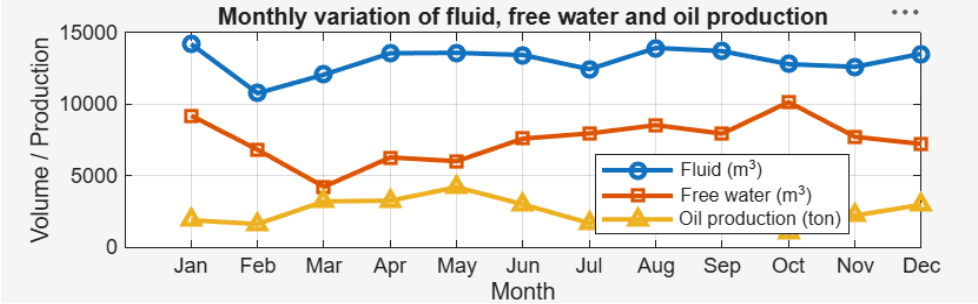


Figure 4. Monthly variation of fluid volume, free water volume and oil production.

Figures 3 and 4 show the evolution of oil production together with the main operational parameters. Although fluid volumes remained relatively stable during the year, noticeable variations in free water production were observed, indicating changes in separation conditions and operational efficiency. The results suggest that production behaviour is influenced by the interaction between fluid handling and water management processes.

Correlation Analysis

Pearson correlation coefficients were calculated to evaluate the relationships among the operational and production variables. The analysis revealed moderate to strong associations between several parameters, indicating that production performance is influenced by multiple interacting factors rather than a single dominant variable. The correlation results provided an initial understanding of the dataset and supported the subsequent PCA and regression analyses (Johnson and Wichern, 2019). The analysis indicated the presence of moderate and strong associations between several variables, suggesting that production performance is controlled by multiple interacting factors rather than a single dominant parameter. The correlation analysis was used only as an exploratory tool and not as the sole criterion for variable selection. Since oil production is influenced by complex multivariate interactions, further investigation was performed using Principal Component Analysis (PCA) and Multiple Linear Regression (MLR).

Principal Component Analysis

Principal Component Analysis (PCA) was applied to reduce data dimensionality and identify dominant patterns within the operational dataset (Jolliffe, 2002).The analysis revealed that several operational variables contribute jointly to the overall variability of the system and can be grouped according to their influence on production performance. The PCA results provided a simplified representation of the dataset and helped identify the most relevant variables for subsequent regression and prediction analyses.

Least Squares Smoothing

Least-squares smoothing was applied to reduce short-term fluctuations in monthly oil production data and to identify the underlying production trend. The smoothed trend confirmed the presence of moderate production variability throughout the study period without a persistent annual increase or decrease.

Three-Dimensional Response Surface Analysis

To investigate the combined influence of operational variables on crude oil production, a three-dimensional response surface was constructed using free water volume, emulsion volume, and monthly oil production data. The response surface provides a visual representation of the relationship between water-handling conditions and production performance. The plotted points represent the observed monthly production data, while the surface represents the estimated production trend. The X-axis corresponds to free water volume (m^3), the Y-axis to emulsion volume (m^3), and the Z-axis to crude oil production (ton).

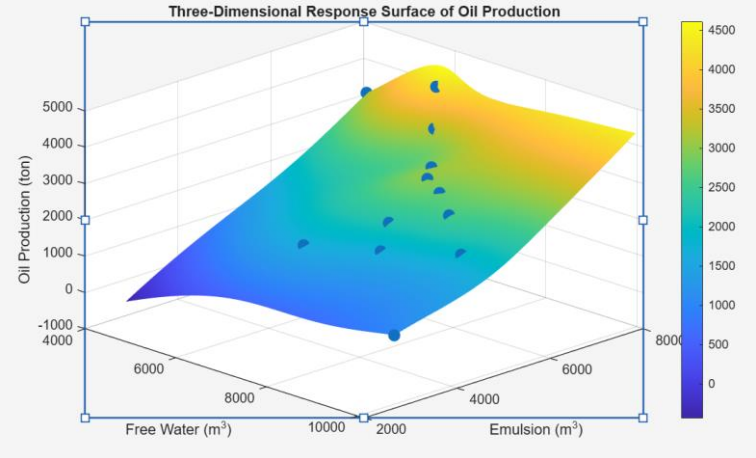


Figure 5. Three-Dimensional Response Surface showing the combined effect of free water and emulsion volume on crude oil production

The results indicate that crude oil production is influenced by the interaction between free water and emulsion volumes rather than by either variable individually. The surface identifies regions associated with higher and lower production performance, while the plotted points represent the observed monthly production data. Overall, the figure highlights the importance of separation-related processes within the decantation system and provides a useful visualization of operational effects on production behaviour.

Multiple Linear Regression

Multiple linear regression was applied to quantify the relationship between oil production and operational parameters (Cohen et al., 2003). The model was developed using fluid volume, free water volume, emulsion volume, bound water volume, demulsifier consumption, diesel consumption, and operating temperature as predictor variables. Regression Model:

Oil Production = f (Fluid, Free Water, Emulsion, Bound Water, Demulsifier, Diesel, Temperature)

The regression equation can be written as follows:

$$Oil = a + b_1 \cdot Fluid + b_2 \cdot FreeWater + b_3 \cdot Emulsion + b_4 \cdot BoundWater + b_5 \cdot Demulsifier + b_6 \cdot Diesel + b_7 \cdot Temperature \quad (1)$$

where a is the intercept and b_1–b_7 are the regression coefficients associated with each operational variable. The regression model quantifies the contribution of the selected operational variables to crude oil production. The estimated coefficients provide information on the relative influence of fluid volume, water handling, emulsion processing, chemical treatment, energy consumption, and operating temperature on production performance. The model achieved a coefficient of determination of R^2 = 0.99996, with a Root Mean Square Error (RMSE) of 5.45 tons and a Mean Absolute Error (MAE) of 4.64 tons. Although these indicators demonstrate a strong agreement between observed and modelled values, the very high R^2 value is partly related to the limited dataset (12 monthly observations) and the relatively large number of predictor variables. Therefore, the regression model should be considered an exploratory analytical tool for evaluating relationships among operational variables rather than a fully validated long-term forecasting model.

Probabilistic Prediction

Because only one year of monthly observations is available, deterministic long-term forecasting is not justified. Therefore, a probabilistic prediction approach based on the observed production distribution was applied. Monthly oil production was approximated using a normal probability distribution with an average production of μ = 2533 ton/month and a standard deviation of σ = 907 ton/month. Three production scenarios were defined:

- Pessimistic scenario: Production < μ − σ, corresponding to production below 1626 ton/month. This scenario may reflect increased water production, higher emulsion volume, and reduced separation efficiency.
- Most likely scenario: μ − σ ≤ Production ≤ μ + σ, corresponding to production between 1626 and 3440 ton/month. This interval represents the most probable operating conditions.
- Optimistic scenario: Production > μ + σ, corresponding to production above 3440 ton/month. This scenario may reflect improved process efficiency and optimized chemical treatment.

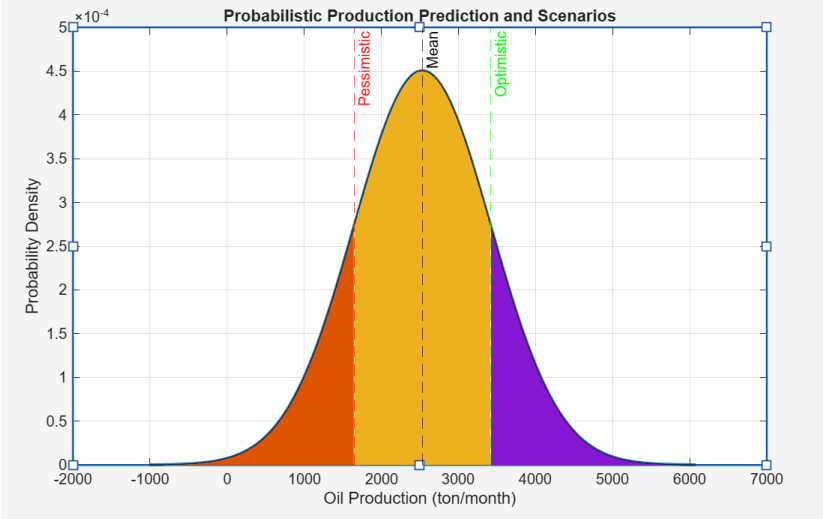


Figure 6. Probabilistic prediction production and scenarios.

The probability distribution of monthly oil production together with the pessimistic, most likely, and optimistic production scenarios. This probabilistic framework provides a practical way to quantify uncertainty and evaluate potential production outcomes under different operational conditions. This approach provides more information than deterministic prediction because it quantifies uncertainty and supports operational decision-making.

DISCUSSION

The results indicate that production behaviour in the Gorisht oilfield is strongly influenced by the interaction between fluid handling conditions and separation efficiency. Although processed fluid volumes remained relatively stable throughout 2025, oil production exhibited significant variability, suggesting that free water production, emulsion volume, and chemical treatment contribute substantially to production performance. The response surface analysis further demonstrated that variations in free water and emulsion volumes are associated with noticeable changes in crude oil production.

The regression model provided a useful quantitative description of the relationships among the operational variables and oil production. However, because the analysis is based on only twelve monthly observations, the results should be interpreted as exploratory rather than predictive. The probabilistic framework complements the regression analysis by quantifying production uncertainty and defining realistic production ranges for operational planning. Overall, the study demonstrates that multivariate statistical methods can provide valuable insights into production behaviour and support decision-making in mature oilfields where water handling and separation processes play an increasingly important role (Ahmed, 2019).

CONCLUSIONS

Monthly crude oil production in the Gorisht oilfield varied from 1,003 to 4,200 tons during 2025, with an average production of 2,533 tons/month and a standard deviation of 907 tons/month, indicating considerable operational variability. Processed fluid volumes remained relatively stable (10,768–14,208 m^3/month), whereas oil production showed significant fluctuations, demonstrating that production performance depends not only on fluid throughput but also on water handling and separation efficiency.

The multivariate analyses confirmed that crude oil production is controlled by the combined influence of free water volume, emulsion volume, chemical treatment, diesel consumption, and operating temperature rather than by a single operational parameter. The three-dimensional response surface analysis highlighted the interaction between free water and emulsion volumes, showing that production performance is strongly affected by separation-related processes within the decantation system. The multiple linear regression model achieved a coefficient of determination of $R^2 = 0.99996$ with RMSE = 5.45 tons and MAE = 4.64 tons. However, due to the limited dataset of twelve monthly observations, the model should be considered an exploratory analytical tool rather than a fully validated forecasting model.

Probabilistic analysis indicated that the most likely production scenario ranges between 1,626 and 3,440 tons/month, while production below 1,626 tons/month represents a pessimistic operational scenario and production above 3,440 tons/month represents an optimistic scenario. The proposed statistical framework provides a practical methodology for analysing production behaviour, quantifying uncertainty, and supporting operational decision-making in mature carbonate oilfields such as Gorisht–Kocul.

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HYDROGEOCHEMICAL CHARACTERIZATION OF GROUNDWATER IN A CARBONATE OIL RESERVOIR

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ABSTRACT

This study investigates the hydrogeochemical characteristics of groundwater in the Gorisht–Kocul oilfield, one of the largest carbonate reservoirs in Albania. The analysis is based on laboratory data from 47 water samples collected from production wells. Statistical and hydrochemical methods were applied to evaluate water composition, identify dominant facies, and determine the main factors controlling groundwater chemistry. The results show that chloride waters dominate the reservoir, with Cl–Ca and Cl–Mg facies representing the most common hydrochemical types. Groundwater is generally neutral to slightly alkaline, while mineralization levels indicate significant salinity variations.Strong correlations between chloride concentration, total mineralization, and water density suggest that salinity is the principal factor controlling the hydrochemical evolution of the studied waters. The observed hydrochemical patterns reflect the influence of water–rock interaction and the long-term evolution of saline waters within a compartmentalized carbonate reservoir. The findings demonstrate that hydrochemical analysis can provide valuable information for reservoir characterization and monitoring and may support future studies linking groundwater composition with oil quality and production performance.

Keywords: hydrogeochemistry, groundwater, chloride waters, carbonate reservoir, matlab.

INTRODUCTION

Hydrogeochemical analysis of subsurface waters is an important tool in petroleum reservoir studies. The chemistry of produced or associated waters reflects lithology, diagenesis, water-rock interaction, mixing processes, and hydrodynamic evolution. In oil-bearing carbonate systems, major-ion composition and salinity patterns often help determine the origin of formation water, the degree of reservoir sealing, and the possible connection between water chemistry and hydrocarbon preservation. Traditional hydrochemical interpretation relies on facies analysis and ionic relationships. This includes using trilinear classification diagrams and cation-anion dominance patterns (Piper, 1944; Back, 1966).

Recent studies show that saline waters found in hydrocarbon reservoirs usually have high chloride levels and are highly mineralized. Researchers often use hydrogeochemical analysis and statistical methods to study salinity changes, interactions between water and rock, and the characteristics of reservoir fluids (Bolaji et al., 2021; Sun et al., 2022). The Gorisht-Kocul structure is one of Albania's significant carbonate oilfield systems. For this conference, the present study focuses on the initial interpretation of the available laboratory dataset. The goal is to identify the dominant hydrochemical facies, the main ionic controls, and the internal variability of the analyzed waters. This study also serves as a methodological bridge for future work linking groundwater chemistry to oil properties through canonical correlation analysis. Hydrochemical investigations commonly combine classical groundwater geochemistry approaches with multivariate statistical methods for the interpretation of groundwater evolution and reservoir processes (Freeze and Cherry, 1979; Hem, 1985; Hair et al., 2019).

MATERIALS AND METHODS

Groundwater samples were collected from production wells located within the Gorisht–Kocul carbonate oil reservoir, one of the major hydrocarbon-bearing structures in Albania. Laboratory analyses were performed on groundwater samples obtained from different production intervals. The original database contained multiple analytical records for each sampling event; however, only the principal analytical record from each set was selected for this study in order to ensure consistency and avoid duplication. A total of 47 groundwater samples were included in the final dataset.

The database comprises a wide range of physicochemical and hydrochemical parameters, including density, pH, sodium plus potassium (Na+K), calcium (Ca), magnesium (Mg), chloride (Cl), sulfate (SO_4), carbonate (CO_3), bicarbonate (HCO_3), iodine (I), bromine (Br), boron (B), ammonium (NH_4), total mineralization, dry residue, interpreted hydrochemical facies, and sampling interval information where available. These variables provide valuable information regarding groundwater salinity, ionic composition, hydrochemical evolution, and water–rock interaction processes within the carbonate reservoir system.

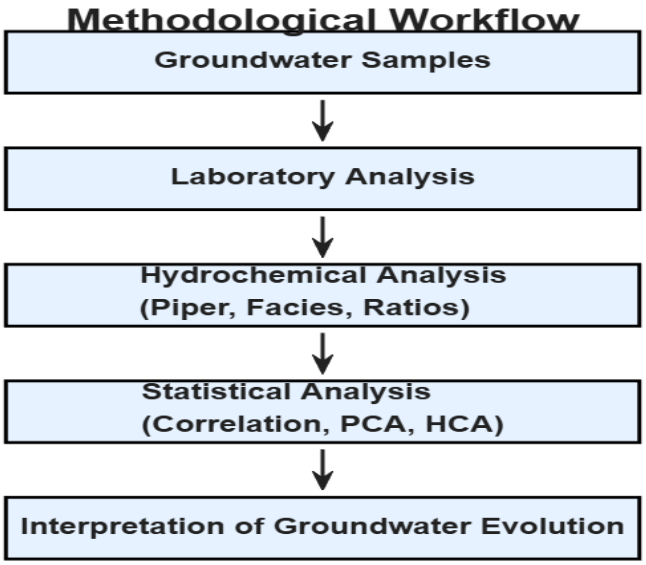


Figure 1. Methodological workflow used for hydrochemical and statistical analysis of groundwater samples.

Prior to analysis, the dataset was examined for consistency, completeness, and potential data-entry errors. Missing values were retained and excluded only from analyses requiring complete observations. For samples reported over depth intervals, the midpoint depth was calculated and used in depth-related evaluations. Because the laboratory records did not include a complete description of analytical units, the study focused primarily on relative variations, hydrochemical classification, and statistical relationships among variables rather than direct comparison with external hydrochemical standards. The analytical procedure consisted of several complementary stages. First, descriptive statistical analysis was performed to summarize the central tendency and variability of the measured parameters. Second, hydrochemical facies classification and frequency analysis were applied to identify the dominant groundwater types within the reservoir. Third, salinity indicators and ionic ratios were evaluated to investigate the processes controlling groundwater chemistry and the evolution of dissolved constituents. Correlation analysis was subsequently employed to quantify relationships among major ions, density, and mineralization parameters.

To further explore hydrochemical variability, multivariate statistical methods were applied, including hierarchical cluster analysis (HCA), which was used to identify groups of samples with similar hydrochemical characteristics. In addition, graphical analyses such as Na+K versus chloride, density versus total mineralization, pH versus mineralization, and total mineralization versus depth were used to evaluate hydrochemical trends and possible geochemical controls. Three-dimensional visualization techniques were also employed to illustrate salinity variations and relationships among key hydrochemical variables. Together, these methods provide an integrated framework for characterizing groundwater chemistry and understanding the hydrochemical evolution of formation waters within the Gorisht–Kocul carbonate reservoir.

RESULTS

Descriptive statistics

Descriptive statistics were calculated to summarize the main hydrochemical characteristics of the groundwater samples. The analyzed parameters include density, pH, major ions, and total mineralization. Table 1 presents the number of observations, mean values, standard deviations, and observed ranges for the principal hydrochemical variables.

Table 1. Descriptive statistics of the principal reported parameters.

Parameter	n	Mean	Std. dev.	Min	Max
Density	33	1.046	0.021	1.000	1.075
pH	35	7.400	0.573	6.000	8.500
Na+K	47	1028.443	435.580	9.900	1629.000
Ca	46	71.707	44.164	12.000	247.300
Mg	47	55.938	39.988	3.000	250.000
Cl	47	1107.223	436.344	100.000	1725.000
SO4	45	32.671	19.762	6.000	122.000
HCO3	47	39.013	11.562	15.000	80.000
Total mineralization	47	67.556	25.955	7.551	105.000

The groundwater samples are generally neutral to slightly alkaline, with an average pH of 7.4. Chloride and Na+K are the dominant dissolved constituents, exhibiting the highest mean concentrations among the analyzed ions. Total mineralization varies from 7.551 to 105.000 g/L, indicating substantial hydrochemical heterogeneity within the reservoir. The wide ranges observed for chloride, calcium, magnesium, and total mineralization suggest the coexistence of waters with different degrees of salinity and hydrochemical evolution. These variations are consistent with the influence of water–rock interaction processes and local reservoir heterogeneity.

Geological setting

The Gorisht–Kocul oil field, located in southwestern Albania, represents one of the largest carbonate hydrocarbon deposits within the Albanian fold-and-thrust belt. Situated in the Ionian tectonic zone, this area is characterized by pronounced compressional tectonics, faulting, and folding associated with the Alpine orogeny. The reservoir is hosted in fractured carbonate rocks, predominantly Jurassic and Cretaceous limestones and dolomitic limestones. Structural trapping is primarily governed by extensive anticlinal folds and fault systems, which significantly influence reservoir compartmentalization and fluid migration. Geological cross-sections of the Gorisht–Kocul–Kremenara area demonstrate a complex structure with substantial vertical and lateral lithological variations. Reservoir depths typically range from about 1,500 to over 3,000 meters, depending on the structure. The carbonate rocks have secondary porosity and permeability caused by fractures, dissolution, and tectonic activity. As a result, fluid flow is mainly controlled by the fracture network instead of just the rock matrix. The reservoir is supported by a strong natural water drive, with groundwater and formation water helping to maintain pressure and influence hydrocarbon production. The interaction between the reservoir rocks and highly

mineralized water has played a key role in shaping the chemistry of the groundwater. These characteristics make the field a good candidate for hydrogeochemical studies that focus on groundwater composition, fluid movement, reservoir connections, and water–rock interactions. The fractured carbonate reservoir characteristics are consistent with the petrophysical behavior commonly observed in carbonate petroleum systems (Tiab and Donaldson, 2015).

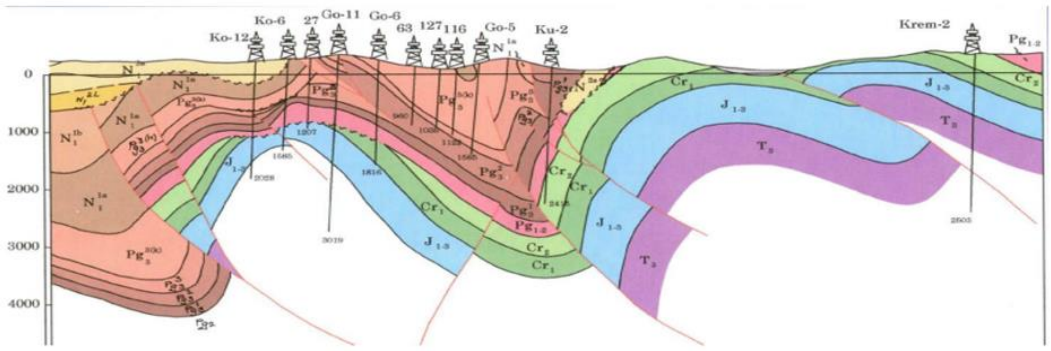


Figure 2. Geological Cross-Section of the Gorisht–Kushtaj–Kremenara Carbonate Reservoir System

The geological setting of the Gorisht–Kushtaj–Kremenara region is characterized by folded and faulted carbonate formations belonging to the Albanian Ionian Zone. The reservoir is mainly developed within fractured Jurassic and Cretaceous limestones and dolomitic limestones, which constitute the principal hydrocarbon-bearing units of the area. Structural compartmentalization and fault-controlled fluid migration strongly influence groundwater circulation and the distribution of highly mineralized waters within the reservoir. The interaction between groundwater and carbonate reservoir rocks has played a fundamental role in controlling the hydrochemical evolution of the system. These geological characteristics provide the framework for understanding groundwater salinity, hydrochemical facies, and the spatial variability of the physicochemical parameters analyzed in this study.

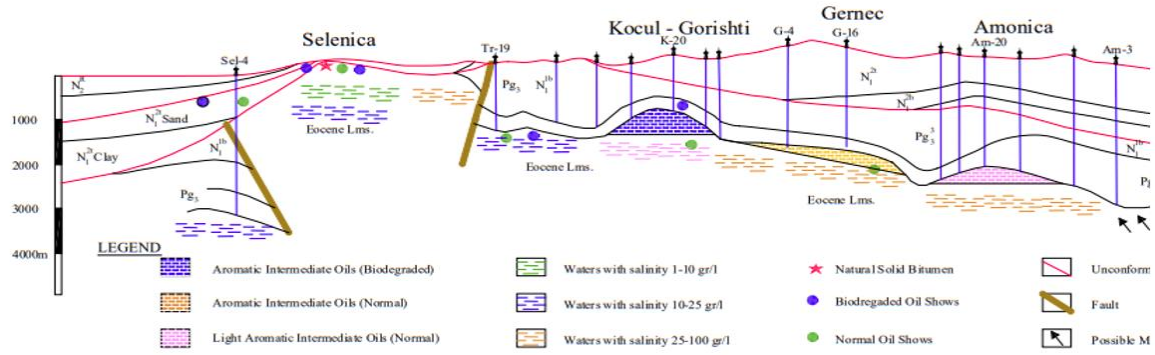


Figure 3. Geological and Reservoir Characteristics of the Gorisht–Kocul Oil Field

The geological–geochemical profile illustrates the structural framework of the Ionian Zone and the position of the Gorisht–Kocul reservoir within the regional tectonic setting. The profile highlights the role of folded and faulted carbonate formations in controlling groundwater circulation, fluid migration pathways, and reservoir compartmentalization. These geological controls contribute to the spatial variability of groundwater salinity and hydrochemical composition observed in the study area.

Hydrogeochemical Analysis

The interpreted water-type column shows a clear dominance of chloride facies. Out of 47 extracted records, 19 samples are classified as Cl-Ca and 19 as Cl-Mg, whereas SO4-Na facies are minor (4 samples). Five records were left unclassified in the source sheet. This distribution indicates that the Gorisht–Kocul waters are predominantly chloride-rich and chemically mature. Such a pattern is

compatible with saline subsurface waters that have undergone prolonged interaction with reservoir rocks and have not been dominated by fresh recharge. Similar hydrochemical characteristics have been reported for saline formation waters in hydrocarbon reservoirs worldwide (Collins, 1975).

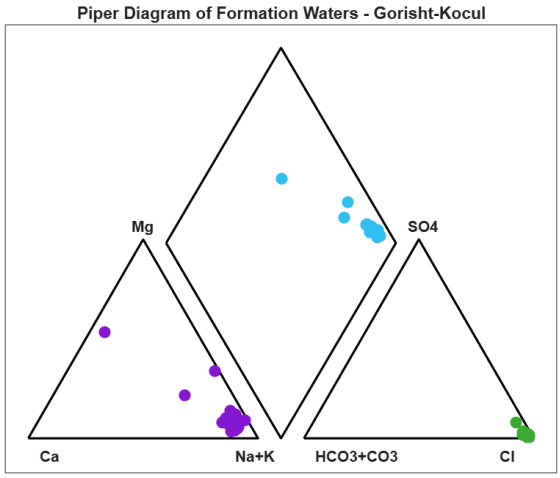


Figure 4. Piper diagram showing the hydrochemical facies of groundwaters from the Gorisht–Kocul carbonate reservoir.

The Piper diagram indicates that chloride-rich waters dominate the Gorisht–Kocul groundwater system, with Cl–Ca and Cl–Mg representing the principal hydrochemical facies. The observed distribution reflects the effects of long-term water–rock interaction, groundwater circulation, and progressive salinity evolution within the carbonate reservoir. These hydrochemical characteristics provide insight into reservoir heterogeneity and the geochemical processes controlling groundwater composition.

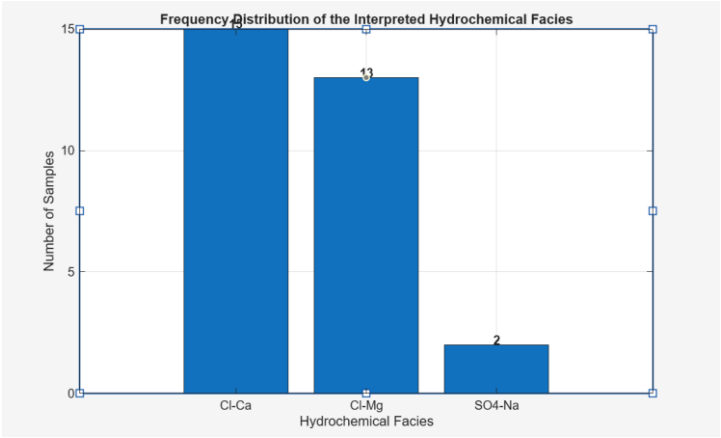


Figure 5. Frequency distribution of the interpreted hydrochemical facies.

The frequency distribution confirms that chloride facies are overwhelmingly dominant within the reservoir, while sulfate-rich waters occur only locally, indicating limited influence of secondary sulfate-bearing processes.

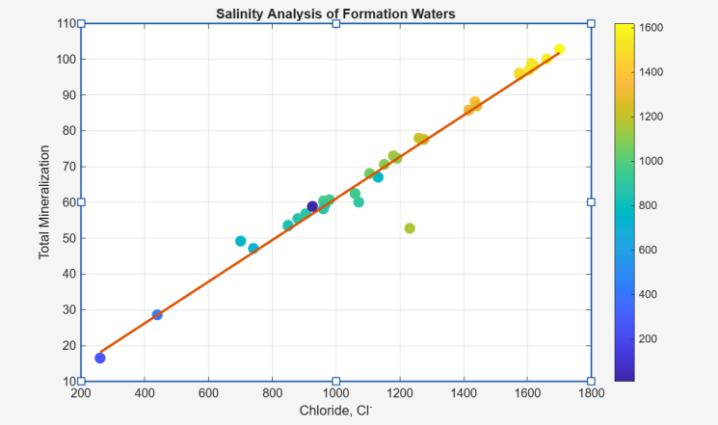


Figure 6. Salinity analysis showing the relationship between chloride concentration and total mineralization.

The salinity analysis reveals a strong positive relationship between chloride concentration and total mineralization in the formation waters of the Gorisht–Kocul carbonate reservoir. As chloride concentrations increase, total dissolved mineral content also increases, indicating that chloride is one of the major contributors to groundwater salinity. This trend suggests the presence of highly evolved formation waters that have undergone prolonged water–rock interaction and extended residence times within the reservoir. The elevated salinity levels are consistent with the dominance of Cl–Ca and Cl–Mg hydrochemical facies identified in the study. Such highly mineralized waters may significantly influence reservoir performance by increasing scaling potential, promoting corrosion processes, affecting fluid properties, and contributing to variations in crude oil quality.

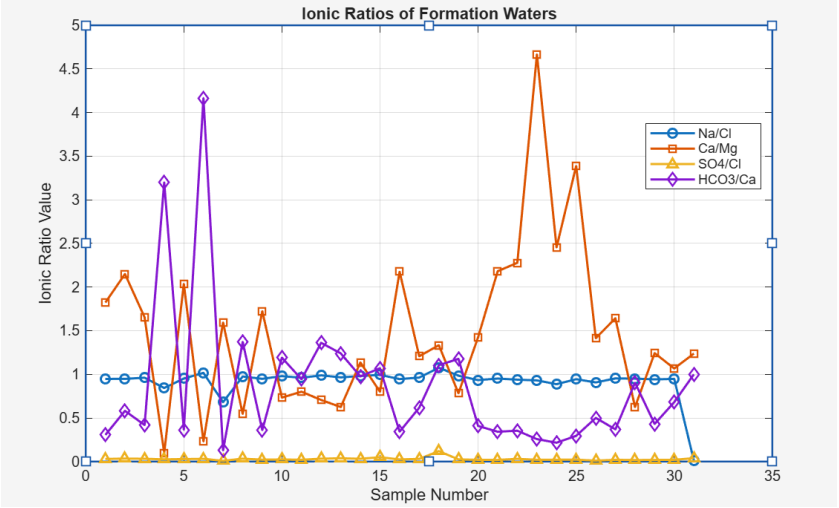


Figure 7. Variation of the principal ionic ratios (Na/Cl, Ca/Mg, SO_4/Cl, and HCO_3/Ca).

The variation of the principal ionic ratios across the analyzed formation water samples. The Na/Cl ratio remains close to unity for most samples, indicating that salinity is primarily controlled by chloride-rich waters and suggesting a common hydrochemical origin. The Ca/Mg ratio exhibits significant variability, reflecting differences in carbonate and dolomite dissolution processes and local lithological heterogeneity within the reservoir. The SO_4/Cl ratio remains consistently low in most samples, indicating limited sulfate contribution relative to chloride and confirming the dominance of saline formation waters. In contrast, the HCO_3/Ca ratio shows moderate variability, suggesting differences in carbonate dissolution intensity and water–rock interaction processes. Overall, the ionic ratio patterns indicate that the hydrogeochemistry of the Gorisht–Kocul formation waters is mainly controlled by prolonged water–rock interaction, carbonate reservoir processes, and progressive salinity evolution.

Multivariate Statistical Analysis

To better understand the factors influencing groundwater chemistry in the Gorisht–Kocul carbonate reservoir, multivariate statistical techniques were applied to the hydrochemical dataset. While descriptive statistics and hydrochemical facies analysis provide information on the general characteristics of groundwater composition, multivariate methods help identify relationships among variables and reveal the dominant geochemical processes controlling groundwater evolution. In this study, correlation analysis and Hierarchical Cluster Analysis (HCA) were used to evaluate interactions among major hydrochemical parameters, identify the principal controls on groundwater chemistry, and classify groundwater samples according to their chemical similarity. These methods provide additional insight into salinity evolution, water–rock interaction processes, and the hydrochemical heterogeneity of the carbonate reservoir system.

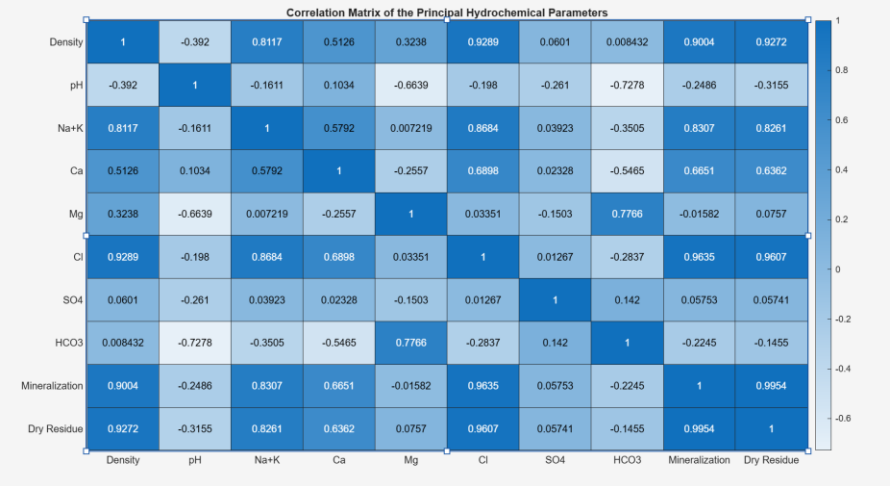


Figure 8. Correlation matrix of the principal hydrochemical parameters of groundwater samples.

The correlation matrix reveals strong positive relationships among chloride, Na+K, density, total mineralization, and dry residue, indicating that salinity is the principal factor controlling groundwater chemistry. The highest correlations are observed between mineralization and dry residue (r = 0.995), chloride and mineralization (r = 0.964), and density and chloride (r = 0.929). These results suggest that the analyzed waters are highly mineralized formation waters whose hydrochemical evolution is largely controlled by dissolved salts and long-term water–rock interaction processes within the carbonate reservoir.

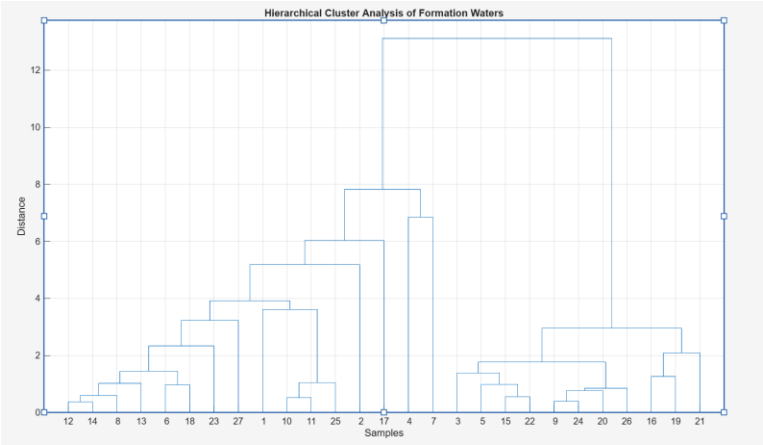


Figure 9. Hierarchical Cluster Analysis (HCA) Dendrogram of the Gorisht–Kocul Groundwater Samples

Hierarchical cluster analysis groups the formation water samples according to their chemical similarity. Samples with similar chloride, mineralization, calcium, and magnesium contents are grouped together,

reflecting common hydrochemical facies and similar reservoir conditions. The clustering pattern supports the separation of chloride-calcium, chloride-magnesium, and sulfate-sodium water types. The identified clusters indicate the existence of hydrochemical heterogeneity within the reservoir system. Variations among clusters may reflect differences in reservoir compartmentalization, groundwater circulation pathways, and the intensity of water–rock interaction processes. The clustering results are consistent with the hydrochemical facies classification and provide additional evidence that salinity-related processes play a dominant role in controlling groundwater composition within the Gorisht–Kocul carbonate reservoir.

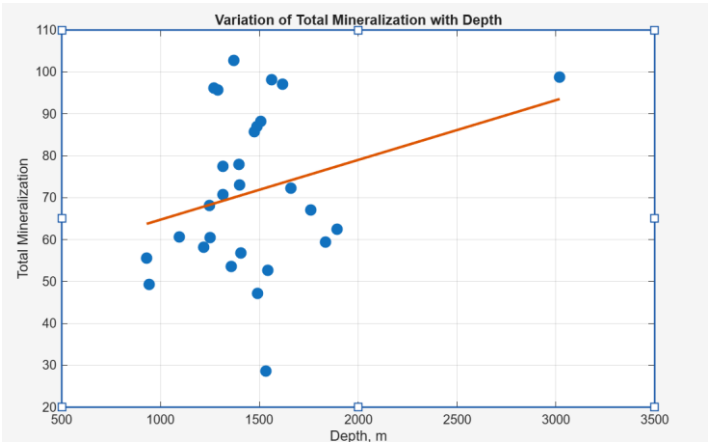


Figure 10. Relationship Between Total Mineralization and Depth

Figure 10 illustrates the relationship between total mineralization and reservoir depth. The observed trend provides information on the vertical evolution of groundwater salinity within the carbonate reservoir. In general, deeper waters tend to exhibit higher mineralization levels, reflecting prolonged residence times and enhanced water–rock interaction processes. The increase in mineralization with depth may be associated with restricted groundwater circulation, dissolution of reservoir minerals, and the progressive accumulation of dissolved salts. These results indicate that salinity evolution is closely linked to the geological and hydrodynamic conditions of the Gorisht–Kocul reservoir. Although the overall trend suggests increasing mineralization with depth, the observed scatter indicates that depth alone does not fully explain groundwater salinity variations. Local geological factors, including fault-controlled fluid migration, reservoir compartmentalization, and lithological heterogeneity, may significantly influence the distribution of dissolved minerals within the reservoir.

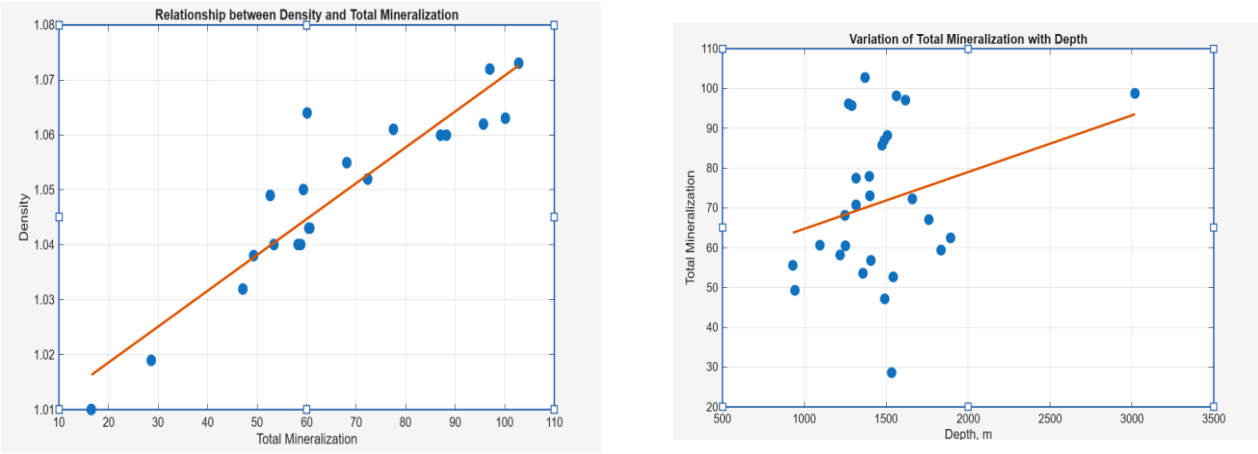


Figure 11. (a) Relationship Between Groundwater Density and Total Mineralization; (b) Relationship Between Na+K and Chloride Concentrations with Linear Trend Line.

Figure 11 illustrates two important hydrochemical relationships within the Gorisht–Kocul groundwater system. Figure 11a shows a positive relationship between groundwater density and total mineralization, indicating that increasing concentrations of dissolved salts contribute to higher water density. Figure 10b demonstrates a strong positive association between Na+K and chloride concentrations, confirming that chloride-rich salts are the dominant contributors to groundwater salinity. Together, these relationships support the interpretation of a saline groundwater system controlled primarily by dissolved chloride ions and long-term water–rock interaction processes within the carbonate reservoir.

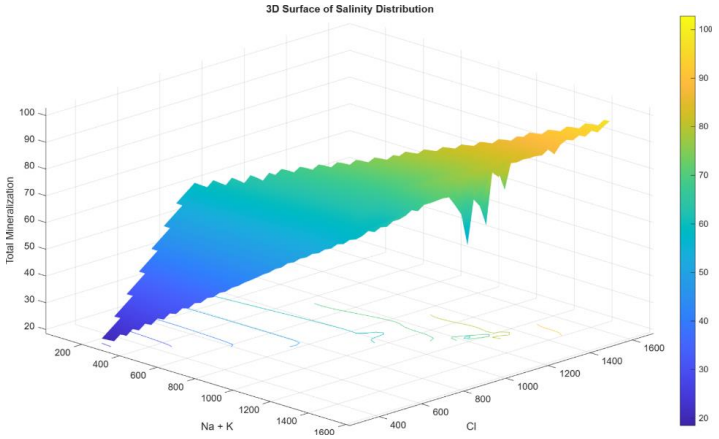


Figure 12. Three-Dimensional Surface Representation of Groundwater Salinity

The three-dimensional surface confirms the strong hydrochemical association among Na+K, chloride concentration, and total mineralization, illustrating the dominant influence of salinity on groundwater composition within the reservoir.

DISCUSSION

Implications for the Gorisht–Kocul reservoir

Looking at the reservoir, the dominance of chloride waters, their close link with mineralization and density, and the limited influence of depth all point to a saline and chemically mature groundwater or formation-water system. In carbonate petroleum reservoirs, this often indicates strong water-rock interaction, limited water movement, and advanced hydrochemical development. The geological cross-section and structure of the Gorisht–Kocul area also support this view. Faults can control how fluids move and divide the reservoir, leading to greater differences in water chemistry and the buildup of highly mineralized waters. For the Gorisht–Kocul structure, these findings suggest that groundwater chemistry can be a useful means of monitoring reservoir differences and can be compared with oil-quality measures such as density, viscosity, sulfur content, or API gravity in the future.

Hydrogeochemical Implications for Reservoir Management

The hydrochemical characteristics identified in this study provide useful information for reservoir management and monitoring. The predominance of chloride-rich waters and the high degree of mineralization indicate conditions that may favor scaling and corrosion processes within production systems. Furthermore, the strong relationships observed among chloride concentration, total mineralization, and water density suggest that hydrochemical monitoring can serve as an effective tool for tracking reservoir evolution and identifying changes in fluid circulation. These findings demonstrate that groundwater chemistry can contribute to reservoir characterization and may support future investigations into the relationships among groundwater composition, oil quality, and production performance. Regular checks of groundwater chemistry can help spot changes in reservoir conditions, water influx, and fluid migration. This information helps reservoir engineers assess production processes and create ways to reduce scaling, corrosion, and formation damage. Combining hydrochemical data with engineering details can improve reservoir monitoring and lead to better field management.

CONCLUSION

A hydrogeochemical study of groundwater in the Gorisht–Kocul carbonate reservoir found that chloride-rich waters are most common, with notable differences in salinity and ion content. The reservoir's fractured Jurassic and Cretaceous carbonate rocks, along with its structural divisions and fault-driven fluid movement, create good conditions for long-term water–rock interaction and the formation of highly mineralized groundwater. Hydrochemical tests showed that chloride waters are the main type in the reservoir, especially Cl–Ca and Cl–Mg types. The Piper diagram and facies classification suggest that the groundwater chemistry has changed over time due to long contact with the carbonate rocks and increasing salinity. This matches the reservoir's geology, where limited water movement and separated flow areas can lead to a buildup of dissolved salts. Analysis of salinity, ionic ratios, and correlations showed strong links between sodium plus potassium, chloride levels, water density, and total mineral content. These results confirm that salinity mainly controls the groundwater's makeup and chemical changes in the reservoir. The connection between density and total mineral content also shows how dissolved salts affect the physical properties of the groundwater.

Multivariate statistical analysis gave more insight into how the reservoir's groundwater behaves. Cluster analysis showed that groundwater samples differ in their chemical makeup, likely due to local geology, reservoir divisions, and different water flow paths. Also, the link between mineral content and depth suggests that depth by itself does not explain groundwater chemistry, underlining the role of structure and rock type. In summary, the methods used were effective for studying groundwater chemistry in a carbonate oil reservoir. Combining geological analysis, hydrochemical facies, salinity checks, ionic ratios, and statistical methods gives a solid approach for understanding and monitoring the reservoir. The data collected also offers a useful starting point for future studies on how groundwater chemistry relates to oil quality, reservoir performance, and further statistical analysis.

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THE NEW LOGIC OF GERMAN INDUSTRIAL POLICY IN A FRAGMENTED WORLD

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ABSTRACT

Recent transformations in the global geo-economic landscape have brought industrial policy back to the core of strategic economic governance, prompting a profound reassessment of the state's role in shaping long-term productive transformation. In Germany, this shift reflects the cumulative pressures generated by the ecological transition, intensifying geopolitical rivalry, techno-nationalism and systemic vulnerabilities within global supply chains. Against this background, the paper examines the emergence of a new logic of Germany's industrial policy under conditions of global fragmentation, assessing the extent to which recent structural shifts mark a departure from the country's traditional ordoliberal emphasis on market coordination, horizontal framework conditions and competitive neutrality. The analysis identifies and discusses the primary vectors of this reconfiguration, namely the imperative of industrial decarbonisation, the systemic challenges posed by China's state-capitalist rise, the abrupt collapse of energy interdependence with the Russian Federation, and the asymmetrical competitive pressures generated by the US Inflation Reduction Act. Methodologically, the article employs qualitative policy analysis, integrating a review of German and European strategic frameworks with an evaluation of the structural strains that have eroded the traditional foundations of Germany's export-oriented, manufacturing-centred model of economic development. The findings suggest that German industrial policy is being fundamentally redefined as an instrument of economic security and technological sovereignty, aimed at mitigating critical dependencies, safeguarding strategic capabilities and preserving the long-term viability of Germany's manufacturing core. At the same time, the analysis shows that this pivot does not imply a wholesale abandonment of the country's coordinated market economy, but rather a strategic recalibration under conditions of geo-economic fragmentation. The paper concludes that the new logic of German industrial policy lies in the attempt to reconcile competitiveness, climate neutrality and economic security within a more interventionist institutional framework, albeit one that is structurally and fiscally constrained. This transformation extends well beyond Germany's domestic trajectory, shaping the broader European debate on strategic autonomy in an increasingly fragmented global order.

Keywords: German industrial policy; geo-economic fragmentation; economic security; technological sovereignty; strategic autonomy.

1. INTRODUCTION

Since the end of the Second World War, industrial policy in Western Europe has evolved in accordance with successive political and strategic cycles. In the post-war phase, governments sought to enhance the performance of national industries and enterprises through targeted interventions, including subsidies for research and development, preferential public procurement and the promotion of mergers (Owen, 2012). The second stage, which began in the 1980s and continued until the early 2000s, was characterised by a shift towards horizontal, non-selective policies designed to improve the business climate and strengthen confidence in competition. In the current phase, however, major global trends, namely the greening of industries, intensifying geopolitical rivalries, the rise of techno-nationalism and disruptions to global supply chains, have reversed the previous consensus. An increasing number of economies are now moving away from the idea that markets are the ultimate arbiter of efficiency (Lütkenhorst, 2018; Tagliapietra & Veugelers, 2023; Altenburg, 2024).

In Germany's case, this paradigmatic shift is particularly significant because it coincides with mounting pressures on the traditional foundations of the federal economy's export-oriented, manufacturing-centred model. Rising energy costs, shortages of skilled labour, administrative rigidity, insufficient

public investment and geopolitical pressures on supply chains have exposed and amplified a set of structural vulnerabilities, forcing a comprehensive reconfiguration of German industrial policy and giving rise to a new model of public intervention and to a redefinition of the state's role in the economy. This marks a profound recalibration of the state's traditional, ordoliberal neutrality in relation to industry, in favour of a more active and strategic approach aimed at safeguarding technological sovereignty, reducing external dependencies and strengthening critical infrastructures.

2. METHODOLOGY

This paper employs qualitative policy analysis to examine the structural reconfiguration of German industrial policy within an increasingly fragmented geo-economic landscape. The research is based on a systematic and interpretative study of German and European strategic documents, institutional reports and key academic contributions addressing industrial policy, economic security, technological sovereignty and the evolving role of the state in shaping long-term productive transformation.

The analysis is organised around a multi-layered framework linking the broader paradigmatic shift in European industrial policy to the domestic and external pressures eroding Germany's export-oriented, manufacturing-centred model. Four major vectors of reconfiguration are then assessed: industrial decarbonisation, China's state-capitalist rise, the collapse of energy interdependence with the Russian Federation and the competitive pressures generated by the US Inflation Reduction Act. To support the qualitative argument, the paper also integrates contextual figures depicting key macro-industrial indicators, including energy cost dynamics, manufacturing performance and shifting trade dependencies. This approach makes it possible to interpret recent strategic responses not as isolated crisis-management measures, but as elements of a broader recalibration through which the federal state seeks to reconcile competitiveness, climate neutrality and economic security within existing fiscal and institutional constraints.

3. FROM HORIZONTAL FRAMEWORK CONDITIONS TO STRATEGIC INDUSTRIAL POLICY

The current reconfiguration of industrial policy must be understood against the background of a broader reversal of the neoliberal consensus that had assigned markets the central role in guaranteeing productive efficiency. After the post-war phase of targeted state intervention and the subsequent shift, from the 1980s onwards, to horizontal and non-selective policies, the present stage is defined by a renewed inclination towards government intervention in the market. This shift has been driven by the greening of industries, the intensification of geopolitical rivalries, the expansion of techno-nationalism and the disruption of supply chains, all of which have prompted an increasing number of economies to move away from the dogma of markets as the supreme arbiter of efficiency (Owen, 2012; Tagliapietra & Veugelers, 2023).

The global economy is currently confronted with two dominant trends that have shaken this earlier consensus and produced a paradigmatic reversal. The first is the greening of industries. The need to decouple economic development from resource-intensive growth and greenhouse gas emissions has placed decarbonisation and circularity at the centre of contemporary policy agendas. Such a transformation requires extensive government intervention, since it involves the internalisation of environmental externalities, the restructuring of entire economic subsystems, especially energy and transport, and the coordination of international efforts through common instruments and agreements (Altenburg, 2024). In this sense, environmental policy is no longer external to industrial policy but becomes one of its structuring rationales.

he second trend is the accentuation of geopolitical rivalry, accompanied by the rise of techno-nationalism and by repeated disruptions to global supply chains. In a context marked by the imperfect functioning of global markets, states have begun to pay greater attention to security of supply and to the protection of domestic industries. Recent crises have revealed the limits of dependence on free trade and have generated protectionist reactions, together with new industrial policy measures. The escalation of tensions between major economic blocs has revived the use of trade restrictions and strategic barriers, while the disruption of flows of energy, raw materials and essential goods has amplified concerns regarding the diversification of supply sources and the consolidation of industrial independence.

Although the greening of industries and the rise of geo-economic rivalry are based on distinct rationales, they converge in their implications for industrial policy. Both require stronger involvement by the state and by national actors in shaping economic transformation. Climate transition calls for regulation, coordination and investment on a scale that exceeds ordinary market mechanisms, while geopolitical fragmentation compels governments to protect strategic sectors, reduce critical dependencies and safeguard technological sovereignty. This convergence marks a clear departure from the late twentieth-century belief that markets alone could secure productive efficiency and long-term competitiveness.

Within this new configuration, industrial policy is no longer a secondary instrument of competitiveness policy. It becomes a systemic architecture through which states and regional blocs seek to redefine their productive base, secure access to critical inputs and preserve their capacity to act in an increasingly fragmented international order. For the European Union, this shift is closely linked to the ambition of strengthening strategic autonomy and resilience, although the relaxation of state aid rules also raises the risk of intra-European asymmetries. For Germany, it creates the framework within which the traditional ordoliberal preference for horizontal conditions and competitive neutrality is being strategically recalibrated in response to pressures that are structural rather than merely conjunctural.

4. GERMANY'S INDUSTRIAL MODEL UNDER STRUCTURAL PRESSURE

Germany occupies a particularly exposed position within the current reconfiguration of industrial policy because its model of economic development has long been centred on export performance, manufacturing strength and dense integration into European and global value chains. This model generated considerable advantages over several decades, allowing the federal economy to combine technological sophistication, industrial specialisation and international competitiveness. However, the same configuration that supported Germany's prosperity has also increased its vulnerability to external shocks, geopolitical fragmentation and structural constraints affecting the domestic economy.

In recent years, the traditional foundations of Germany's manufacturing-centred model have been progressively weakened by the cumulative interaction of internal and external pressures. Escalating energy costs (Figure 1), acute shortages of skilled labour, persistent administrative rigidity and chronic underinvestment in public infrastructure have exposed and amplified a set of structural vulnerabilities, further intensified by geopolitical pressures on supply chains. Taken together, these constraints erode the capacity of the federal economy to adapt to the new requirements of industrial transformation. They do not operate in isolation, but reinforce one another, creating a configuration in which the preservation of industrial competitiveness can no longer be secured through horizontal framework conditions alone.

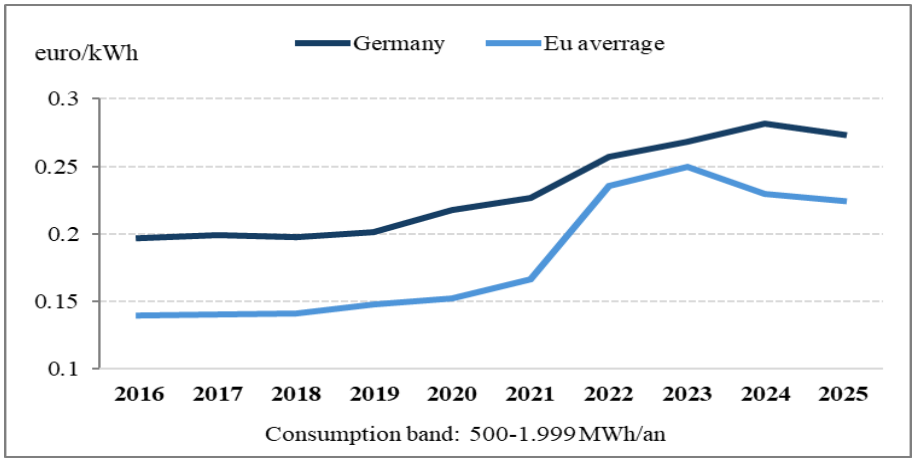


Figure 1. Electricity prices for non-household consumers in Germany and the EU average, 2016-2025

Source: Author's representation based on Federal Statistical Office of Germany (Destatis, 2026), *Electricity prices for non-household consumers, nrg_pc_205, consumption band IC, 500-1,999 MWh/year, all taxes and levies included*.

The energy dimension is central to this structural vulnerability. For a long period, the competitiveness of several German industrial branches was supported by access to relatively stable and affordable energy inputs. The sharp increase and volatility of energy prices after the disruption of relations with the Russian Federation revealed the fragility of this arrangement and transformed energy security into a constitutive element of industrial policy. In this context, the issue is no longer limited to cost management. It concerns the capacity of the German industrial base to sustain investment, preserve production capabilities and remain competitive in sectors exposed to international competition.

The pressure is particularly acute because the ecological transformation of industry requires substantial investment precisely at a time when the macroeconomic environment is unfavourable, energy-intensive activities have been under strain and global competitors do not always face comparable climate-related costs. The greening of German industry is therefore not merely a normative obligation, but a strategic condition for preserving the competitiveness of the national economy in an environment increasingly shaped by the decarbonisation of value chains (Federal Ministry for Economic Affairs and Climate Action, 2023; Kyllmann, 2024). At the same time, this transformation entails a high degree of uncertainty for firms and workers, as certain industrial segments may contract, others may be restructured, and new competencies will be required across the production system.

These pressures explain why German industrial policy has moved beyond the traditional reliance on horizontal framework conditions and competitive neutrality. Rather than abandoning the coordinated market economy, the federal state is increasingly recalibrating its role through more selective instruments, targeted financing and strategic support for critical industrial capabilities. The objective is to mitigate the combined effects of high domestic energy costs, investment requirements and asymmetrical external competition, while preserving the manufacturing core on which Germany's economic strength and Europe's industrial resilience continue to depend.

5. THE RECONFIGURATION OF GERMAN INDUSTRIAL POLICY UNDER GEO-ECONOMIC PRESSURE

The reconfiguration of German industrial policy is shaped by four major vectors, each of which reveals the erosion of earlier assumptions concerning interdependence, market coordination and the neutrality of the state in relation to industry. Taken together, these vectors explain why industrial policy is increasingly being redefined as an instrument of economic security, technological sovereignty and strategic resilience.

5.1. Industrial decarbonisation

The first vector is the imperative of industrial decarbonisation. Within the current European and German policy framework, the green transition has evolved from a primarily environmental agenda into a central axis of industrial transformation and long-term competitiveness. Decoupling economic development from resource-intensive growth and greenhouse gas emissions requires the restructuring of production systems, the mobilisation of large-scale investment and the development of new technological capabilities. For Germany, this transformation is particularly challenging because it must take place without undermining the manufacturing base on which the federal economy continues to depend. In this sense, decarbonisation is a strategic test of whether Germany can preserve industrial value creation while adapting to a global economy increasingly shaped by climate regulation and the reorganisation of value chains. This challenge has materialised in more interventionist mechanisms such as Carbon Contracts for Difference and the National Hydrogen Strategy, through which the federal government seeks to reduce investment uncertainty, support the deployment of clean technologies and accelerate the development of carbon-neutral manufacturing capabilities. These selective instruments mark a shift from competitive neutrality towards a more active industrial policy, without amounting to a wholesale abandonment of Germany's coordinated market economy.

5.2. China's state-capitalist rise

The second vector derives from the systemic challenges posed by China's state-capitalist rise. For several decades, the German economy benefited from deep commercial and investment relations with China, which functioned simultaneously as an export market, a production location and a critical engine

of global demand. However, this relationship has been progressively reinterpreted in light of China's industrial upgrading, state-directed technological ambitions and asymmetric market practices. The Federation of German Industries captured this shift by defining China through a triad of positions: partner, competitor and systemic rival (BDI, 2019). This distinction is essential for German industrial policy, since it preserves economic cooperation while recognising the strategic risks generated by a state-capitalist economic model. The rise of Chinese firms in advanced technologies, large-scale state subsidies, the expansion of state-owned enterprises and China's assertive pursuit of technological leadership have compelled Germany to move beyond the assumption that economic interdependence alone can stabilise bilateral relations. Consequently, the policy response is no longer framed by absolute decoupling, but by strategic de-risking, the reduction of critical dependencies and the protection of technological capabilities within a broader European economic security framework (European Commission, 2023; Weidenfeld, 2022).

The strategic importance of China's rise becomes clearer when considered alongside Germany's broader external economic exposure. Germany's trade relations with China, the United States and the Russian Federation illustrate three different forms of interdependence that have been politically reinterpreted under conditions of geo-economic fragmentation: systemic competition in the case of China, energy vulnerability in the case of Russia and asymmetrical industrial competition in the case of the United States (Figure 2).

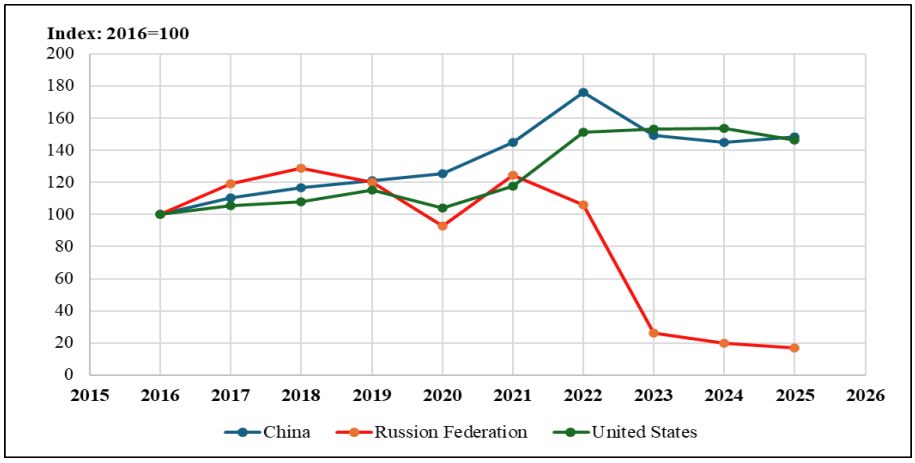


Figure 2. Germany's trade with China, the United States and the Russian Federation, 2016-2025 (2016=100)

Source: Author's representation based on Federal Statistical Office of Germany (Destatis, 2026), *Foreign trade, years, countries, code: 51000-0003;*

Notes: Total trade is calculated as exports plus imports; Index values are calculated using 2016 as the base year.

The sharp contraction of trade with the Russian Federation after 2022 contrasts with the continued relevance of China and the United States in Germany's external economic relations, illustrating the uneven ways in which external economic exposure has been transformed into a strategic concern. The most abrupt rupture in this configuration concerned the energy relationship with the Russian Federation.

5.3. The collapse of energy interdependence with the Russian Federation

The third vector is the collapse of energy interdependence with the Russian Federation. Russia's invasion of Ukraine exposed the strategic fragility of an industrial model that had linked German manufacturing competitiveness to relatively stable and affordable Russian energy supplies. This rupture demonstrated that economic interdependence does not necessarily prevent geopolitical conflict and that a concentrated reliance on authoritarian suppliers can become a direct vulnerability for an advanced industrial economy (Figure 3).

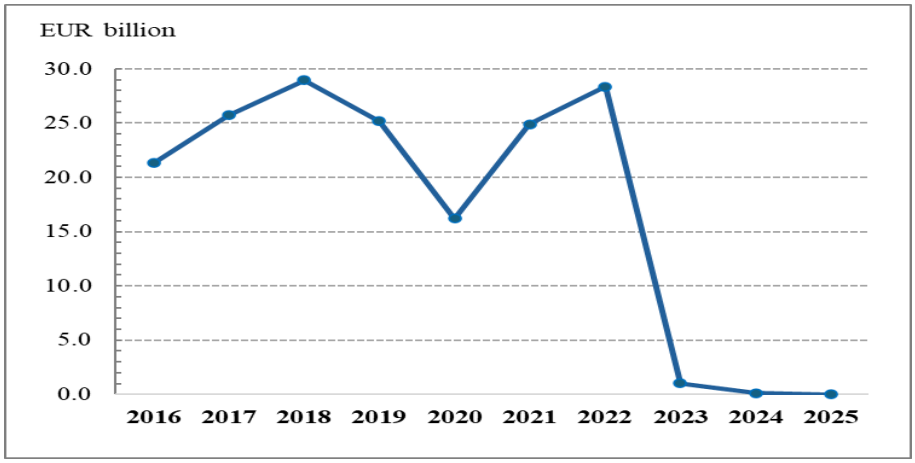


Figure 3. Germany's imports of mineral fuels from the Russian Federation, 2016-2025

Source: Author's representation based on Federal Statistical Office of Germany (Destatis, 2026), *Foreign trade, years, countries, classifications of trading goods, code: 51000-0007 (WA 27: Mineral fuels, mineral oils);*

Note: Values are expressed in EUR billion.

The subsequent energy shock transformed security of supply from a technical or sectoral concern into a central dimension of national industrial strategy. The structural scale of this rupture is visible in Germany's imports of mineral fuels from the Russian Federation, which collapsed from more than EUR 28 billion in 2022 to almost zero by 2025.

The contraction in Germany's imports of mineral fuels from the Russian Federation also shows that the strategic relevance of Russia in Germany's external economic relations was not primarily derived from the overall volume of bilateral trade, but from the concentration of imports in energy-related products. For Germany, the implications are profound: energy diversification, infrastructure expansion, accelerated deployment of renewable energy and the stabilisation of industrial energy costs have become inseparable from the preservation of manufacturing capabilities. The collapse of the previous energy relationship with the Russian Federation therefore represents not only a geopolitical turning point, but also a structural moment in the redefinition of German industrial policy after 2022 (Monteiro de Macedo et al., 2025).

5.4. The US Inflation Reduction Act

The fourth vector concerns the competitive pressures generated by the US Inflation Reduction Act (IRA). Although the IRA was broadly welcomed in Europe as a substantive contribution to climate mitigation, its large-scale subsidies, tax credits and local-content requirements soon raised significant concerns regarding fair competition and investment diversion. In substance, the IRA represents a major industrial policy framework designed to accelerate the green transformation of the American economy through public incentives, while strengthening domestic production capacities in key technologies. For Germany and the European Union, the challenge lies not only in the sheer scale of American financial support, but also in its asymmetrical impact on investment location, capital allocation and the competitive conditions faced by European firms.

By stimulating clean-tech deployment in the United States, the IRA risks diverting capital away from Europe, placing additional structural pressure on industrial hubs already strained by high domestic energy costs and stringent regulatory frameworks. Consequently, the German response has become deeply embedded within a broader European imperative to construct a more robust green industrial policy, achieve greater flexibility in state aid rules and deploy a coordinated strategy capable of preserving the European manufacturing core without fragmenting the internal market (Franco-German Council of Economic Experts, 2023; Hüther & Matthes, 2023).

Taken together, these four vectors demonstrate that the emerging logic of German industrial policy cannot be reduced to transient crisis management. It reflects a structural attempt to reconcile competitiveness, climate neutrality and economic security under conditions in which traditional, horizontal market coordination is no longer sufficient to guarantee stability. The federal state does not replace market mechanisms, but increasingly acts to shape the conditions under which critical industrial capabilities can be preserved, strategic dependencies reduced and technological sovereignty defended.

6. DISCUSSION AND CONCLUSIONS

The analysis has shown that the recent reconfiguration of German industrial policy cannot be understood either as a simple return to traditional state intervention or as a complete departure from the institutional foundations of Germany's coordinated market economy. Instead, it reflects a strategic recalibration of the relationship between the state, markets and industry under conditions of geo-economic fragmentation. The cumulative pressures generated by industrial decarbonisation, China's state-capitalist rise, the collapse of energy interdependence with the Russian Federation and the competitive effects of the US Inflation Reduction Act have weakened the assumption that horizontal framework conditions alone can sustain Germany's manufacturing-centred model.

The new logic of German industrial policy is therefore defined by an attempt to reconcile competitiveness, climate neutrality and economic security. Decarbonisation requires large-scale investment and selective support for clean technologies, while systemic competition with China necessitates de-risking and the protection of strategic capabilities. The rupture with the Russian Federation has transformed energy security into a core component of industrial strategy, while the IRA has intensified the European debate on the need for a more robust green industrial policy. In this context, the federal state does not replace market mechanisms but increasingly shapes the conditions under which industrial capabilities can be preserved, strategic dependencies reduced, and technological sovereignty defended.

At the same time, however, this transformation remains structurally constrained. Germany's emerging industrial policy logic operates within a complex institutional environment characterised by stringent fiscal constraints, administrative inflexibility, European state aid regulations, the discipline of the single market and the risk of exacerbating intra-European imbalances. These institutional constraints explain why the current paradigm shift should not be interpreted as a wholesale rejection of ordoliberal principles, but rather as a pragmatic response to a global order in which open markets, unmediated interdependence and competitive neutrality no longer provide adequate guarantees of systemic resilience.

The German case also carries wider implications for the European Union. Given the centrality of Germany's manufacturing sector within European cross-border supply chains, changes in its industrial policy affect not only national competitiveness, but also the resilience of the European industrial system as a whole. The core governance challenge lies in strengthening productive and technological capacities without undermining the cohesion of the single market or deepening economic divergences between member states with different fiscal capacities. For this reason, the long-term future of German industrial policy remains closely linked to the evolution of the broader European industrial policy architecture.

Ultimately, this paper concludes that the emerging logic of German industrial policy represents a deliberate attempt to preserve the manufacturing core of the federal economy while adapting it to the contemporary imperatives of decarbonisation, economic security and technological sovereignty. While this new logic does not eliminate the inherent tensions between horizontal market coordination and selective state intervention, it reorganises them around a more strategic understanding of competitiveness. In an era defined by geo-economic fragmentation, German industrial policy is no longer merely an institutional framework for improving business conditions. Instead, it has been redefined as an instrument for safeguarding domestic productive capacity, mitigating strategic vulnerabilities and repositioning the German economy within an evolving European and global order.

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THE IDEOLOGICAL AND FORMAL TRANSFORMATION OF THE MONUMENT IN PUBLIC SPACE: FROM 19th-CENTURY NATION-STATE REPRESENTATION TO 20th-CENTURY MODERNIST SCULPTURE

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ABSTRACT

In the nineteenth century, monuments functioned not merely as aesthetic objects, but as political and ideological instruments used to construct collective memory, legitimise state authority, and materialise a sense of "we-ness." Celebrating military victories and founding leaders, these traditional sculptures were produced from durable materials such as marble and bronze and were predominantly positioned at the centres of public squares, thereby becoming stages for national identity and ceremonial practices. From the early twentieth century onwards, modernism fundamentally transformed both the function of the public monument and the representational character of art. Whereas the traditional logic of the monument required it to be figurative and vertical because of its commemorative purpose, the approach to abstraction adopted by artists such as Constantin Brancusi liberated sculpture from its dependence on a fixed site and endowed it with a nomadic quality. This aesthetic transformation was accompanied by the introduction of industrial materials such as steel and concrete. With the acceleration of technological progress, such works challenged the elevated and hierarchical structure of monuments and created experiential spaces that actively engage the viewer.

This study examines the role of monuments constructed in public spaces during the rise of modern nationalism in the nineteenth century in the formation of the nation-state, as well as the formal and spatial transformations experienced in sculpture with the emergence of modernism in the twentieth century. The transition from the figurative to the abstract and the process of formal simplification in monumental design are analysed through the works of Brancusi and Richard Serra, together with various examples of postmodern monuments. In addition, by examining symbolic urban squares and victory monuments in different countries, ranging from the Arc de Triomphe in France to the Republic Monument in Türkiye, the study reveals the spatial representation of state ideology and collective memory.

Keywords: Nation-State, Monument Tradition, Modernism, Abstract Space, Collective Memory

INTRODUCTION

Throughout history, public space has not merely functioned as a physical void; rather, it has constituted a strategic arena in which collective memory, forms of political representation, and state ideologies become visible (Çeper, 2024). In this context, monuments are among the most concrete spatial products of humanity's effort to leave a trace in the world, to remember the past, and to transmit particular events

to future generations. Bringing individual memories together with collective consciousness, monuments—alongside cemeteries, museums, and squares—are considered "sites of memory" that ensure the continuity of collective memory (İpek, 2020; Polat, 2019). The sites of memory theorized by Pierre Nora have gained particular significance in the modern period as symbolic spaces in which memory is preserved and reproduced, especially with the weakening of organic ties to the past.

The function and formal language of monuments have changed throughout history in relation to transformations in nation-state formation, public memory policies, and artistic approaches (Field, 2017; Kuljić, 2019; Pirro, 2025). Particularly with the rise of nation-states in the nineteenth century, public monuments became effective ideological instruments for making national identity, state authority, and a shared historical narrative visible. During this period, monuments were generally positioned at the centers of urban squares as figurative, vertical structures set on high pedestals, representing founding leaders, military victories, and heroic narratives. Thus, monuments became not only aesthetic objects, but also symbolic instruments that strengthened a sense of "we," reinforced national belonging, and rendered the legitimacy of the state visible in public space (Gür, 2015; Williamson, 2024). By the twentieth century, modernism had significantly transformed the ideological and formal structure of the traditional understanding of monuments. The figurative, didactic, and hierarchical tradition of monumentality shifted, through the modernist conception of sculpture, toward a new mode of expression that was abstract, simplified, established different relationships with space, and no longer positioned the viewer merely as a passive observer. Constantin Brancusi's approach to abstraction and Richard Serra's spatial relations constructed through industrial materials may be considered important examples of this transformation. In this process, alongside traditional materials of permanence such as bronze and marble, industrial materials such as steel, concrete, and glass were also incorporated into the expressive language of public sculpture (Savaşer, 2021; Turgut, 2017).

The central problem of this study is to examine how the function assumed by public monuments in the nineteenth century as spatial representations of nation-state ideology was transformed in the twentieth century through modernism in terms of form, material, spatial positioning, and the relationship established with the viewer. Accordingly, the main research question of the study is formulated as follows: While public monuments functioned in the nineteenth century as instruments for representing nation-state ideology and collective memory, what kind of formal and spatial transformation did they undergo with modernism in the twentieth century? The study was conducted within a qualitative research framework and employed literature review and comparative case analysis as its main methods. In order to concretize the reflections of ideological and formal transformation in public space, the Arc de Triomphe from France, the Brandenburg Gate from Germany, the Altare della Patria from Italy, the Tomb of the Unknown Soldier from Greece, the Angel of Independence from Mexico, and the Taksim Republic Monument and Ulus Victory Monument from Türkiye were selected as case studies. These examples constitute the comparative analytical basis of the study, as they demonstrate the ideological and spatial representational power of public monuments in relation to the nation-state, victory, independence, founding leaders, collective memory, and the urban square.

THEORETICAL FRAMEWORK OF COLLECTIVE MEMORY AND COMMEMORATIVE SPACES

Collective memory is a fundamental concept which suggests that individual memories are not formed solely through personal experiences; rather, they are shaped through the social, cultural, and spatial frameworks within which the individual exists. Introduced into the sociological literature by Maurice Halbwachs, this concept demonstrates that remembering is a social process as much as an individual one. Accordingly, individuals do not remember the past in isolation, but through the values, symbols, narratives, and shared experiences of the social groups to which they belong (İpek, 2020; Polat, 2019). In this respect, collective memory plays a decisive role in the construction of social identity and in the continuity of a shared consciousness of the past (Polat, 2019).

One of the most significant approaches explaining the spatial dimension of collective memory is Pierre Nora's conceptualization of "sites of memory." According to Nora, with the process of modernization, the organic ties that societies establish with the past have weakened; therefore, memory has come to be preserved through particular symbolic spaces, objects, and rituals (Polat, 2019). Cemeteries, museums,

monuments, squares, and ceremonial spaces are, in this context, considered sites of memory that prevent the past from being forgotten, render collective memory visible, and enable its transmission across generations (İpek, 2020; Polat, 2019).

As one of the most important components of these sites of memory, the monument is a symbolic structure constructed to keep past events, social achievements, heroic acts, or shared values alive in the memory of future generations. According to Alois Riegl, the monument is a deliberate production intended to recall significant events and values created by human beings (Polat, 2019). Rosalind Krauss, on the other hand, states that the fundamental function of the monument is to produce a form of representation oriented toward commemoration (Krauss, 1979). For this reason, traditional monuments are generally designed as figurative, vertical structures of monumental scale, establishing a direct relationship with the historical meaning of the space in which they are located. In this way, the monument fixes the past at a specific point and renders collective memory visible in public space (Krauss, 1979). There is, however, an important distinction between the monument and the commemorative space. While the monument is often a singular and symbolic object viewed from a distance, the commemorative space refers to a more comprehensive spatial arrangement that physically, emotionally, and intellectually engages the visitor. In this respect, commemorative spaces transform the act of remembering from a merely visual representation into an experiential process. Particularly in commemorative spaces that address themes such as war, loss, trauma, and social confrontation, the visitor encounters the past not as a passive observer, but as an active subject who moves through the space and reconstructs meaning through their own experience (Polat, 2019).

Krauss's evaluations of public sculpture further clarify the distinction between the traditional monument and modern public sculpture. The traditional monument is a structure that establishes a strong connection with its site, carries the responsibility of representing the past, and often possesses a hierarchical narrative order. By contrast, modern public sculpture largely moves away from this burden of representation and turns into an autonomous art object (Krauss, 1979). Therefore, while the monument assumes the function of fixing collective memory to a particular place, public sculpture often produces meaning through its material, form, scale, void, and physical relationship with the viewer, without necessarily aiming at direct commemoration or didactic representation (Chevaillier, 2007; Krauss, 1979).The counter-monument approach, which emerged in the last quarter of the twentieth century, offers a critical alternative to the traditional understanding of monuments. Counter-monuments are regarded as contemporary commemorative practices that question such characteristics of traditional monuments as permanence, vertical hierarchy, figurative representation, heroization, and a one-directional historical narrative (Stevens et al., 2018). In this approach, the monument ceases to be an authoritative structure that dictates to the viewer what and how to remember; instead, it becomes a multilayered and open-ended field of experience that transfers the responsibility of remembering to the visitor. Designs that may change over time, become invisible, be embedded in the ground, or acquire meaning through the bodily participation of the viewer are among the fundamental characteristics of the counter-monument approach (Young, 1998; Stevens et al., 2018). One of the best-known examples of this approach is the Vietnam Veterans Memorial in Washington, D.C., designed by Maya Lin. Unlike the traditional typology of white, vertical monuments that glorify victory, this work was designed as a horizontal incision descending into the ground, made of black granite. The names of those who lost their lives in the war are inscribed on the surface of the memorial in chronological order; however, no heroic narrative, official interpretation of history, or directive explanation is presented. Thus, rather than being guided toward a single and closed historical narrative, the visitor is included in a multilayered process of commemoration and confrontation through their own experiences, memory, and emotions (Young, 1998; Stevens et al., 2018).

THE IDEOLOGICAL AND FORMAL TRANSFORMATION OF THE PUBLIC MONUMENT

Modernism and Abstraction in Sculpture

With the rise of modern nation-states, monumental sculptures were positioned at the centers of public spaces as figurative structures that legitimized state ideology, conveyed messages, and served a didactic function (Stevens et al., 2018). In this period, monuments were generally shaped through realistic human figures, high pedestals, and hierarchical compositions that glorified military victories, founding leaders,

and national heroes. According to Rosalind Krauss, the traditional monument is a structure that speaks in a symbolic language about the meaning of its site and establishes a direct connection with the historical event it represents. From the late nineteenth and early twentieth centuries onward, modernism radically transformed the traditional understanding of monuments. Krauss argues that, in this process, modern sculpture moved away from the logic of the traditional monument and weakened its function of marking a specific historical event or place. With this rupture, sculpture ceased to be a fixed object of commemoration and turned into a more autonomous art object associated with the concepts of placelessness, homelessness, and nomadism (Krauss, 1979).

The works of Constantin Brancusi are among the significant examples of this process of abstraction in modernist sculpture. By reducing figurative details, Brancusi transformed forms into simple, smooth, and essential configurations, thereby distancing sculpture from the obligation of traditional representation (Savaşer, 2021). In this context, modernism removed the public monument from its role as a figurative representation of the state that presented a single and closed historical narrative to the masses; instead, it transformed it into an abstract structure that produces meaning through material, form, void, and viewer experience.

The Transition from the Figure to Abstraction

In the nineteenth century, monuments functioned as fundamental public instruments that embodied national identity through heroic figures and directed collective memory. Nation-states seeking to strengthen the weakened bonds of belonging brought about by modernization aimed to unite society around a shared identity by attributing sacred meaning, through the ideology of nationalism, to the homeland, founding leaders, military victories, and national symbols (Zabunoğlu, 2018). In this process, monuments came to the fore in public spaces as figurative and hierarchical structures that rendered the continuity and power of state authority visible (Vale, 2008). According to Krauss, traditional monuments are commemorative structures that are figurative, vertical, and symbolically connected to the meaning of the site in which they are placed. However, from the late nineteenth century onward, this traditional logic of the monument weakened; modernist sculpture moved away from its site-dependent representational function and acquired a more autonomous and abstract character. Krauss states that Brancusi achieved this transformation in two fundamental ways: by incorporating the traditional pedestal into the sculpture itself and by moving away from the direct representation of the human body toward a radical form of abstraction (Krauss, 1979).

Brancusi's works in Romania, The Endless Column and The Table of Silence, may be regarded as significant examples of the transition from the traditional logic of the monument to modernist abstraction. While The Endless Column symbolically expresses the sacrifice of Romanian soldiers who lost their lives in war and the ascent of the human spirit, it employs a simpler, rhythmic, and open-ended formal language rather than a figurative narrative of heroism (Savaşer, 2021). Thus, the monument moves away from being an object that directly conveys a didactic state narrative and instead offers the viewer a more open, experiential, and interpretive field.

Material Transformation

In nineteenth-century nation-state monuments, the choice of material was directly related to the ideological function of the monument. Heavy and durable materials symbolizing permanence, such as marble, bronze, stone, and copper, were preferred in order to render the continuity of state authority and historical legitimacy visible. Combined with high pedestals and monumental scale, these materials aimed to evoke in the viewer a sense of respect, power, and permanence (Stevens et al., 2018; Williamson, 2024). In the twentieth century, with modernism and the counter-monument approach, the use of materials in sculpture changed significantly. New materials associated with steel, concrete, glass, granite, and industrial production expanded the expressive possibilities of public sculpture (Horowitz, 1996). This transformation was not merely a technical innovation; it was also an indication of the changing ideological and spatial meaning of the monument. While material in traditional monuments represented permanence, grandeur, and authority, in modernist and counter-monument examples it is often associated with void, weight, loss, confrontation, or viewer experience.

The counter-monument approach stands out as a contemporary commemorative practice that questions such characteristics of traditional monuments as eternity, vertical hierarchy, figurative representation, and the glorification of the past (Stevens et al., 2018). In this approach, the monument ceases to be a massive and closed structure that dictates to the viewer what to think; instead, it becomes a field of experience that may change over time, be embedded in the ground, become invisible, or acquire meaning through the bodily participation of the visitor (Young, 1998). One of the most striking examples of this transformation is the Vietnam Veterans Memorial, designed by Maya Lin. Unlike traditional vertical, white monument models symbolizing victory, this work was conceived as a horizontal and negative void descending into the ground, made of black granite (Stevens et al., 2018). Richard Serra's large-scale steel installations, on the other hand, demonstrate that material is not merely an object to be viewed from a distance, but can become an active element that redefines space and directs the viewer's bodily experience (Horowitz, 1996; Stevens et al., 2018). Thus, industrial material ceases to function as a hierarchical monumental mass and becomes a dynamic instrument that transforms public space.

Formal Simplification

Formal simplification in modernist sculpture represents an important field of transformation that developed in opposition to the detailed, figurative, and heroic narrative language of traditional monuments. In this process, rather than directly representing historical events and heroic figures, artists turned toward producing more open-ended meanings through basic geometric forms, abstract surfaces, and simple compositions (Stevens et al., 2018). Constantin Brancusi's *Bird in Space* is one of the significant examples of this understanding of simplification. Instead of representing the anatomical details of the bird, the artist sought to express the essence of flight through a simple and fluid form (The Metropolitan Museum of Art, 2026). According to Krauss's evaluation, modernist simplification is closely related to sculpture's departure from the obligation to mark a specific historical event or place (Krauss, 1979). For this reason, in modern and minimalist monuments, meaning is constructed not so much through direct figurative representation, but rather through form, void, material, and the viewer's spatial experience. While traditional monuments present the masses with a definite message or an official historical narrative, abstract and minimalist monuments often leave meaning open and allow space for the viewer's interpretation (Stevens et al., 2018). Barnett Newman's *Broken Obelisk* may be regarded as an important example of the modernist understanding of the abstract monument. Made of Cor-Ten steel, this work reverses the form of the obelisk, which in the classical tradition of monuments is associated with power, victory, and vertical ascent, thereby producing a more questioning and symbolic narrative (The Museum of Modern Art, 2026). Similarly, Maya Lin's *Vietnam Veterans Memorial*, with its minimalist formal language, directs the viewer not only to look, but also to walk along the memorial, encounter the names, and establish an individual relationship with loss (Young, 1998; Kimmelman, 2002).

The counter-monument practices that developed in the late twentieth century may also be regarded as a continuation of this process of abstraction and simplification. In contrast to traditional monuments, which are elevated on high pedestals, separated from the city, and convey a one-directional message, counter-monuments are generally designed as spatial arrangements that integrate with the city, engage the visitor, and transform the act of commemoration into an experiential process (Stevens et al., 2018). *The Memorial to the Murdered Jews of Europe* in Berlin, with its abstract and repetitive structure composed of concrete blocks, is one of the strong examples of this approach (Archiplanet, 2026). In such works, rather than a specific focal point or a singular heroic figure, the movement of the visitor within the space, bodily perception, and personal interpretation come to the fore.

In this context, the transformation between nineteenth-century nation-state monuments and twentieth-century modernist and abstract monuments reveals clear differences in terms of ideological function, formal language, material use, spatial positioning, mode of representation, and the relationship established with the viewer. While traditional monuments generally render national identity, military victories, and state authority visible through a figurative and hierarchical language, modernist and abstract monuments tend toward a more open-ended narrative structure that foregrounds mourning, loss, trauma, individual experience, and viewer interpretation. The main comparative criteria of this transformation are summarized in Table 1.

Table 1. Comparison of 19th-Century Nation-State Monuments and 20th-Century Modernist/Abstract Public Monument-Sculpture Approaches (Prepared by the authors based on Krauss (1979), Stevens et al. (2018), Williamson (2024), Young (1998), and related case analyses)

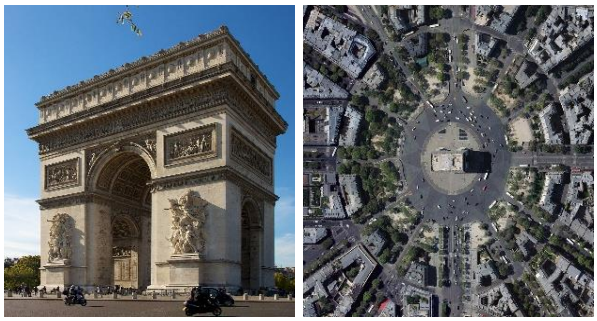
Comparative creation	19th-century nation-state monuments	20th-century modernist/abstract public monument-sculpture approaches
Period context	A period in which nation-states gained strength and nationalism and public representation came to the fore.	A period in which modernism, post-war memory, mourning, loss, trauma, and individual experience became prominent themes.
Ideological function	Makes national identity, heroism, military victory, and state authority visible; directs collective memory.	Emphasizes mourning, loss, trauma, confrontation, and individual interpretation rather than direct heroic narratives.
Formal language	Based on figurative, realistic, detailed, and hierarchical composition.	Employs abstract, geometric, simplified, minimalist, and spatial forms.
Use of materials	Traditional, durable materials such as bronze, marble, and stone, which symbolize permanence, are preferred.	Concrete, steel, glass, granite, stainless steel, and mixed materials may be used.
Spatial positioning	Located in squares, in front of state buildings, or on elevated pedestals; they display a dominant presence over their surroundings.	Spatial arrangements that integrate with the site, become part of the landscape, and center visitor experience come to the fore.
Relationship with the viewer	The viewer is mostly a passive observer; the monument conveys a one-way, explicit, and didactic message.	The viewer becomes an active part of the process of commemoration and meaning-making; meaning is formed through spatial experience and individual interpretation.
Mode of representation	Historical events, national heroes, military victories, and political leaders are directly represented.	Emotions, concepts, memory, loss, and trauma are expressed through non-figurative forms.
Examples	Arc de Triomphe, The Angel of Independence, Taksim Republic Monument, and Ulus Victory Monument can be given as examples.	Vietnam Veterans Memorial, Constantin Brancusi's *Endless Column* / *Table of Silence*, and Richard Serra's steel installations can be given as examples.

IMPORTANT VICTORY MONUMENTS AND URBAN SQUARES IN NATION-STATES

In the formation and consolidation processes of nation-states, victory monuments and the urban squares in which they are located have been among the most visible means of representing national identity, military achievements, founding leaders, and state authority in the public realm. With modernization, the weakening of traditional bonds of belonging increased the need for states to reproduce social cohesion through shared symbols, historical narratives, and public rituals (Gür, 2015; Zabunoğlu, 2018). Urban squares, in turn, have functioned as the stage of this process of representation. The positioning of monuments at the centers of squares, in front of state buildings, or at the intersections of important urban axes has ensured not only their visibility, but also their continual re-experiencing through ceremonies, commemorations, military parades, and mass events. Thus, the relationship between the monument and the square has produced a powerful spatial order in which national identity becomes visible in everyday life, collective memory is reiterated, and state ideology is represented in public space. This section examines the examples of the Arc de Triomphe from France, the Brandenburg Gate from Germany, the Altare della Patria from Italy, the Tomb of the Unknown Soldier from Greece, the Angel of Independence from Mexico, and the Taksim Republic Monument and Ulus Victory Monument from Türkiye. The selected examples are included in the scope of the evaluation because they demonstrate different forms of representation of nation-state ideology in public space in terms of victory, independence, national unity, founding leaders, collective memory, and the relationship between the monument and the square. Although the Brandenburg Gate was constructed in the late eighteenth century, it was included in the scope of the study not solely on the basis of its date of construction, but because of the ideological and symbolic meanings it acquired in later historical periods. In the nineteenth century, it became associated with German national identity and the idea of unity, while in the twentieth century it gained further significance through the division and reunification of Berlin. Therefore, the

periodization adopted in this study is based not only on construction dates, but also on the monuments' changing roles in nation-state representation and collective memory.

Arc de Triomphe: The Triumphal Arch of France



Built between 1806 and 1836 to honor the military victories of Napoléon Bonaparte, the Arc de Triomphe is located at the center of a star-shaped square where twelve avenues converge. The monument represents military power, national victory, and ceremonial culture in public space. It is one of the important symbols of France's national memory (Paris Digest, 2026).

Figure 1. The Arc de Triomphe / Triumphal Arch, Paris (Paris Digest, 2026)

Tomb of the Unknown Soldier-Greek



The Tomb of the Unknown Soldier is a national commemorative space representing Greek soldiers who lost their lives in wars and whose identities remain unknown. The monument, continuously guarded by the Evzones, renders sacrifice, mourning, and collective memory visible in the public realm. It is also regarded as one of the most important monumental spaces symbolizing Greece's national identity (This is Athens, 2026).

Figure 2. Tomb of the Unkown Soldier (This is Athens, 2026)

Angel of Independence-Mexico



Located in Mexico City, the Angel of Independence is a monumental victory column built in 1910 to commemorate the centennial of Mexico's independence from Spain. Symbolizing the struggle for independence, national pride, and the ideal of freedom, the monument forms a powerful public focal point on one of the city's main boulevards. Today, it is regarded as one of the important symbols of Mexico's national identity (Zorrilla, 2019).

Figure 3. Angel of Independence (Alluring World, 2026)

Brandenburg Gate-Germany



The Brandenburg Gate is a monumental city gate built in the late eighteenth century during the Prussian period. Initially associated with Prussian monarchical power, it became a powerful political symbol in the twentieth century through Berlin's division and reunification. During the Berlin Wall period, it symbolized division; after the Wall's fall, it became one of the principal public symbols of German unity, freedom, and reunification (Berlin.de, 2024; visitBerlin, 2026).

Figure 4. Brandeburg Gate (Stiftung Haus der Geschichte der Bundesrepublik Deutschland, 2022)

Altare Della Patria-Italy



The Altare della Patria was designed to glorify Italian national unity and to honor Victor Emmanuel II. With its monumental scale and white marble structure, it stands as a powerful symbol that renders modern Italian national identity and state continuity visible in public space. It is also one of the most important national commemorative spaces representing Italy's historical memory. Today, it continues to host official ceremonies and commemorative events (VIVE, 2026).

Figure 5. Altare della Patria (Martina, 2026)

Taksim Republic Monument, Türkiye



Unveiled in Taksim Square in 1928, the Taksim Republic Monument symbolizes the War of Independence and the foundation of the modern Republic of Türkiye. Closely connected with the square, it contributes to the reproduction of Republican values in public memory through national holidays, official ceremonies, and mass events, while reflecting the symbolic identity of modern Türkiye (Çelebi, 2021).

Figure 6. Taksim Republic Monument (İşbilir, 2021)

Ulus Victory Monument, Türkiye



Located in Ulus Square in Ankara, the Ulus Victory Monument is a figurative sculptural group representing the unity and spirit of struggle of the Turkish nation during the War of Independence. Through Atatürk's equestrian statue, the figures of Mehmetçik, and the Turkish woman carrying ammunition, it makes national independence, sacrifice, and the founding ideals of the Republic visible in public space. As an important example of early Republican monumental art, its central location enables continuous interaction with everyday life and helps keep national memory, historical consciousness, and collective identity alive (Şaşmaz, 2019).

Figure 7. Ulus Victory Monument (Şaşmaz, 2019)

The monuments discussed in this section were evaluated comparatively in terms of how they represent nation-state ideology in public space across different countries. The selected examples were examined with regard to their dates of construction, the historical event or ideology they represent, their formal characteristics, their relationship with the square, and their functions in relation to collective memory. Thus, it has been demonstrated that monuments are not merely aesthetic or architectural objects, but also symbolic focal points through which national identity, political legitimacy, and shared memory are reproduced in the public realm. The main comparative criteria of the examined monuments are summarized in Table 2.

Table 2. Comparative Analysis of the Monuments Examined

Name of the Monument	Country	Date of Constr.	Ideology /Historical Event Represented	Formal Characteristics	Relationship with the Square	Function in Collective Memory
Arc de Triomphe	France	1806-1836	Built to commemorate Napoleon's military victories and French national unity.	Monumental arch with relief figures.	It forms a focal point at the intersection of urban axes.	It strengthens national identity by symbolizing national victories and military achievements.
Brandenburg Gate	Germany	1788-1791	A symbolic urban gate representing Prussian monarchical power and, later, the ideals of German unity and reunification.	Monumental urban gate and symbol of national unity.	It functions as a symbolic entrance point to the city and as a public event space.	It represents collective memory as a symbol of historical transformations and national integration.
Altare della Patria	Italy	1885-1935	Represents the political unification of Italy and the establishment of the nation-state.	Monumental marble structure with a symmetrical and figurative composition.	It is one of the focal points of ceremonial and public life in Rome.	It symbolizes national unity, independence, and the continuity of the state.
Tomb of the Unknown Soldier	Greece	1932	A monumental commemorative space representing unidentified soldiers who lost their lives in wars within Greek national memory.	Simple wall monument and relief with classical influences.	It is located in front of the Parliament building.	It serves to sustain the memory of shared sacrifice and national remembrance.
The Angel of Independence	Mexico	1910	Built to commemorate the centennial of the Mexican War of Independence.	Bronze angel of victory.	It is a symbolic focal point on the city's main boulevard.	It represents the struggle for independence and national pride.
Taksim Republic Monument	Türkiye	1928	Represents the founding of the Republic and the construction of modern Türkiye.	Figurative composition with bronze sculptures and a stone pedestal.	It is a central element of public life in the square.	It is a symbolic site of memory that conveys the values of the Republic and national identity to future generations.
Ulus Victory Monument	Türkiye	1927	Represents unity and solidarity during the War of Independence.	Bronze sculpture and stone pedestal.	Located in Ulus Square, the political center of the early Republic, it strengthens the historical and ceremonial identity of the square.	It is a powerful site of memory that conveys the victory of the War of Independence, national independence, and the founding ideals of the Republic to future generations.

DISCUSSION AND CONCLUSION

Although the authoritarian monument tradition underwent a formal rupture through modernism and counter-monument practices, the ideological function of the monument over the masses did not disappear; rather, it changed form by producing new mechanisms. According to the sources, abstract and minimalist monuments can also become ideological instruments in the construction of national identity or in the mediation of social traumas. For example, art critics have argued that the effect

produced by Maya Lin's *Vietnam Veterans Memorial* on the viewer transformed it into a national monument by covering over a national wound (Stevens et al., 2018). Such practices appear to serve a new politics of reconciliation rather than opening up a critical field.

On the other hand, in cases where a monument or public artwork becomes a tool that exposes the power relations embedded in space, rather than consolidating the existing ideology of the state, the reaction of the state itself demonstrates the continuing ideological power of such works. The removal and destruction of Richard Serra's monumental steel work, *Tilted Arc*, from Federal Plaza in New York is one of the clearest examples of this power struggle (Stevens et al., 2018). Serra's sculpture dismantled the illusion that the square was a democratic public space by making visible the alienating and authoritarian nature of the surrounding bureaucratic buildings.

In brief, the discussion shows that although modernism profoundly challenged the form, material, and physical relationship of the monument with the viewer, the ideological nature of the monument did not disappear. Today, monuments continue to exist either as instruments that smooth over traumatic pasts or as arenas of power struggle that conflict with the spatial ideology of authority.

In the nineteenth century, public monuments were used as powerful ideological instruments in the identity-building processes of nation-states. During this period, monuments were positioned at the centers of urban squares as figurative, hierarchical, and permanent structures that rendered visible concepts such as heroism, victory, state authority, national unity, and shared memory. By the twentieth century, however, under the influence of modernism, the form, material, and relationship of the monument with public space began to transform. Traditional figurative expression gave way to abstract, simplified forms open to viewer interpretation. Alongside materials such as marble and bronze, which symbolized permanence, steel, concrete, glass, and industrial materials were also incorporated into the expressive language of public sculpture.

This transformation demonstrates that art and public space are not static, but dynamic fields that are continually reshaped according to the conditions of their period. As social structures, political ideologies, technological developments, modes of production, and aesthetic approaches change, the expressive language of art and its relationship with space inevitably change as well. Therefore, the formal and ideological transformation of the monument is not merely a change belonging to art history; it is also a reflection of transformations in societies' understandings of memory, identity, and public space.

Thus, the public monument has moved beyond being merely an object that glorifies the past and represents the state; it has become an artistic practice that integrates with space, interacts with the viewer, and remains open to different meanings. The authoritarian and univocal structure of representation characteristic of the nineteenth century shifted in the twentieth century toward a more pluralistic, experiential, and spatial mode of expression. This process reveals that public space is not only the stage of state ideology, but also a living field in which collective memory, art, viewer experience, and contemporary conditions are reproduced together.

In conclusion, the figurative, hierarchical, and ideological nation-state monuments of the nineteenth century were transformed in the twentieth century, under the influence of modernism, into abstract, simplified public art forms that integrate with space and remain open to viewer interpretation. This transformation demonstrates that art and space are not fixed entities, but dynamic structures that constantly change in relation to social, political, technological, and aesthetic conditions. Accordingly, the transformation of the monument is not only a formal artistic change, but also a visible expression of the historical transformation of societies' understandings of identity, memory, and public space.

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PRELIMINARY EEG OBSERVATIONS OF PAREIDOLIA PROCESSING IN CHILDREN WITH AUTISM SPECTRUM DISORDER: A PILOT STUDY

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ABSTRACT

Background: Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by atypical social interaction, communicative differences, and altered face processing. Pareidolia stimuli—illusory faces perceived in inanimate objects—offer a controlled probe of face-selective network flexibility, bypassing some of the social valence confounds inherent in real-face paradigms. This pilot study aimed to characterize early-latency electroencephalography (EEG) neural responses to real faces and pareidolic objects in children diagnosed with ASD relative to typically developing peers, with the explicit goal of generating hypothesis-level observations rather than definitive conclusions.

Method: Three children diagnosed with ASD (ages 6–15) and three age- and sex-matched typically developing controls participated. Participants viewed randomized images of real faces and pareidolic objects (1000 ms presentation) during continuous EEG recording. Analyses focused on temporal-region oscillatory activity reflecting early visual cortical processing.

Results: Preliminary observations indicate that children with ASD showed reduced oscillatory amplitude and delayed response onset to pareidolic stimuli relative to typically developing controls. In typically developing children, neural suppression in response to pareidolia resolved within an early and narrow time window; in children with ASD, however, oscillatory activity not only began later but also persisted abnormally through 450–500 ms, suggesting disrupted temporal dynamics in face-network recruitment.

Conclusion: Despite the severely limited sample size, these findings are consistent with atypical face-recognition network engagement during pareidolia processing in ASD. The latency prolongation and sustained oscillatory activity may reflect inefficient top-down modulation of the face-selective network. Larger, controlled studies are needed before any generalizable claims can be made; this work provides a methodological and hypothesis-generating foundation for such investigations.

Keywords: Autism Spectrum Disorder (ASD), Electroencephalography (EEG), Face Pareidolia, Social Cognition, Neurodevelopmental Disorders.

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition associated with persistent difficulties in social communication and restricted, repetitive patterns of behavior. One of the more consistent findings in ASD research is that affected individuals process faces atypically they attend less to faces, have difficulty recognizing facial expressions, and show altered gaze behavior compared to typically developing peers. Because faces carry so much of the information we use for social interaction, these differences likely contribute to the broader communicative challenges characteristic of ASD.

Face pareidolia the perception of face like configurations in inanimate objects such as clouds, vehicles, or electrical outlets provides a useful experimental window into face selective processing. These stimuli reliably engage the brain's face sensitive networks despite containing no real facial features, and they carry far less social and emotional content than photographs of actual faces. This makes them a relatively clean probe of perceptual face detection mechanisms, uncoupled from the social valence confounds present in real face paradigms.

A small number of behavioral studies have examined pareidolia processing in ASD. Ryan et al. (2016) reported that children with ASD were less likely to spontaneously detect face like patterns. Pavlova et al. (2017) found that children with ASD required more salient configurations before reliably identifying a stimulus as a face. More recently, a behavioral study using a new digital pareidolia test administered to 21 children with ASD and 20 typically developing controls found that children with ASD were both slower to react and less accurate in identifying pareidolic images; the group difference in accuracy was more pronounced for pareidolia than for real faces, and pareidolia images were harder to detect than real faces for both groups (Akdeniz, 2024). These findings suggest that the deficit in ASD is not simply a general slowing but reflects something specific about the processing of ambiguous face like stimuli.

Electroencephalography (EEG) allows these questions to be addressed at the neural level with millisecond resolution. A pilot EEG study in a comparable age group (children with ASD, ages 6–15) examined delta and theta band power during face and face pareidolia processing and found that children with ASD showed lower oscillatory amplitude and delayed latency compared to typically developing peers, particularly in the theta (4–6 Hz) and delta (0.5–4 Hz) bands within the 140–190 ms time window (Akdeniz, 2025). That study also reported a delayed and attenuated N170 response to pareidolia stimuli at temporoparietal electrodes in the ASD group. Taken together, these behavioral and electrophysiological observations suggest that both the early perceptual detection of face like stimuli and the underlying neural dynamics of face network recruitment may be atypical in ASD.

The present study is a small pilot investigation aimed at characterizing these neural differences in more detail. Three children with ASD and three typically developing controls completed an EEG paradigm in which they viewed real face images and face pareidolia images. Our goal was not to draw definitive conclusions the sample is far too small for that but to examine whether EEG patterns were consistent with the behavioral and oscillatory differences documented in prior work, and to build a methodological foundation for a larger study.

Materials and Methods

Six children between 6 and 15 years of age participated: three with a prior clinical diagnosis of ASD and three age and sex matched typically developing controls with no reported history of neurological or developmental conditions. All had normal or corrected to normal vision.

Visual stimuli consisted of real human face photographs and pareidolia images photographs of inanimate objects that naturally elicited the perception of a face. Images were standardized for size, resolution, and luminance. Stimuli were presented on a monitor in randomized order, each for 1000 ms, while participants were asked to watch and remain still.

Continuous EEG was recorded using scalp electrodes placed according to the International 10–20 system, sampled at 1000 Hz, in a quiet laboratory environment with participants seated approximately 60 cm from the screen. After recording, data were epoched around stimulus onset and artifacts from eye movements, blinks, and muscle activity were excluded. Analysis focused on oscillatory activity in temporal and temporoparietal regions, which are established as central to face selective processing. Given the pilot nature of the study, comparisons between groups were primarily descriptive.

Results

In the typically developing group, pareidolia stimuli produced a clear, early neural response. Oscillatory activity emerged shortly after stimulus onset and resolved within a relatively narrow time window, suggesting efficient engagement and release of face detection mechanisms.

Children with ASD showed a different pattern. The onset of oscillatory activity was delayed compared to controls, and the response amplitude appeared reduced. More notably, neural activity in the ASD group persisted through approximately 450–500 ms post stimulus well beyond the window in which controls had returned to baseline. This sustained late activity was a consistent observation across all three children with ASD.

For real face stimuli, both groups showed activation in temporal face selective regions, and the between group differences were less pronounced than those observed for pareidolia. This suggests that the ambiguity of pareidolic stimuli may be what drives the between group difference real faces appear to engage the face network in both groups, while face like objects place greater demands on the system in ASD.

Discussion

The main observation from this pilot is that children with ASD showed delayed, reduced, and prolonged neural responses to pareidolia stimuli relative to typically developing peers. The delay and amplitude reduction are consistent with less efficient recruitment of face selective networks a pattern compatible with behavioral findings showing that children with ASD require more salient or unambiguous face like configurations before detecting them (Pavlova et al., 2017; Ryan et al., 2016).

The behavioral findings of Akdeniz (2024) are directly relevant here. In that study, children with ASD were significantly slower (median reaction time 2.55 s vs. 1.20 s for typically developing controls) and less accurate (83% vs. 96% mean accuracy) for pareidolia stimuli. The digital pareidolia test used in that study demonstrated good sensitivity to group differences and was proposed as a candidate neuropsychological tool for subclinical assessment in ASD. The neural delays observed in the present study may partly explain these behavioral delays: if the face selective network is recruited later and less robustly, downstream perceptual decisions would be expected to take longer.

The EEG findings are also consistent with those of Akdeniz (2025), who reported significantly reduced delta power ($p = 0.009$) and theta power ($p = 0.007$) in the frontal region of children with ASD during pareidolia processing, within the 140–190 ms time window. In that study, typically developing children showed delta and theta activity that declined by approximately 400 ms and 350 ms respectively for pareidolia stimuli, while children with ASD showed sustained responses extending to 600 ms and 500 ms. The prolonged activity we observe in the 450–500 ms range in the present study is consistent with this temporal profile and supports the interpretation that face like ambiguous stimuli require prolonged neural processing in ASD.

The sustained activity between 450 and 500 ms is the most noteworthy observation in the present data. In controls, the brain appeared to resolve the pareidolia percept quickly. In children with ASD, processing continued longer, which could reflect difficulty resolving perceptual ambiguity the brain continuing to work on the stimulus beyond the point at which typically developing children have already categorized it. One plausible account is a deficit in top-down modulation: face perception involves not only bottom-up visual analysis but also higher order contextual integration, and if these regulatory processes are less efficient in ASD, prolonged activation would be expected. The link between delta/theta oscillations and top-down processing (Akdeniz, 2025) supports this interpretation. The observed reduction in low frequency frontal power in the ASD group may reflect weaker engagement of the attentional and cognitive control mechanisms that normally guide face network recruitment. This remains speculative, but it is mechanistically coherent and testable.

The fact that group differences were more evident for pareidolia than for real faces is worth noting, and is consistent with the behavioral literature. Real faces are highly salient, feature rich, and presumably well rehearsed stimuli. Pareidolic faces are ambiguous and require more active inference which may be exactly where atypical top-down modulation in ASD becomes most apparent.

The limitations here are obvious. Three participants per group is not enough to generalize anything. The age range is wide, and individual differences in developmental stage and cognitive ability likely add noise. These observations should be read as a preliminary signal worth pursuing, not as evidence of a generalizable effect.

Conclusion

This small pilot study found that children with ASD showed delayed response onset, reduced oscillatory amplitude, and prolonged neural activity particularly between 450 and 500 ms when viewing face pareidolia stimuli. The pattern is consistent with prior behavioral findings (Akdeniz, 2024) showing slower and less accurate pareidolia detection in ASD, and with prior EEG findings (Akdeniz, 2025) showing reduced delta and theta power and sustained oscillatory responses during pareidolia processing. The study demonstrates that EEG and pareidolia paradigms can be combined to investigate face network function in this population. Future adequately powered research is needed to determine whether these neural differences reflect a mechanistically coherent deficit in top-down modulation of face selective processing in ASD.

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A COMPARATIVE REVIEW OF TRANSFORMER-BASED NAMED ENTITY RECOGNITION MODELS FOR DOMAIN-SPECIFIC OPERATIONAL TEXT ANALYTICS

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ABSTRACT

Named entity recognition is a central information-extraction task for converting unstructured operational text into structured analytical signals. In domain-specific environments such as banking, e-commerce, customer service operations, compliance workflows, and incident management, entity recognition is more demanding than general-purpose tagging because the relevant entities are often context-dependent, unevenly distributed, and expressed in domain-specific terminology. This article presents a literature-grounded comparative framework for evaluating transformer-based named entity recognition models in domain-specific operational text analytics. Rather than reporting new experimental results, the study synthesizes findings from prior transformer, domain-adaptation, and NER benchmarking studies and maps them onto a representative operational entity schema. The discussion covers BERT, RoBERTa, DistilBERT, DeBERTa, ELECTRA, and domain-adapted BERT-style models with respect to entity-level precision, recall, F1-score, macro-F1, inference latency, model size, and deployment feasibility. The proposed framework emphasizes that model selection should not rely solely on the aggregate F1-score but should also consider low-resource entity behavior, annotation consistency, latency constraints, and domain-vocabulary alignment. The article concludes that domain adaptation and entity-schema quality are as important as model architecture when designing NER systems for operational analytics.

Keywords: Named Entity Recognition, Transformers, Domain-Specific NLP, Operational Text Analytics, BERT, DeBERTa, Entity-Level Evaluation, Deployment Feasibility.

INTRODUCTION

Operational organizations generate large volumes of unstructured text through customer complaints, transaction narratives, service tickets, compliance notes, product reviews, call-center summaries, incident reports, and internal process logs. These texts often contain entities essential to downstream analytics, including customers, organizations, locations, products, amounts, dates, identifiers, failure modes, complaint reasons, and operational risk events. Named entity recognition provides a mechanism for transforming such textual evidence into structured variables that can support search, monitoring, reporting, risk analysis, and decision support.

Although general-purpose NER is a mature task, domain-specific NER remains challenging. Operational text differs from newswire or encyclopedic text because it is noisy, abbreviated, multilingual in practice, and frequently shaped by organizational conventions. Entity boundaries may be ambiguous, entity mentions may be incomplete, and rare categories may appear only in specific business processes. In addition, operational entities often overlap with task-specific terminology. A phrase that appears to be a normal noun in general text may denote a risk event, complaint category, transaction status, or operational incident within a specific domain.

Transformer-based language models have substantially improved sequence labeling by learning contextual representations that capture long-range dependencies and semantic variation [1], [2]. However, the suitability of transformer models for operational NER cannot be inferred solely from general NLP benchmarks. A model that performs strongly on general NER may not be optimal for operational text if it fails to recognize domain-specific entities or if its latency and memory requirements are unsuitable for deployment. Since the present article does not report a new experimental benchmark,

its contribution is organized as a comparative review of transformer-based NER model families and their expected behavior in domain-specific operational text analytics.

RELATED WORK

Named entity recognition has traditionally been approached as a sequence-labeling task using rule-based systems, hidden Markov models, conditional random fields, and neural architectures. The introduction of contextual word representations and transformer encoders shifted the performance frontier by allowing token representations to vary with sentence context [1]. BERT established masked-language-model pretraining as a strong foundation for token classification, while RoBERTa refined the pretraining procedure and often improved downstream performance [2]. ELECTRA introduced replaced-token detection as an alternative pretraining objective that improves sample efficiency [5], while DeBERTa further improved representation learning by separating content and position information through disentangled attention [4].

Prior NER evaluation literature shows that entity-level evaluation is more informative than token-level accuracy alone because a model must identify the complete entity span and its correct type. Standard CoNLL-style scoring emphasizes exact-match entity evaluation, requiring both the entity boundary and entity type to be correct [8]. This evaluation principle is particularly relevant when extracted entities feed downstream systems such as search indexes, alerting engines, audit workflows, and customer intelligence platforms. Neural sequence-labeling architectures such as BiLSTM-CRF and CNN-BiLSTM-CRF models established strong pre-transformer baselines for NER by combining contextual sequence modeling with structured label decoding [9], [10]. In operational settings, partial boundary errors can be costly because an incorrectly extracted identifier, product name, or monetary value may propagate into structured databases.

Domain-specific NER has also been studied in biomedical, legal, financial, and technical domains. BioBERT demonstrated the value of continued pretraining on domain corpora for biomedical text [6], while FinBERT and related financial language models showed that domain adaptation can improve sentiment and information extraction in finance [7]. These findings suggest that model architecture alone is not sufficient; the pretraining corpus, annotation schema, and vocabulary alignment strongly affect the practical success of NER systems.

METHODOLOGY

This article adopts a comparative review methodology rather than an original experimental design. The objective is to synthesize design considerations for transformer-based named entity recognition in domain-specific operational text analytics. The reviewed model families were selected because they represent widely used approaches to contextual sequence labeling, domain adaptation, compact transformer deployment, and token-level information extraction.

The comparison considers BERT-base, RoBERTa-base, DistilBERT, DeBERTa-base, ELECTRA-base, and domain-adapted BERT-style models. These models were selected because they represent distinct pretraining and adaptation strategies. BERT provides a general masked-language-modeling baseline; RoBERTa represents optimized BERT-style pretraining; DistilBERT illustrates knowledge distillation; DeBERTa introduces disentangled attention; ELECTRA uses replaced-token detection; and domain-adapted BERT-style models represent continued pretraining on specialized corpora.

The operational NER setting is conceptualized as a domain-specific text analytics environment involving customer-service records, transaction descriptions, product-related messages, compliance notes, incident reports, and process logs. The assumed entity schema includes PERSON, ORGANIZATION, PRODUCT, LOCATION, DATE, MONEY, TRANSACTION_ID, COMPLAINT_REASON, RISK_EVENT, and OPERATIONAL_INCIDENT. Generic entity categories support indexing, reporting, search, and timeline reconstruction, whereas domain-specific categories support risk monitoring, voice-of-customer analytics, audit linking, and incident management.

The review is structured around two groups of criteria. The first group concerns predictive suitability, including entity-level exact-match quality, precision tendency, recall tendency, macro-level robustness,

rare-entity sensitivity, and boundary-error behavior. The second group concerns deployment feasibility, including expected latency, model footprint, memory requirements, domain-adaptation cost, implementation complexity, and suitability for high-throughput operational serving. Because this article is a comparative review, numerical performance values are not presented as experimental findings. Instead, the tables summarize relative tendencies based on architectural characteristics and the established literature on transformer-based NER and domain adaptation.

DATASET AND ENTITY SCHEMA

The entity schema considered in this review is intended to represent operationally useful information rather than only generic named entities. It includes PERSON, ORGANIZATION, PRODUCT, LOCATION, DATE, MONEY, TRANSACTION_ID, COMPLAINT_REASON, RISK_EVENT, and OPERATIONAL_INCIDENT. Generic entity categories support standard indexing and reporting, while domain-specific categories capture the analytical value of operational text. Low-frequency classes such as RISK_EVENT and OPERATIONAL_INCIDENT are included because they are often valuable for downstream risk monitoring, even though they are typically harder to recognize reliably.

Table 1. Representative entity schema for domain-specific operational NER.

Entity type	Operational meaning	Example use in analytics	Expected difficulty
PERSON	Customer, agent, or stakeholder mention	Identity resolution and service context	Medium
ORGANIZATION	Company, merchant, bank, or partner	Counterparty and channel analysis	Low
PRODUCT	Product, plan, SKU, or service item	Product-level complaint and demand analysis	Medium
LOCATION	City, branch, delivery region, service area, or operational site	Geographic segmentation, branch-level monitoring, service-region analysis	Low
DATE	Transaction date, complaint date, delivery date, deadline, or incident time	Timeline reconstruction, SLA tracking, temporal risk analysis	Low
MONEY	Amount, fee, refund, or charge	Financial issue extraction	Low
TRANSACTION_ID	Payment, order, ticket, or case identifier	Traceability and audit linking	Medium
COMPLAINT_REASON	Reason for dissatisfaction or dispute	Voice-of-customer analytics	High
RISK_EVENT	Fraud, abuse, dispute, breach, or warning signal	Risk monitoring and alert triage	High
OPERATIONAL_INCIDENT	Failure, outage, delay, or service disruption	Incident management and root-cause analysis	High

TRANSFORMER MODELS COMPARED

The comparative review considers models that differ in pretraining strategy, capacity, and expected deployment profile. BERT represents the standard encoder baseline. RoBERTa illustrates the effect of stronger BERT-style pretraining. DeBERTa represents disentangled attention and improved contextual span modeling. ELECTRA represents replaced-token detection pretraining, which can be efficient in representation learning. DistilBERT is considered a compact model for resource-constrained settings. Domain-adapted BERT-style models represent continued pretraining on unlabeled domain-specific text prior to supervised NER fine-tuning.

Table 2. Qualitative comparison of transformer-based NER model families.

Model	Pretraining characteristic	Main expected advantage	Main deployment concern
BERT-base	Masked language modeling with next-sentence objective	Stable general baseline	Moderate latency
RoBERTa-base	Optimized BERT-style pretraining	Strong contextual representations	Larger computational cost
DistilBERT	Knowledge-distilled BERT variant	Lower latency and model size	Potentially lower rare-entity recall
DeBERTa-base	Disentangled attention representation	Strong span and context modeling	Higher inference cost
ELECTRA-base	Replaced-token detection	Efficient pretraining signal	May underperform on rare semantic classes
Domain-adapted BERT	Continued pretraining on operational text	Better domain vocabulary alignment	Requires unlabeled corpus and extra training

Model footprint is considered a deployment-relevant factor because storage requirements, tokenizer files, framework format, and numerical precision can influence practical serving cost.

COMPARATIVE REVIEW FINDINGS

The comparative review suggests that domain adaptation is an important design consideration for operational entity recognition. Domain-adapted BERT-style models are expected to be advantageous when operational text contains specialized vocabulary, organization-specific terminology, abbreviations, product names, transaction expressions, or process-specific risk language. This advantage is especially relevant for low-resource operational categories such as RISK_EVENT, COMPLAINT_REASON, and OPERATIONAL_INCIDENT, where general-purpose pretraining may not provide sufficient domain alignment.

DeBERTa-style models are expected to be strong candidates when span sensitivity and contextual distinction are important. Their disentangled attention design may be useful for multi-token entities, boundary-sensitive mentions, and entity categories whose interpretation depends heavily on surrounding context. RoBERTa-style models may remain competitive for frequent and generic entities such as ORGANIZATION, PRODUCT, DATE, and MONEY, but may require domain adaptation or additional supervision when the entity inventory includes rare operational categories.

DistilBERT offers a practical option when the deployment setting requires lower latency, smaller model footprint, or higher serving efficiency. Its compact design may be attractive for large-scale operational pipelines, although rare-entity recall may be weaker than in larger or domain-adapted models. ELECTRA can be attractive because of its efficient pretraining objective, but its suitability for operational NER depends on the target entity schema, domain vocabulary, and availability of task-specific fine-tuning data.

Across model families, three qualitative error patterns are especially important for operational NER. First, low-resource operational classes may be confused with generic issue terms when the model lacks a domain-specific representation. Second, boundary errors may occur when entity mentions include modifiers such as disputed, delayed, failed, recurring, suspicious, or unauthorized. Third, identifier-like entities may be fragmented when they contain mixed alphanumeric patterns. These error types suggest that annotation quality, tokenizer behavior, domain adaptation, and entity-schema design should be considered alongside aggregate NER performance.

Table 3. Qualitative comparison of transformer-based NER models for operational text analytics.

Model	Expected entity recognition quality	Expected deployment efficiency	Main strength	Main limitation
BERT-base	High	Moderate	Stable general-purpose encoder for token classification	May require adaptation for specialized operational vocabulary
RoBERTa-base	High	Moderate to low	Strong contextual representation from optimized pretraining	Higher computational cost and possible weakness on rare domain entities
DistilBERT	Moderate to high	High	Compact model with favorable efficiency for large-scale serving	May lose recall on rare or context-dependent entity categories
DeBERTa-base	High	Moderate to low	Strong span-sensitive and context-aware representation	Higher inference cost than smaller transformer variants
ELECTRA-base	Moderate to high	Moderate	Efficient replaced-token pretraining objective	Operational NER performance may depend strongly on fine-tuning data and entity schema
Domain-adapted BERT	High for domain-specific entities	Moderate	Better vocabulary and terminology alignment for operational text	Requires unlabeled domain corpus and additional pretraining effort

DISCUSSION

The comparative review indicates that selecting a transformer-based NER model should be treated as a design problem shaped by both entity-recognition requirements and deployment constraints. Full-size encoders such as BERT and RoBERTa remain useful when a stable contextual representation is the primary concern, but they may not be the most practical option for operational systems that require high-throughput processing, low latency, or limited memory usage. Compact models such as DistilBERT may be more appropriate when serving efficiency is a central requirement.

Domain adaptation is particularly important in operational NER because the meaning of an entity often depends on organizational vocabulary and process-specific context. A phrase that appears generic in general text may represent a complaint reason, operational incident, risk event, transaction status, or

service failure in a domain-specific corpus. Therefore, continued pretraining or other forms of domain adaptation may improve robustness for rare and semantically specialized categories, provided that sufficient unlabeled domain text is available.

The review also suggests that entity-schema design should be considered a core methodological choice rather than a secondary annotation detail. Generic entity types such as DATE, MONEY, ORGANIZATION, and PRODUCT are usually easier to define and recognize than operational categories such as COMPLAINT_REASON, RISK_EVENT, and OPERATIONAL_INCIDENT. However, the latter categories may carry greater downstream value for monitoring, routing, compliance, or incident management. For this reason, domain-specific NER assessment should include sensitivity to rare entities and boundary-error behavior, rather than relying solely on the aggregate F1-score.

Finally, deployment feasibility should be evaluated alongside predictive suitability. Model size, latency tendency, memory footprint, tokenizer behavior, and implementation complexity can influence whether a model is practical in operational analytics pipelines. A model with stronger expected entity-level performance may not be preferable if its serving cost exceeds the target environment's constraints. Conversely, a compact model may be sufficient if the entity inventory is relatively stable and the main requirement is scalable extraction from large volumes of short text.

CONCLUSION

This article presented a comparative review of transformer-based named entity recognition models for domain-specific operational text analytics. Rather than reporting a new experimental benchmark, the article synthesized design considerations for BERT, RoBERTa, DistilBERT, DeBERTa, ELECTRA, and domain-adapted BERT-style models. The review suggests that domain-adapted models are promising when operational text contains specialized terminology and rare entity categories, while DeBERTa-style models may be useful when span sensitivity and contextual distinction are central. DistilBERT offers a practical option for deployment efficiency, whereas BERT and RoBERTa remain strong general-purpose reference models. The broader conclusion is that operational NER should be evaluated as a joint design problem involving model architecture, domain adaptation, annotation quality, entity schema, rare-category behavior, and deployment constraints. Future work should validate these comparative observations through controlled experiments on multilingual operational corpora, weak-supervision settings, active-learning workflows, and continually evolving business terminology.

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MORALLY DEFENSIBLE VOLUNTARY TERMINATION OF PREGNANCY
GEBELİĞİN İSTEYEREK SONLANDIRILMASININ AHLAKEN SAVUNULABİLİRLİĞİ

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ABSTRACT

Does a woman have the unconditional right of disposal within her own body? How true and fair, if at all, can it be to attribute this right directly to the right to life? On the other hand, in cases where the woman cannot control her own fertility, she has no choice but to terminate her pregnancy willingly or unwillingly. In societies where abortion is prohibited, many women miscarry on their own under hygienically unfavourable conditions, illegally, using drugs, or similar methods.Is it morally justifiable to terminate a pregnancy willingly with a miscarriage, aside from abortion bans or debates about whether abortion is legal? Ethically, can there be a justification for killing a person who has not yet been born? Apart from the debates about how realistic the questions that can be expressed in this way are, it can be argued how moral it is to try to prevent the abortion rights of women who are living and trying to protect their other children and family by risking their own health. How can it be morally defended that in cases where the woman cannot control her own fertility, the pregnancy is terminated with a miscarriage or abortion, willingly or unwillingly?

Keywords: Women's Rights, Right to Abortion, Termination of Pregnancy.

ÖZET

Kendi yaşama hakları tehdit altında olmayan annelerin gebeliklerine son vermek istemeleri, başta etik, hukuk ve tıp olmak üzere birçok bilim dalı açısından incelenebilecek bir meseledir. Hukuk sistemlerinin genellikle bu hususta anneye tanıdığı özgürlüğü fetüsün gelişim evresi ile sınırlarlar. Özgürlükçü olmayan yaklaşımlar, kadınları ilkel yöntemlerle tek başına veya yasadışı tekinsiz ortamlarda canları pahasına düşük yapmaya sürükler. Kadınının kendi bedeni üzerindeki egemenlik hakkının yasalarla sınırlandırılması, fetüsün yaşam hakkının korunması ile açıklanmaktadır.

Anahtar Kelimeler: Yaşam hakkı, bedensel egemenlik, rıza, engellilik.

GİRİŞ

Gebeliğin isteyerek sonlandırılması konusu yalnızca bir "kadın hakkı" veya yalnızca bir "fetüsün yaşama hakkı" meselesi değildir. Aynı zamanda insan onuru, yaşamın değeri, bedensel özerklik, ahlaki sorumluluk, devletin müdahale sınırları ve hukuk-ahlak ilişkisini aynı anda ilgilendiren çok katmanlı bir etik problemdir.

Bu çalışma, gebeliğin isteyerek sonlandırılması sorununu belirli bir ideolojik veya siyasal yaklaşımın doğrulanması amacıyla değil, hukukun ve ahlakın temel kavramları ışığında değerlendirmeyi amaçlamaktadır. Çalışmamız, tartışmayı yalnızca, kadının hakkı mı, fetüsün hakkı mı? ikilemine

sıkıştırmak yerine, insan yaşamının ahlaki değeri nasıl temellendirilir? Bedensel özerklik hangi etik sınırlar içinde anlam kazanır? gibi sorulara cevap aramaktadır.

Çok Katmanlı Bir Olgu: Gebeliğin Sonlandırılması

Gebeliğin sonlandırılması yalnızca iki hak arasında tercih yapılmasını gerektiren hukuki bir sorun değildir. Gebeliğin sonlandırılması olgusu, hukuki bir sorun olmanın çok ötesinde insan yaşamının değeri, insan onuru, ahlaki sorumluluk, ebeveynlik yükümlülüğü ve toplumun ortak etik değerlerini ilgilendiren çok katmanlı bir olgudur. Gebeliğin isteyerek sonlandırılması, gerçekten çağdaş ahlak felsefesi, insan hakları teorisi ve hukuk düşüncesinin en tartışmalı meselelerinden biridir. Kürtaj karşıtı yaklaşımlar, insan yaşamının döllenmeyle başladığını ve fetüsün doğuştan yaşama hakkına sahip olduğunu ileri sürerken; kürtaj hakkını savunan yaklaşımlar, bireyin bedensel özerkliğinin ve üreme özgürlüğünün temel insan hakları arasında bulunduğunu savunmaktadır. Çağdaş etik teorilerde biyolojik insan olmak ile ahlaki kişi olmak arasında ayrım yapılmaktadır. Bazı filozoflar, ahlaki statünün yalnızca genetik insan olmaktan değil, bilinç, öz farkındalık, duyarlılık veya bağımsız yaşam kapasitesi gibi özelliklerden kaynaklandığını da ileri sürmektedir. Bu nedenle fetüsün hangi aşamada tam ahlaki statü kazandığı konusunda ortak bir görüş bulunmamaktadır.

Sorun, bir bireyin yaşama hakkının başka bir bireyin bedenini kullanma hakkını da içerip içermediği hususundaki görüş ayrılıklarından kaynaklanmaktadır. Organ nakillerinde aranan donörün rızasının belirleyiciliği kürtajda da aranmamalı mıdır? Eğer yaşam hakkı başka bir bireyin bedenini kullanma hakkını içeriyorsa, kadının kendi bedeni üzerindeki tasarruf yetkisi hangi ölçüde sınırlandırılabilecek, içermiyorsa, fetüsün yaşama hakkının sınırları nasıl belirlenecektir? Kadının isteyerek gebe kalmamış olması veya başlangıçta istekli olmasına rağmen gebelikten sonradan vaz geçmesi sorunun cevabını değiştirecek midir? Fetüsün yaşam hakkı annenin yaşam hakkı tehdit altında değilken hangi andan itibaren üstün kabul edilecektir? Bütün bu soruların cevabı sadece etik ilklerde değil hukuki düzenlemelerde de aranmalıdır.

Ahlaki Değerlerin Dengelenmesi Sorunu

Gebeliğin isteyerek sonlandırılmasının ahlaken savunulabilirliği, fetüsün değerinin inkâr edilmesine dayanmaz. Aksine bu tartışma, iki önemli ahlaki değerin nasıl dengeleneceği sorununa işaret etmektedir. Fetüsün yaşamı önemli bir ahlaki değer taşısa da yaşama hakkının başka bir kişinin bedenini kullanma konusunda sınırsız bir yetki doğurduğunu söylemek güçtür. Bu nedenle kürtajın ahlaki savunusu, yaşamın değersiz olduğu düşüncesine değil; bedensel özerklik, insan onuru ve bireysel özgürlük ilkelerine dayanmaktadır. Çoğulcu toplumlarda farklı ahlaki görüşlerin varlığı dikkate alındığında, gebeliğin sürdürülmesine ilişkin nihai kararın öncelikle kadın bedeninin özerkliği ve insan hakları temelinde değerlendirilmesi gerektiği sonucuna ulaşılmaktadır.

Judith Jarvis Thomson'un bedensel bağımlılık argümanı, Ronald Dworkin'in yaşamın içkin değeri yaklaşımı ve çağdaş insan hakları teorileri kürtaj yanlısı yaklaşımlardır. Judith Jarvis Thomson'un geliştirdiği bedensel bağımlılık yaklaşımı, kürtajın ahlaki savunusuna ilişkin en etkili teorilerden biridir. Thomson'a göre fetüsün tam anlamıyla kişi olduğu varsayılsa bile, bu durum fetüse kadının bedenini kullanma konusunda doğrudan bir hak yaratmaz. Yaşama hakkı, başkasının bedeninden yararlanma hakkını içermez. Bu yaklaşım, kürtajı fetüsün değersiz olduğu iddiasına değil, bireyin kendi bedeni üzerindeki egemenliğine dayandırmaktadır. Dolayısıyla kürtajın ahlaken savunulabilirliği, yaşamın değerinin reddedilmesinden değil, bireysel özgürlüğün ve insan onurunun korunmasından doğar. (Thomson, 2004).

Türk Hukuk Sisteminde Gebeliğin Sonlandırılması

Türk hukuk sisteminde kadın sadece on haftaya kadar olan gebeliğinden iradi olarak vaz geçebilecekken, bu süre sadece kadının mağduru olduğu bir suç sonucu gebe kalması halinde yirmi haftaya kadar uzayacaktır. Gebeliğin yirmi haftadan fazla olması halinde kadının suç mağduru olması sebebiyle yapılacak rahim tahliyesi uzman hekimler tarafından hastane ortamında gerçekleştirilecektir (Türk Ceza Kanunu madde 99). Gebeliğin kadının yaşam hakkını tehdit etmesi halinde ne kadar uzun süreli olursa olsun kadının isteği ile sonlandırılabilesi mümkündür. (Tıbbi Deontoloji Nizamnamesi, madde 22). Bu koşulların yokluğunda kadın gebeliğini iradi olarak sonlandıramayacaktır. Türk Hukuku

için aranan on haftalık süre Avrupa ülkelerinde değişmekte hatta yirmi ikinci haftaya kadar çıkabilmektedir.

Türk Medeni Kanunu'nda ebeveyn olan annelere babalar gibi çocuklarının maddi manevi gelişimi için sorumluluk almayı yüklenmiş (TMK madde 321-363), Türk Ceza Kanunu'nda aile hukukundan doğan bakım, eğitim veya destek olma yükümlülüğünü yerine getirmeyen kişinin şikâyet üzerine, bir yıla kadar hapis cezası ile cezalandırılacağı kabul edilmiştir (TCK madde 233). Başka bir ifade Türk Hukukunda ebeveynlik sadece ahlaki ve sosyal bir yükümlülük değil hukuki sonuçları da olan bir statüdür.

Avrupa Parlamentosu'nun 2020 Tarihli Raporu

Avrupa Parlamentosu'nun 2020 yılında yayımladığı Avrupa Birliği'ndeki Bekar Ebeveynler hakkındaki raporda tek ebeveynli ailelerin giderek yaygınlaşmakta olduğu, bu ailelerin büyük çoğunluğunun başında kadınların bulunduğu ve bekar annelerin, çift ebeveynli ailelere kıyasla; yoksulluk riskiyle daha sık karşılaştıkları, maddi yoksunluk yaşama olasılıklarının, düşük gelirli ve güvencesiz işlerde çalışma oranları daha yüksek olduğu ve istihdam oranlarının yükselmesine rağmen yoksulluk oranlarının anlamlı biçimde düşmemiş olduğu tespit edilmiştir. Başka bir ifade ile raporda dünyaya gelecek çocuk üzerindeki sorumluluğun erkeklere kıyasla kadınlar için bireysel olarak daha zorlu olduğu tespit edilmiştir. (https://www.europarl.europa.eu/RegData/etudes/STUD/2020/659870/IPOL_STU(2020)659870_EN.pdf) "Bekâr Türk anneleri için en önemli destek kaynağı geniş aile olup; büyükanneler, bekâr kızlarının çocuk bakımındaki sorumluluklarını önemli ölçüde paylaşmakta iken büyükbabalar daha çok maddi destek sağlamaktadır. Bu sonuçlar, Türk kültüründe yaygın olan toplulukçu (kolektivist) değerlerle uyumludur. (Cakir, 2010).

Türk Hukukunda Kadının Yaşam ve Bedensel Bütünlük Hakkının Korunması

Türk Hukukunda kimsenin hak ve fiil ehliyetlerinden ve özgürlüklerinden vazgeçemeyeceği veya onları hukuka ya da ahlâka aykırı olarak sınırlayamayacağı ilkesi de benimsenmiştir (TMK madde 23). Kişilik hakları yaşam hakkından başka bir ifade ile nefes alıp vermekten ibaret olmayıp kişinin bedeni, özel ve aile hayatı, sosyal ve iş hayatı ve eğitim hakkı ile ilgili kararları özgürce alabilme yetkisi de içermektedir. Kaldı ki kürtaj yasağı, kadınları hijyenik bakımdan elverişsiz koşullar altında, yasadışı bir şekilde, ilaç kullanarak veya benzer yöntemlerle, kendi kendilerine düşük yapmaya iterek, yaşam hakkını da tehdit etmektedir. "Tahmini olarak her yıl yaklaşık 18 milyonu gelişmekte olan ülkelerde olmak üzere 20 milyon kadın güvenli olmayan kürtaj geçirmekte; bu durum yaklaşık 78.000 kadının ölümüne ve milyonlarca kadının kronik hastalıklara ve engellilik durumlarına maruz kalmasına neden olmaktadır (Olukoya & AbouZahr, 2001).

Kürtajın yasal olması üreme özerkliği açısından anlamlı da olsa, geniş ölçüde yasal olduğu ülkelerde bile bireylerin güvenli ve yasal kürtaj hizmetlerine erişebilmesini etkileyen damgalanma, sağlık personelinin kürtajı reddetmesi, kürtaj için kamu fonlarının yasaklanması, kürtaj hizmetlerinin sigorta kapsamının sınırlandırılması ve kürtajın kamu sağlık sistemlerine yeterince entegre edilmemesi gibi kısıtlayıcı politika önlemler gibi çok sayıda caydırıcı faktörler bulunmaktadır (Mayall, Ajayi & Gruer, 2025). Kadınların merdiven altı uygulamalarla düşük yapmaya çalışmalarında kadın cinayetlerine kurban gitmekten kurutulma niyetleri de göz ardı edilmemelidir (Sev'Er & Yurdakul, 2001).

Kürtaj kararını verecek olan annenin kim olduğu ve fiil ehliyeti koşullarını taşıyıp taşımadığı da önemlidir. Annenin tam ehliyetli olması durumunda bu kararı alabilmesi mümkünken ayırt etme gücüne sahip olmayan bir kadının rızası hilafına gebe bırakılması halinde bu kararı kanuni temsilcisi verebilmelidir. Nüfus Hizmetleri Kanunu'nun 6'ıncı maddesi gereğince; rahim tahliyesi (küretaj) "… gebe kadının iznine, küçüklerde küçüğün rızası ile velinin iznine, vesayet altında bulunup da reşit veya mümeyyiz olmayan kişilerde reşit olmayan kişinin ve vasinin rızası ile birlikte sulh hakiminin izin vermesine bağlıdır. Ancak akıl maluliyeti nedeni ile şuur serbestisine sahip olmayan gebe kadın hakkında rahim tahliyesi için kendi rızası aranmaz."

Gebelikte Taşıyıcı Annelik Uygulamaları

Taşıyıcı annelik ve sonuçları Türk Hukukunda düzenlenmemişse de Türk vatandaşı bir kadının taşıyıcı anne olmasına veya taşıyıcı anneye donör olmasına yasal bir engel yoktur. Bu durumda küretaj kararının donör veya taşıyıcı durumda olan annelerden hangisi tarafından verilebileceği etik olduğu kadar hukuki de bir sorudur. Yumurta vericisi annenin annelikten vaz geçmesi halinde taşıyıcı annenin bedeni üzerinde söz hakkının doğup doğmayacağı kadar, taşıyıcı annenin tek başına küretaj kararı almasında donör annenin hakları da tartışma konusu olabilecektir.

Özellikle fetüste görünen anomonilerde taşıyıcı annenin bebeği dünyaya getirme kararı karşısında annenin çocuğu evlat edinmek istememesine rağmen, babanın babalık davasına maruz kalacak olması sebebi ile, kararın sonuçlarından doğrudan etkilenmesi mümkündür. Yakın dönemde, gebeliğin beşinci ayında yapılan ultrason incelemesinde fetüste yarık damak, beyin kisti ve kalp kusurları gibi ciddi anomaliler tespit edilmiş ve bu sorunlarla doğacak bir çocuğun çok sayıda ameliyata ihtiyaç duyacağı ve buna rağmen yetişkinliğe ulaşma ya da iyi bir yaşam kalitesine sahip olma olasılığının oldukça düşük olmasına rağmen taşıyıcı anne Crystal Kelley'in genetik ebeveynlerin küretaj talebini reddetmesi üzerine açılan bir Connecticut davasında çocuğu dünyaya getirilmemesi talebi görüşülmüştür.

Kelley'yi eleştiren birçok kişi, onun ne genetik anne ne de gelecekteki sosyal anne olduğunu, dolayısıyla karar verme hakkına sahip olmadığını ileri sürerken Kelly'e hak veren ikinci görüşte olanlarca Amerikan Kadın Doğum Uzmanları ve Jinekologlar Koleji'nin görüşü doğrultusunda Kelley'nin yumurtanın rahmine yerleştirilmesi öncesi yaptığı protokolle anomoli halinde küretaj yaptıracağını kabul etmesine rağmen, bedensel egemenliği üzerindeki haklarını devredilemeyeceği ve sözleşmenin geçersizliği savunulmuştur (Walker & Van Zyl, 2015).

Çocuğun engelli olmasının küretaj için haklı sebep olmadığını kabul eden etik ve teolojik görüşler de bulunmaktadır. "Devletin vatandaşlarını fetüsün sağlığını bozabilecek toksik maddelere karşı korumada başarısızlığına rağmen vatandaşlarını sağlık sorunları veya engellilik taşıyan fetüsleri dünyaya getirmeye zorlamakta" olması Disgenik Devlet tartışmalarını doğurmaktadır (Bridges, 2022).

Türk Hukukunda Tıbbi Zorunluluk Halleri ve Rıza

Türk Hukukunda tıbbi zorunluluk varsa fetüsün on haftanın üzerinde olmasına rağmen rahim tahliyesi suç değildir. (Türk Ceza Kanunu madde 99) Öte yandan Türk Hukukunda ana, doğuran olduğundan (Türk Medeni Kanunu madde 282/1) küretaj konusunda karar verecek olan çocuğu taşıyan annedir. Yumurta donörü annenin bu konuda söz hakkı bulunmamaktadır.

Küretajla ilgili rızası aranacak bir diğer kişi de Nüfus Planlaması Hakkında Kanun'un 6'ıncı maddesi gereğince kadının eşidir. Ancak Türk Ceza Kanunu'nda ayrık durumlar haricinde on haftaya kadar olan gebeliklerde rızası aranacak kişi gebe kadın olup kocanın rızasının alınmaması suç değildir. Bekar kadınlar açısından ise çocuğun babasının rızası aranmaz. Zira babanın çocuk ile soybağı kurabilmesi için çocuğun dünyaya gelmiş olması aranır (Türk Medeni Kanunu 296).

Öte yandan babanın rızası sadece rahim tahliyesinde çocuğun dünyaya gelmemesinde aranırken çocuğun dünyaya getirilmesinde aranmamaktadır. "Bazı erkek hakları grupları, kadınlara bir gebeliği sürdürme ya da sonlandırma konusunda karar verme yetkisi tanınıyorsa, genetik babaların çocuk nafakası ödeme konusunda mali olarak sorumlu tutulmalarının adaletsiz olduğunu ileri sürmektedir" (Sheldon, 2003).

Küretajın sağlık personeli nezdinde ve doğru ve hijyenik ortamlarda gerçekleştirilmesi yasal mevzuatın özgürlükçülüğü ile yakından ilintilidir. Sağlıklı koşullarda gerçekleşmeyen rahim tahliyeleri sadece kadının yaşamını riske atmamakta düşük yaptığını düşünen kadının dünyaya engelli çocuklar getirmesine de yol açmaktadır. Bu durum çocukların üstün yararına aykırı olduğu gibi engelli çocuklara sahip anne ve babanın yükümlülüklerini de ağırlaştırmaktadır (Işıkhan, 2006).

Kadının bedensel egemenliğinin tanınmaması, yaşama hakkı kadar kadının yaşamını düzenlemesi için karar almasını da engellemekte, dünyaya getirilen çocuğun yükü hiçbir zaman annenin üstlendiği ölçüde ne devletçe ne de baba tarafından paylaşılmamaktadır. Kadınların planlanmayan hamilelikler veya planlı hamilelikler ardından yaşam koşullarının değişmesi sonrasında gebelik haline son vermesi

istemleri şahsa sıkı sıkıya bağlı bir hak olarak kabul edilmelidir. Ancak kadının bu kararı vermesinde olağan üstü durumlar haricinde her hakkın dürüstlük ilkesine uygun kullanılmasının bir gereği olarak fetüsün olgunluğu da göz ardı edilmemelidir.

Küretaj kararı, kadının kendi bedenindeki egemenlik hakkının kullanılmasının doğal bir sonucudur. Türk Hukukunda kadın, gebeliğe onuncu haftasına kadar rızası ile son verebilmekte, mağduru olduğu bir suç sebebi ile gebe kalmış ise bu süre yirmi haftaya çıkmaktadır.

Fetüsün veya annenin doğuma bağlı sağlık problemleri varsa rahim tahliyesi için fetüsün olgunluğu dikkate alınmamaktadır. Küretaj yasağı sadece merdiven altı hijyenik olmayan uygulamalar sebebiyle kadının hayatını riske atmakta kalmamakta hamileliğin ortaya çıkması kadının namus cinayetlerine kurban gitmesine de yol açmaktadır.

Küretaj hakkı tanınmaması özellikle bekar ebeveynliklerde kadını zora sokmakta; bilhassa engelli doğan çocukların sorumluluğun altında ezilmesine yol açmaktadır. Öte yandan küretaj için babanın rızası aranacaksa da aranmaması suç değildir. Kadının babanın rızası hilafına gebe kalması ise babanın temel haklarına bir müdahale olarak görülmelidir.

SONUÇ

Gebeliğin isteyerek sonlandırılması, insanlık tarihinin en eski ahlaki tartışmalarından biri olmasına rağmen günümüzde de çözümü üzerinde uzlaşma sağlanamayan sorunlardan biridir. Hukuk sistemleri, dinî yaklaşımlar, kültürel değerler ve etik kuramlar bu konuya birbirinden oldukça farklı cevaplar vermektedir. Bunun temel nedeni, gebeliğin sonlandırılmasıyla ilgili tartışmaların yalnızca tıbbi bir müdahaleye ilişkin olmamasıdır.

Gebeliğin sonlandırılması, yaşamın ne olduğu, insan olmanın ne anlama geldiği ve insan yaşamının hangi aşamada ahlaki koruma kazanacağı gibi yaşamsal sorunların temelinde yer almaktadır. Bu konuda ortaya çıkan sorunlar ve klasik tartışmaların büyük bölümü iki temel yaklaşım etrafında şekillenmektedir. Birinci yaklaşım, kadının kendi bedeni üzerinde tasarruf hakkını merkeze almakta ve gebeliğin sürdürülüp sürdürülmeyeceğine karar verme yetkisinin öncelikle gebeye ait olduğunu savunmaktadır.

İkinci yaklaşımda ise döllenmeyle birlikte başlayan insan yaşamının bağımsız bir ahlaki değere sahip olduğunu ileri sürülmekte ve fetüsün yaşamının korunması, temel etik yükümlülük olarak görülmektedir. Günümüzde kamuoyundaki tartışmalar, büyük ölçüde bu iki yaklaşım arasında olmasına rağmen, konu yalnızca kimin hakkı daha üstündür? Sorusuna, indirgenemeyecek kadar karmaşıktır. Çünkü gebelik süreci, biyolojik gerçeklik ile ahlaki sorumluluk arasında benzersiz bir ilişki kurmaktadır. Anne ile fetüs arasındaki bağ, klasik hak çatışmalarında karşılaşılan iki bağımsız hukuk öznesi ilişkisinden farklıdır. Fetüsün yaşamı, belirli bir süre annenin bedensel varlığına bütünüyle bağımlıdır. Bu nedenle kürtaj tartışmaları, yaşam hakkı ile bedensel özerklik arasında basit bir dengeleme problemi olarak açıklanamaz.

Embriyoloji alanında yaşanan bilimsel gelişmeler, fetüsün gelişim evrelerine ilişkin bilgilerin artmasını sağlamış; buna karşılık insan hakları hukukunda bireysel özerklik, özel hayatın korunması ve üreme hakları da giderek güçlenmiştir. Bilimsel ilerleme ile hak temelli yaklaşımlar aynı anda gelişmiş olsa da gelişmeler ortak bir etik sonuca ulaşılmasını kolaylaştırmamış, tam tersine, yaşamın başlangıcı, ahlaki statü, insan onuru ve devletin koruma yükümlülüğü gibi konuları çok daha karmaşık bir hâle getirmiştir.

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PROBLEMATIC OF THE RIGHT TO LIFE IN THE MOTHER-FETUS RELATIONSHIP
ANNE FETÜS İLİŞKİSİNDE YAŞAMA HAKKI PROBLEMATİĞİ

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ABSTRACT

Does the mother have an unconditional right to dispose within her own body? From the third month of pregnancy, the organism in the womb is called the fetus. The right of the fetus to live is provided by the mother. When this right conflicts with the mother's right to life, the issue of who should be preferred between the mother and the fetus is both morally and legally problematic. Because when the right to life of the mother conflicts with the right to life of the fetus, the right to superiority and superior benefit belongs to the mother. In cases where the fetus does not threaten the life of the mother, even when there is no conflict of rights with the mother, the woman's right to dispose of her own body gives her the right to end the life of the fetus intentionally. The woman's body belongs to herself, not to the fetus. Doesn't the woman have the right to use her own body as she wants? Can the mother's decision to terminate the pregnancy be considered an unfair killing for the fetus? The body that hosts the child is the mother's body. The fetus' right to life does not give it the right to forcibly use and continue to use someone else's body. The woman has no responsibility and no duty to keep the fetus alive when her own body is threatened. Moreover, in cases where the woman cannot control her own fertility, when she is forced to terminate the pregnancy voluntarily or involuntarily, how can it be morally defended that the pregnancy is voluntarily terminated by miscarriage or abortion when the woman has no choice but to exercise her right of disposition over her body?

Keywords: Women's Rights, Abortion, Abortion Right, Fetus.

ÖZET

Yaşam hakkı, temel insan haklarının başında gelmekte olup diğer bütün hakların kullanımı yaşam hakkının korunduğu hallerde mümkündür. Uluslararası sözleşmeler ve ulusal hukuk sistemleri, yaşama hakkını temel haklar olarak tanımışsa da bu hakkın sınırlarının yasalarla çizilebileceğini de kabul etmişlerdir. Yaşam hakkı, çağdaş hukuk sistemlerinde kişiyi ırk, yaş, inanç, cinsiyet gibi birbirinden farklı kılan unsurlar göz ardı edilerek, herkes için eşit olarak korunur. Ancak mesele, hukuk sisteminin kişiyi haklara ve borçlara ehil gören o herkesten biri kılmasıdır. Bu noktada da yaşam hakkının başlangıç anı, sadece hukuken değil etik açısından tartışmalı bir hal alır. Bu sunumda anne ve fetüsün yaşama haklarının yarışması tartışılmıştır.

Anahtar Kelimeler: Anne, fetüs, kişiliğin başlangıcı, kürtaj

Giriş

Anne çocuk ilişkisi, neredeyse kadının en güçlü kimliğidir. Zira Kadın, çoğu kültür de sadece anne kimliği ve doğurganlığıyla tanımlanır. Çalışmamızda anne ve doğmamış çocuğu arasındaki ilişkiyi, Kişiliğin özellikle fetüsün yaşam hakkının başlangıcını da dikkate alarak yaşam hakkı bağlamında

annenin yaşama hakkıyla fetüsün yaşama hakkı ve yaşam ilişkisi açısından insan hakları bağlamında tartışarak, hak çatışması olduğunda ise üstün yararlı hakkın korunması noktasında tartışmaya açmaktayız.

Temel Haklar Ekseninde Yaşama Hakkı ve Sınırları

Yaşama hakkı, insan haklarının temelidir. Zira yaşamayan kimsenin yararlanabileceği bir hak yoktur. Birleşmiş Milletler İnsan Hakları Bildirgesi'nin 4'üncü maddesinde "herkesin yaşam, özgürlük ve kişi güvenliği hakkı" olduğu esası benimsenmiş olup 25'inci maddede ise "yaşam hakkının güvencesi olarak bireyin, kendisinin ve ailesinin sağlığı ve refahı için yeterli bir yaşam standardına sahip olma hakkının olduğu, bu hakkın, yiyecek, giyim, barınma, tıbbi bakım ve gerekli sosyal hizmetleri de içerdiği, işsizlik, hastalık, sakatlık, dul kalma, yaşlılık veya kontrolü dışında gelişen diğer geçim kaynaklarından yoksun kalma durumlarında güvence hakkına" da sahip olduğu kabul edilmiştir.

Avrupa İnsan Hakları Sözleşmesi'nin 2'inci maddesinde "herkesin yaşam hakkının yasayla korunacağı, yasanın ölüm cezası ile cezalandırdığı bir suçtan dolayı hakkında mahkemece hükmedilen bu cezanın infaz edilmesi dışında, hiç kimsenin yaşamına kasten son verilemeyeceği, bir kimsenin yasa dışı şiddete karşı korunmasının sağlanması; bir kimsenin usulüne uygun olarak yakalanmasını gerçekleştirme veya usulüne uygun olarak tutulu bulunan bir kişinin kaçmasını önleme veya bir ayaklanma veya isyanın yasaya uygun olarak bastırılması sebebiyle meydana gelen öldürmelerin bu hükmün ihlali anlamı taşımayacağı" esasları benimsenmiştir.

Amerika Birleşik Devletleri Temel Haklar Bildirgesi'nin 7'inci maddesinde "hiç kimsenin hukukun öngördüğü usuller izlenmeksizin yaşam hakkından mahrum edilmeyeceği", Afrika İnsan Hakları Bildirgesi'nin 6'ıncı maddesinde ise "her bireyin özgürlüğe ve can güvenliğine sahip olma hakkına sahip olduğu" esası benimsenmiştir.

Türk Anayasası'nda da sayılan ayrık haller dışında "kişinin yaşama hakkına, maddi ve manevi varlığının bütünlüğüne dokunulamayacağı" (Madde 15); "herkesin, yaşama, maddi ve manevi varlığını koruma ve geliştirme hakkına sahip olduğu, tıbbi zorunluluklar ve kanunda yazılı haller dışında, kişinin vücut bütünlüğüne dokunulamayacağı; rızası olmadan bilimsel ve tıbbi deneylere tabi tutulamayacağı; kimseye işkence ve eziyet yapılamayacağı; kimsenin insan haysiyetiyle bağdaşmayan bir cezaya veya muameleye tabi tutulamayacağı" (Madde17); "herkesin yaşamını sağlıklı ve dengeli bir çevrede sürdürme hakkına sahip olduğu" (Madde 56) kabul edilmiştir. Türk Hukukunda "meşru müdafaa hali, yakalama ve tutuklama kararlarının yerine getirilmesi, bir tutuklu veya hükümlünün kaçmasının önlenmesi, bir ayaklanma veya isyanın bastırılması veya olağanüstü hallerde yetkili merciin verdiği emirlerin uygulanması sırasında silah kullanılmasına kanunun cevaz verdiği zorunlu durumlarda meydana gelen öldürme fiilleri" de yaşam hakkının hukuka uygun ihlalleri olarak kabul edilmiştir (Anayasa madde 17).

Yaşam hakkının korunması gerektiği konusunda genel bir uzlaşma bulunmasına rağmen, yaşamın hangi aşamada başladığı ve bu hakkın kimler tarafından kullanılabileceği konusunda önemli görüş ayrılıkları bulunmaktadır.

Yaşam Hakkında Üstün Yarar Yarışması

Antik çağlarda Hammurabi Kanunlarında babasının borcu sebebiyle oğlunun hayatının güvence gösterilmesi mümkünken (Godbey,1905). Çağdaş hukuk sistemlerinde birleşilen nokta herkesin yaşam hakkına eşit olarak sahip olduğu kimsenin yaşamının bir diğerininkinden eksiz veya fazla önemli olmadığıdır. Başka bir ifade ile hiç kimsenin bir diğerinin ölümü pahasına yaşamasında kural olarak üstün yararı yoktur.

Yaşam hakkının sınırları sadece hayatta kalmaktan ibaret olmayıp vücut bütünlüğünü de içerir ve bu anlamda hiç kimse bir diğerini yaşatmak için organ nakline zorlanamaz. Palermo Protokol'ünün 3'üncü maddesinde, insan ticaretinin tanımına "organların alınması amacıyla kişilerin tedarik edilmesini, kaçırılmasını veya sömürülmesi" açıkça dahil edilmiştir.

Avrupa Konseyi İnsan Ticaretine Karşı Eylem Sözleşmesi'nin başlangıç hükümlerinde Palermo Protokolü ile benzer şekilde, kişilerin iradeleri sakatlanarak organlarının zorla veya hileyle alınması amacıyla ticaretinin yapılmasının engellemesi ve mağdurların korunması hedeflenmiştir. Uluslararası

Transplantasyon Derneği (TTS) ve Uluslararası Nefroloji Derneği (ISN) öncülüğünde hazırlanan 2008 tarihli İstanbul Deklarasyonu, dünya genelinde "nakil turizmi" (zengin hastaların yoksul ülkelerden organ satın alması) ve organ ticari faaliyetlerini küresel ölçekte kınayan ve tıbbi etik kurallarını belirleyen en güçlü uluslararası belgedir. Dünya Sağlık Örgütü (WHO) İnsan Hücresi, Dokusu ve Organ Nakline İlişkin Kılavuz İlkeleri'nde de organ bağışının tamamen gönüllü ve karşılıksız olması gerektiği, organların satılık birer meta haline gelemeyeceğini net bir şekilde savunulmuştur.

Türk Medeni Kanunu madde 23'de Türk Anayasası madde 15 ve 17'ye paralel olarak "kimsenin, hak ve fiil ehliyetlerinden kısmen de olsa vazgeçemeyeceği, aynı şekilde özgürlüklerinden de vazgeçemeyeceği veya onları hukuka ya da ahlâka aykırı olarak sınırlayamayacağı, yazılı rıza üzerine insan kökenli biyolojik maddelerin alınması, aşılanması ve nakli mümkünse de biyolojik madde verme borcu altına girmiş olandan edimini yerine getirmesi veya getirmemiş olmaması sebebiyle maddî ve manevî tazminat istemeyeceği" esasları kabul edilmiştir.

Organ ve Doku Alınması, Saklanması, Aşılanması ve Nakli Hakkında Kanun 1979 yılında 2238 Kanun numarası ile yürürlüğe girmiş olup canlıdan ve ölüden organ ve doku alınmanın sınırları çizilmiştir. Türk Ceza Kanunu madde 91'de organ ve doku ticareti nakli yapan aynı zamanda organ ve dokuyu satın alan kişinin eylemleri suç olarak kabul edilmiştir.

Hayatta Kalabilmek İçin Başkasının Yaşamına Son Verme

Meşru savunma hakkı haksız fiilde ve suçta aranan hukuka aykırılık unsurunu ortadan kaldırır. Türk Anayasası'nda (madde 17) meşru savunma halinde kalan kişinin yaşama hakkını ihlal etmiş kabul edilemeyeceği ve Türk Ceza Kanunu'nda (madde 25) meşru savunma halinde faile ceza verilemeyeceği esasları kabul edilmiştir.

Meşru savunmanın varlığından bahsedebilmek için faile yöneltilmiş bir saldırı aranacakken böyle bir saldırı olmadığı ancak "gerek kendisine gerek başkasına ait bir hakka yönelik olup, bilerek neden olmadığı ve başka suretle korunmak olanağı bulunmayan ağır ve muhakkak bir tehlikeden kurtulmak veya başkasını kurtarmak zorunluluğu ile ve tehlikenin ağırlığı ile konu ve kullanılan vasıta arasında orantı bulunmak koşulu ile işlenen fiillerden dolayı" da zorda kalan faile ceza verilmeyecektir (TCK madde 25) .

İlk kez 13. yüzyılda Thomas Aquinas tarafından meşru savunmayı gerekçelendirmek amacıyla geliştirilmiş olan çifte etki doktrinine (doctrine of double effect) göre; kişi doğrudan kötü bir eylemi, örneğin masum birini öldürmeyi amaçlayamazsa da kötü sonuç dolaylı olarak ortaya çıkıyor ve yeterince güçlü bir gerekçeyle haklılaştırılabiliyorsa buna izin verilebilecektir. (Mangan, 949).

Tartışmalar sadece etik açından ele alınmamış, yaşanan olayların yargıya yansıması sonucunda da yaşanmıştır. Örneğin; 1985 yılında Peru'daki And Dağları'na yapılan zorlu tırmanışta bacağı kırılan Joe Simson'dan ipi keserek ayrılan Simon Yates'in kararı etik ve hukuki tartışmalara yol açmıştır. (Holman, 2023). 1884 tarihli R v Dudley and Stephens davasında İngiliz mahkemelerinde, gemi kazasından kurtulan üç denizcinin açık denizde yirminci günde hayatta kalmak için dördüncü mürettebat üyesini öldürüp yemesini haklı sebep olarak görülmemiştir. (Simeone, 2001).

Başkasının Bedenine Bağımlı Yaşama Hakkı

Dünya genelinde ortaya çıkan tartışmalardan biri Siyam ikizleri olarak adlandırılan yapışık ikizlerin durumudur. Çoğunlukla uzun yaşama şansı olmayan yapışık ikizlerin hayati risk taşımasalar bile yaşam kalitelerinin zor olduğu kanaatimizce tartışmasızdır. Her ikisinin hayatta kalmasının imkânsız olduğu durumlarda birinin yaşayabilmesi için diğerinin feda edilmesi haklı bir sebep midir, ya da yapışık yaşamalarında hayati risk olmayan durumlarda insan onuru için doğru olan biri veya her ikisi için de riski göze alarak ayrılmaları mı olacaktır, eğer öyleyse bu konuda karar vermeye kim yetkili olmalıdır, tüm bu sorularının cevabı hukuken ve etik açısından sorgulanmaya değerdir. (Paris & Elias-Jones, 2001).

Yaşam hakkının bir başkasının bedeni ile bağımlı olması noktasında ortaya çıkan tartışmaların en görünür olduğu alanlardan biri de kürtaj meselesidir. Kürtaj, yalnızca tıbbi bir müdahale değil; aynı zamanda insan yaşamının başlangıcı, bireysel özgürlük, insan onuru ve devletin koruma yükümlülüğü gibi temel sorunları içeren çok boyutlu bir etik ve hukuki meseledir.

Bir görüşe göre insan yaşamı döllenme anından itibaren başlamaktadır ve fetüs gelişimin erken aşamasındaki bir insan varlığıdır (George & Tollefsen, 2008). Bu yaklaşım açısından fetüsün yaşamına son verilmesi, potansiyel bir insan yaşamının ortadan kaldırılması anlamına gelmektedir. Bununla birlikte çağdaş etik teoriler arasında fetüsün hangi aşamada tam ahlaki statü kazanacağı konusunda ortak bir görüş bulunmamaktadır. Bilinç, duyarlılık ve yaşama yeteneği gibi farklı ölçütler ileri sürülmektedir (Warren, 1973).

Gebeliğin üçüncü ayından itibaren ana rahmindeki canlıya cenin ya da fetus adı verilmektedir. Ceninin yaşama hakkını, anne kendi bedeninde sağlamaktadır. Bu hak, annenin yaşama hakkıyla çatıştığında, anne ve cenin arasında kimin tercih edilmesi gerekeceği konusu hem ahlaki ve hem de hukuki bir meseledir. Zira annenin yaşama hakkı ile fetüsün yaşama hakkı çatışabilecektir.

Anne ve fetüsün yaşam hakları yarıştığında, başka bir ifade ile birinin yaşaması diğerinin ölmesine bağlı ise kimin yaşayacağına kim karar verecektir, örneğin annenin zaten ölümcül bir hastalığa sahip olması durumunda fetüsün yaşaması mı tercih edilmelidir, ya da fetüsün yaşama kapasitesi düşük bir hastalıkla dünyaya geliyor olması durumunda annenin yaşam hakkı fetüsün yaşam hakkına üstün mü görülecektir, her ikisinin de sağlıklı olması durumunda kimin hayatı diğerinden üstündür sorularının cevabı hukuken de etik açısından da görecelidir.

Türk Medeni Kanunu'nda fetüsün hak özneliğinin başlangıcı tamamıyla doğduğu anda sağ olmasına bağlanmış ve cenin sadece müstakbel bir hak süjesi olarak kabul edilmiştir. Ana rahminde ölen bir cenin de her hâlükârda dünyaya getirilecekse de hak süjesi olarak kabulü mümkün değildir (TMK madde 28). Bu anlamda ölü doğan çocuğun nüfus kütüğüne kaydı dahi yapılmayacak ve herhangi bir hakkı olduğundan bahsedilemeyecektir (NHK madde 15/7). Söz gelimi tam ve sağ doğan çocuk doğumun peşi sıra hayatını kaybetse de mirasçılık haklarından yararlanıp ölümü sonrasında kendisine kalan terekeyi kendisine mirasçı olan kişilere bırakabilecekken ölü doğan çocuğun mirasçılığından ve kendi mirasçılarından bahsedilemeyecektir (TMK madde 582/2).

Fetüsün müstakbel kişiden ibaret görülmesi yaşam hakkı tartışmalarını da gündeme getirmiştir. Bu anlamda Türk Ceza Kanunu'nda ananın rızası olmaksızın gebeliğin herhangi bir evresinde çocuğun düşürtülmesi ile rızaya dayalı olsa bile "tıbbi zorunluluk bulunmadığı halde on haftadan büyük olan çocuğunu düşürtülmesi "suç olarak kabul edilmiştir (TCK madde 99/1-2). Kadının mağduru olduğu bir suç sonucu gebe kalması halinde ise, süresi yirmi haftadan fazla olmamak ve kadının rızası olmak koşuluyla, gebeliği hastane ortamında sona erdiren uzman hekimlere ceza verilmeyecektir (TCK madde 99/6). Gebelik süresi on haftadan fazla olan bir kadının çocuğunun düşürülmesine izin vermesi (TCK madde 99/2) veya kadının çocuğunu isteyerek bizzat düşürmesi (TCK madde 100) de suç olarak kabul edilmiştir.

Bununla beraber, ciddi bir tehlikede bulunan ananın hayatı, cerrahi müdahaleyi veya gebeliğe son verebilecek bir tedaviyi gerektiriyorsa ananın hayatını kurtarmak için gebeliğin sonlandırılması mümkündür ve bu durumda fetüsün ne kadar büyük olduğu önem taşımaz. Başka bir ifade ile yaşam hakları yarıştırıldığında ananın yaşam hakkı henüz tam ve sağ doğmamış olmakla kişi olarak kabul edilmeyen fetüsün yaşam hakkına tercih edilmiştir (Tıbbi Deontoloji Nizamnamesi, madde 22).

Etik ve hukuki anlamda ortaya çıkabilecek diğer bir problem, annenin yaşam hakkının doğum sebebi ile yaşamsal bir risk taşımadığı halde bedeni üzerindeki egemenlik hakkının fetüsün yaşam hakkı ile yarıştırılmasında ortaya çıkabilecektir.

SONUÇ

Yaşama hakkının, insan haklarının en başında yer alması, yaşama hakkı ile ilintili birçok problemin de hukuken ve etik açıdan tartılmasını doğurmuştur. Yaşama hakkı tartışmaları fetüsün yaşama hakkını gündeme getirmiştir. Kürtaj meselesi, etik, felsefe, hukuk, teoloji, sosyoloji, psikoloji ve demografi gibi birçok bilim açısından doğrudan veya dolaylı olarak sonuçları olabilecek tıbbi bir müdahale halidir. Bu

müdahale tıbbi açıdan yetkin kişilerce ve yasal koşullar altında gerçekleştirilebilecek iken yasa dışı yollarla yetkin olmayan kişilerce de yapılabilmektedir. Bir tercihten öteye fetüsün, dünyaya getirilmesinin annenin yaşama hakkını ihlal etmesi durumunda kürtaj annenin hayatta kalabilmesi için bir zorunluluktur.

Türk Hukukunda kişiliğin içe doğru korunması kişinin kendisinden korunması anlamına gelir ki kişi hak ve fiil ehliyetlerinden vaz geçemez veya onları hukuka ya da ahlâka aykırı olarak sınırlayamaz. Bu anlamda hukukumuzda kişinin yaşama hakkına kendi isteği ile feragat etmesi mümkün olmayıp, kişiye koşulları sağlanmış olsa dahi ötanazi hakkı tanınmamıştır. Annenin isteği kendi canı pahasına çocuğun yaşaması yönünde de olsa, tıbbi mevzuatımız buna izin vermemektedir. Esasen bu durum tam ve sağ doğmadığı sürece çocuğu hak öznesi olarak tanımlamayan Medeni Kanun ile de örtüşmektedir.

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SYNTHESIS AND SELECTIVE METAL EXTRACTION PERFORMANCE OF A MORPHOLINE-FUNCTIONALIZED AZOCALIX[4]ARENE

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ABSTRACT

In this study, a novel morpholine-functionalized azocalix[4]arene derivative **(5)** was synthesized and its metal ion extraction performance was systematically evaluated. The structure of the compound was fully elucidated by ^{1}H NMR, FTIR spectroscopy, and elemental analysis, confirming the cone conformation of the calix[4]arene scaffold. The compound was designed with azo groups at the upper rim and morpholine-amide moieties at the lower rim, providing a preorganized cavity decorated with soft nitrogen and hard oxygen donor sites. Liquid-liquid extraction experiments were performed using a modified Pedersen method in a chloroform/water biphasic system at neutral pH against twelve metal perchlorates (Na^{+}, K^{+}, Mg^{2+}, Sr^{2+}, Ag^{+}, Hg^{2+}, Co^{2+}, Ni^{2+}, Pb^{2+}, Cr^{3+}, Al^{3+}, La^{3+}).

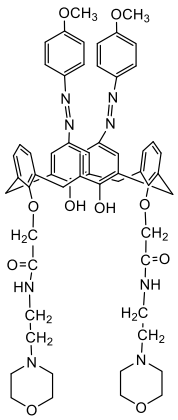


Figure 1. Chemical structure of compound **(5)**

The extraction results revealed outstanding selectivity toward Hg^{2+} (93.1%), followed by Cr^{3+} (86.4%) and Al^{3+} (78.8%). In contrast, alkali (Na^{+}, K^{+}) and alkaline earth metals (Mg^{2+}, Sr^{2+}) were extracted very poorly (0.4–6.8%), demonstrating exceptional chemoselectivity. The remarkably high affinity for Hg^{2+} is rationalized by strong soft-soft interactions between the mercury(II) cation and the nitrogen donors of the morpholine rings and amide linkages (HSAB principle). The high extraction of Cr^{3+} and Al^{3+} arises from hard-hard interactions with the amide carbonyl and phenolic oxygen atoms. The low extraction of alkali and alkaline earth metals is attributed to their unfavorable charge density and mismatch with the cavity's donor set. These findings demonstrate that compound **(5)** is a highly selective and versatile supramolecular host for the removal of toxic heavy metals from aqueous environments.

Keywords: Calix[4]arene, metal extraction, mercury selectivity, host-guest chemistry, morpholine, cone conformation

SYNTHESIS AND THERMAL DECOMPOSITION BEHAVIOR OF A NOVEL MORPHOLINYL-FUNCTIONALIZED AZOCALIX[4]ARENE

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ABSTRACT

In this study, a new amide-functionalized azocalix[4]arene derivative bearing morpholinyl groups was successfully synthesized and its thermal decomposition behavior was investigated in detail. The target compound, 5,11,17,23-tetrakis[(4-ethylphenyl)azo]-25,26,27-trihydroxy-28-[2-(morpholin-4-yl)ethylamino-2-oxoethoxy]calix[4]arene, was prepared via amide bond formation under reflux conditions and characterized by ^{1}H NMR, FTIR, HRMS and elemental analysis. The ^{1}H NMR spectrum supported a partial cone conformation. HRMS analysis confirmed the molecular structure with a monoisotopic peak at m/z = 1123.5558 $[M+H]^+$.

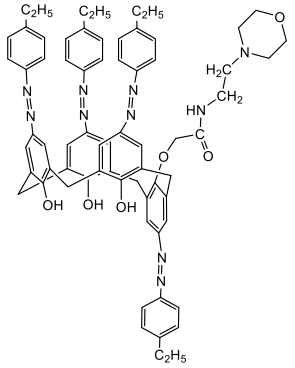


Figure 1. Chemical structure

The thermal behavior was systematically investigated by thermogravimetric (TG) and differential thermal analysis (DTA) under nitrogen atmosphere. The thermogram exhibited a well-defined stepwise degradation pathway. The first step, occurring between 50-150°C, corresponds to the removal of trapped acetonitrile molecules from the macrocyclic cavity, confirming the host-guest inclusion capability of the calixarene scaffold. The second step, observed in the range of 250-400°C, is attributed to the cleavage of peripheral ethyl groups and morpholinyl ether linkages. The final step, above 450°C, involves the complete collapse of the calix[4]arene core structure. Each degradation step was accompanied by characteristic endothermic and exothermic peaks in the DTA curve.

Unlike conventional calix[4]arene derivatives that typically focus solely on upper-rim azo functionalization or lower-rim alkylation separately, our design uniquely integrates three key features in a single molecular architecture: upper-rim azo chromophores, lower-rim morpholinyl group, and an amide linkage. This combination is unprecedented in the literature and offers distinct advantages for thermal stability and host-guest chemistry. The presence of the morpholinyl-amide tether not only enhances the cavity's preorganization but also provides additional coordination sites. These structural innovations position our synthesized macrocycle as a promising and versatile platform for future applications in supramolecular sensing, selective recognition, and thermally responsive materials. The findings open new avenues for designing next-generation calixarene-based hosts with tunable thermal properties.

Keywords: Azocalix[4]arene, thermal decomposition, host-guest chemistry, morpholinyl group, TG/DTA

INVESTIGATION OF THE RELATIONSHIP BETWEEN PAIN, STRESS, AND LIFESTYLE FACTORS IN FEMALE UNIVERSITY STUDENTS WITH AND WITHOUT BRUXISM SYMPTOMS

BRUKSİZM SEMPTOMU OLAN VE OLMAYAN KADIN ÜNİVERSİTE ÖĞRENCİLERİNDE AĞRI ŞİDDETİ, TEMPOROMANDİBULAR BOZUKLUK SEMPTOMLARI, UYKU KALİTESİ VE ALGILANAN STRESİN KARŞILAŞTIRILMASI

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ABSTRACT

The aim of this study was to comparatively investigate pain, stress, and lifestyle factors in female university students with and without bruxism symptoms. A total of 121 female students (54 with bruxism symptoms and 67 without bruxism symptoms) studying at Pamukkale University were included in the study (mean age: 21.52 years). Data were collected from participants via an online questionnaire. After recording participants' age, height, weight, and body mass index (BMI), lifestyle factors including smoking and alcohol use, pillow height preference (low, medium, or high), and daily phone usage duration (hours) were assessed. Bruxism symptoms were evaluated using the Bruxism Assessment Questionnaire, temporomandibular joint pain intensity was assessed using the Visual Analog Scale (VAS), and perceived stress levels were measured using the Perceived Stress Scale. The normality of the data was assessed using the Kolmogorov-Smirnov test and skewness values. Independent samples t-tests or Mann-Whitney U Test were used for group comparisons of continuous variables, while categorical variables were analyzed using the Chi-square test. No significant differences were found between the groups in terms of BMI, smoking, alcohol, and medication use ($p > 0.05$). Regarding pillow height preference, medium pillow use was significantly more common in the group without bruxism symptoms ($p = 0.018$). Perceived stress levels and VAS scores were significantly higher in the group with bruxism symptoms ($p = 0.01$ and $p = 0.00$). In conclusion, female university students with bruxism symptoms demonstrated higher perceived stress levels and temporomandibular joint pain intensity. In terms of lifestyle factors, a significant difference was observed only in pillow height preference between the groups. These findings suggest that, in the assessment and management of bruxism, psychosocial factors and pain symptoms should be considered in addition to lifestyle factors.

Keywords: Bruxism; stress; pain; university students; female

ÖZET

Bu çalışmanın amacı, bruksizm semptomu olan ve olmayan kız üniversite öğrencilerinde ağrı, stres ve yaşam tarzı faktörlerini karşılaştırmalı olarak incelemektir. Çalışmaya Pamukkale Üniversitesinde öğrenim gören toplam 121 kız öğrenci (54 bruksizm semptomu olan ve 67 bruksizm semptomu olmayan) dahil edilmiştir (ortalama yaş: 21,52 yıl). Veriler, katılımcılardan çevrim içi bir anket aracılığıyla toplanmıştır. Katılımcıların yaş, boy, vücut ağırlığı ve vücut kütle indeksi (VKİ) kaydedildikten sonra; sigara kullanımı, alkol tüketimi, yastık yüksekliği tercihi (alçak, orta veya yüksek) ve günlük telefon kullanım süresi (saat) gibi yaşam tarzı faktörleri değerlendirilmiştir. Bruksizm semptomları Bruksizm Değerlendirme Anketi ile, temporomandibular eklem ağrı şiddeti Görsel Analog Skala (VAS) ile ve algılanan stres düzeyi Algılanan Stres Ölçeği ile değerlendirilmiştir. Verilerin normal dağılıma uygunluğu Kolmogorov-Smirnov testi ve çarpıklık (skewness) değerleri kullanılarak değerlendirilmiştir. Sürekli değişkenlerin gruplar arası karşılaştırılmasında bağımsız örneklem t-testi veya Mann–Whitney U testi, kategorik değişkenlerin analizinde ise Ki-kare testi kullanılmıştır. Gruplar arasında VKİ, sigara kullanımı, alkol tüketimi ve düzenli ilaç kullanımı açısından anlamlı bir farklılık bulunmamıştır ($p > 0,05$). Yastık yüksekliği tercihi açısından ise orta yükseklikte yastık kullanımı, bruksizm semptomu olmayan grupta anlamlı düzeyde daha yaygındı ($p = 0,018$). Algılanan stres düzeyi ve VAS skorları, bruksizm semptomu olan grupta anlamlı olarak daha yüksekti (sırasıyla $p = 0,01$ ve $p = 0,00$). Sonuç olarak, bruksizm semptomu olan kız üniversite öğrencilerinin algılanan stres düzeylerinin ve temporomandibular eklem ağrı şiddetlerinin daha yüksek olduğu belirlenmiştir. Yaşam tarzı faktörleri açısından ise gruplar arasında yalnızca yastık yüksekliği tercihinde anlamlı bir farklılık saptanmıştır. Bu bulgular, bruksizmin değerlendirilmesi ve yönetiminde yaşam tarzı faktörlerinin yanı sıra psikososyal faktörlerin ve ağrı semptomlarının da dikkate alınması gerektiğini göstermektedir.

Anahtar Kelimeler: Bruksizm, stres, ağrı, üniversite öğrencileri, kız öğrenciler

INTRODUCTION

Bruksizm, Amerikan Orofasiyal Ağrı Akademisi tarafından "Dişlerin kenetlenmesi, gıcırdatılması, öğütülmesi ve kuvvetli şekilde sıkılması ile karakterize uyku ya da uyanık durumda görülen parafonksiyonel bir aktivite" olarak tanımlanmaktadır (Medicine, 1997). Fizyolojik olmayan diş sıkma ve gıcırdatma davranışı olarak ortaya çıkan bruksizm uyku sırasında veya uyanıklık döneminde ortaya çıkabilmektedir. Bruksizm dişlerde aşınma ve kırıklara, diş mobilitesi, çiğneme kasları ve temporomandibular eklem (TME) bölgesinde ağrı gibi klinik problemlere neden olabilir (Murali ve ark., 2015).

Bruksizm her yaşta gözlenebilmekle birlikte özellikle 20-50 yaş arası kadınlarda daha sık ortaya çıktığını bildirilmiştir ve genç yaştaki popülasyonda yaygın olarak görülmektedir (Shetty ve ark., 2010). Bu nedenle genç bireylerin dahil edildiği çalışmalarda üniversite öğrencileri çalışmanın popülasyonunu oluşturmuştur. Diş hekimliği ve tıp fakültesi öğrencilerinin dahil edildiği çalışmalar bruksizm ile ilişkili dental problemlerin yüksek prevalansa sahip olduğu bildirmiştir. Ayrıca, çene ağrısından yakınan üniversite öğrencilerinin yaklaşık %90,7'sinde bruksizm saptanmıştır (P. Cavallo ve ark., 2016). Bu bulgular, üniversite öğrencilerinin bruksizm ve buna bağlı komplikasyonlar açısından önemli bir risk grubu olduğunu desteklemektedir (Soares ve ark., 2017).

Bruksizmin etyopatogenezi henüz tam olarak açıklığa kavuşturulamamış olsa da güncel literatürde çok faktörlü bir yapıya sahip olduğu bildirilmektedir. Oklüzal özellikler ve orofasiyal bölgenin anatomik yapısı gibi biyolojik faktörlere ek olarak, anksiyete ve stres gibi psikososyal faktörler ile uyku bozuklukları ve genetik yatkınlık gibi patofizyolojik süreçlerin de santral mekanizmalar aracılığıyla bruksizmin ortaya çıkışında rol oynadığı bildirilmektedir (Lobbezoo ve ark., 2006). Bruksizm tek başına bir hastalık olarak kabul edilmese de diş aşınmaları, dental hasarlar, temporomandibular eklem ağrısı açısından potansiyel bir risk faktörü olarak değerlendirilmektedir (Garrett & Hawley, 2018).

Bruksizm ile ilgili psikososyal teori incelendiğinde, stres ve kişilik yapısının bruksizm üzerinde önemli bir etkiye sahip olduğunu ileri sürülmüş, günlük hayattaki streslerin bruksizm şiddetini ve sıklığını artırdığı bildirilmiştir (Ahlberg ve ark., 2004). Bununla birlikte birçok araştırmacı bruksizmin anksiyete

ve strese karşı reaktif bir yanıt olduğunu savunmaktadır (Pingitore ve ark., 1991; Rugh, 1975). Yakın zamanda yapılan bir çalışmada, öz bildirime dayalı bruksizm ile psikolojik bozukluklar (stres ve anksiyete) arasında tutarlı bir ilişki olduğu gösterilmiştir. Ayrıca, akademik performansa bağlı stresin bruksizm ve çene ağrısı ile ilişkili olduğu bulunmuş, bu durum söz konusu faktörler arasında bir bağlantı olduğunu düşündürmüştür. Tükürük kromogranin A düzeyi kullanılarak stresin değerlendirildiği bir çalışmada ise stres, anksiyete ve bruksizm arasında pozitif bir ilişki olduğu bildirilmiştir (Abekura ve ark., 2011). Bunun yanı sıra, öz bildirime dayalı bruksizm bildiren katılımcıların Algılanan Stres Ölçeği-10 (PSS-10) ve Beck Anksiyete Envanteri (BAI) puanlarının daha yüksek olduğu gösterilmiştir (Pierpaolo Cavallo ve ark., 2016).

Psikolojik faktörlerin yanı sıra çeşitli yaşam tarzı alışkanlıklarının da bruksizm ile ilişkili olabileceği düşünülmektedir. Sigara kullanımının bruksizm ile ilişkisini açıklamak için nikotinin dopaminerjik sistemi aktive etmesi, santral sinir sistemi uyarılabilirliğini artırması ve çiğneme kası aktivitesini etkilemesi gibi mekanizmalar öne sürülmektedir. Sigara kullanımının nikotin, asetilkolin ve glutamat aracılı sinaptik iletimi uyardığı ve dopamin salınımını artırdığı; bu nörokimyasal etkilerin, bruksizmin ortaya çıkış mekanizmasında rol oynayabileceği düşünülmektedir (Rintakoski ve ark., 2010). Bazı araştırmacılar sigara içmenin, çiğneme kası aktivitesinde artış ile pozitif yönde ilişkili olduğunu bildirmiştir (Bertazzo-Silveira ve ark., 2016). Bununla birlikte, bu iki faktör arasında bir ilişki olmadığını ileri süren çalışmalar da mevcuttur (Hilgenberg-Sydney ve ark., 2022). Benzer şekilde, psikolojik faktörlerin bruksizm ile sigara kullanımı arasındaki ilişki üzerindeki etkisi de henüz tam olarak açıklığa kavuşturulamamıştır. Sigara kullanan bireyler, sigara içmenin stresi azaltmaya yardımcı olduğunu sıklıkla bildirmekte (Berlin ve ark., 2003) ve sigaranın potansiyel anksiyolitik (kaygı azaltıcı) etkilerine ilişkin görüşler de bulunmaktadır (Buckner ve ark., 2020). Bir diğer yaşam tarzı faktörü olan alkol tüketiminin de bruksizmi tetikleyebilecek potansiyel etmenlerden biri olduğu öne sürülmektedir. Alkolün merkezi sinir sistemi üzerindeki depresan etkileri, uyku mimarisini değiştirerek uyku sırasında motor aktivitenin normal düzenlenmesini bozabilmektedir (Carvalho ve ark., 2019). Bu durum, uyku bruksizmi ataklarının sıklığını artırarak daha ciddi dental ve kas-iskelet sistemi sorunlarının ortaya çıkmasına katkıda bulunabilir (Bertazzo-Silveira ve ark., 2016). Ancak mevcut kanıtlar, bu olumsuz etkilerin özellikle yüksek düzeyde alkol tüketimi veya alkol kötüye kullanımı olan bireylerde daha belirgin olduğunu göstermektedir. (Ronsivalle ve ark., 2024).

Akıllı telefon kullanımının uzun süreli fleksiyon postürüne neden olarak servikal bölge kas aktivitesini artırabileceği ve kas-iskelet sistemi semptomlarına katkıda bulunabileceği bildirilmektedir (Hansraj, 2014; Xie ve ark., 2020). Bunun yanı sıra, akıllı telefon kullanımının yalnızca fiziksel etkilerle sınırlı kalmayıp psikolojik stres ve uyku kalitesi üzerinde de olumsuz sonuçlar doğurabileceği belirtilmektedir (Elhai ve ark., 2017; Sohn ve ark., 2019). Buna karşın, telefon kullanım süresi ile bruksizm arasındaki doğrudan ilişkiyi inceleyen çalışmalar sınırlıdır. Mevcut literatürde, kullanım süresinden ziyade akıllı telefon kullanımına bağlı psikolojik stresin bruksizm gelişiminde daha önemli bir rol oynayabileceği öne sürülmektedir. Nitekim Divya Lalitha ve ark. (2024), akıllı telefonunu kullanamadığında stres yaşayan öğrencilerde bruksizm prevalansının anlamlı düzeyde daha yüksek olduğunu bildirmiştir. Benzer şekilde, Mitova ve Dimitrova (2025), artan ekran süresinin uyku bruksizmi ile ilişkili olabileceğini; ancak bu ilişkinin büyük ölçüde uyku kalitesi ve psikolojik stres gibi aracı faktörlerden etkilendiğini belirtmiştir. Bu bulgular, akıllı telefon kullanım süresinin tek başına bruksizm gelişimini açıklamak için yeterli olmayabileceğini ve akıllı telefon kullanımına bağlı psikolojik ve davranışsal faktörlerin de dikkate alınması gerektiğini göstermektedir.

Son yıllarda uyku ergonomisi ile ilişkili faktörlerin de bruksizm üzerindeki olası etkileri araştırılmaktadır. Uygun olmayan yastık kullanımı servikal postürü olumsuz yönde etkileyerek servikal kaslarda yüklenmeye neden olabilir. Servikal kas aktivitesindeki artışın temporomandibular sistem üzerindeki biyomekanik etkileri göz önüne alındığında, uygun uyku pozisyonu ve yastık seçiminin bruksizm semptomlarını dolaylı olarak etkileyebileceği düşünülmektedir. Bununla birlikte bu ilişkiyi doğrulayan doğrudan kanıtlar sınırlıdır (Lobbezoo ve ark., 2018; Ren ve ark., 2016).

Mevcut literatürdeki bu boşluk doğrultusunda, bu çalışmanın amacı bruksizm semptomu olan ve olmayan kız üniversite öğrencilerinde ağrı şiddeti, algılanan stres düzeyi ve yaşam tarzı faktörlerini karşılaştırmalı olarak incelemektir.

MATERYAL VE METOD

Çalışmamız, 2025-2026 Eğitim Öğretim Yılı bahar döneminde gerçekleştirilmiştir. Çalışmaya Pamukkale Üniversitesi'nde öğrenimine devam eden, 18-30 yaş aralığında, bruksizm semptomu olan ve bruksizm semptomu olmayan kız üniversite öğrencileri dahil edildi. Katılmcılara Google Forms üzerinden oluşturulan anketin ilk sayfasında araştırmanın amacı, kapsamı, gönüllülük esasları, gizlilik ve veri güvenliği hakkında bilgilendirme yapıldıktan sonra, 'Araştırmaya gönüllü olarak katılmayı kabul ediyorum' seçeneğini işaretleyen katılımcılar ankete yönlendirildi. Bu çalışma, Pamukkale Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu tarafından (Karar No: E-60116787-020-887455) onaylanmıştır.

Çalışmaya diş sıkma şikâyeti olan, hikayesinde temporomandibular eklem bölgesine majör travma şikâyeti bulunmayan, temporomandibular eklem cerrahi operasyonu geçirmemiş olan, 18-30 yaş aralığında, çalışmaya katılmayı kabul eden bireyler dahil edildi. Temporomandibular eklem bölgesine yönelik majör travma öyküsünün bulunan, temporomandibular eklem cerrahisi geçirmiş, tanı almış nörolojik/psikiyatrik hastalık öyküsünün bulunması veya düzenli psikiyatrik ilaç kullanım olan, son 6 ay içerisinde ortodontik tedavi gören, 18 yaş altı veya 30 yaş üstü katılımcılar çalışmadan dışlandı. Bruksizm semptomlarının varlığı "Bruksizm Tespit Anketi"nden elde edilen sonuçlara göre belirlendi. Daha önce yapılan çalışmaların sonuçlarında, bruksizmi olan bireyler anket sorularından en az ikisine pozitif cevap vermiştir. Bu veriler dikkate alınarak, en az iki pozitif cevap veren bireyler bruksizm semptomu olan katılımcılar, ikiden daha az soruya pozitif cevap veren katılımcılar bruksizm semptomu olmayan katılımcılar olarak çalışmaya dahil edilmiştir.

Tüm katılımcılar tek bir zaman noktasında değerlendirildi. Değerlendirme ölçütleri aşağıda sunulmuştur:

1. Sosyodemografik faktörler (yaş, boy, kilo, vücut kitle indeksi (VKİ) ve yaşam tarzı faktörleri (sigara kullanımı, alkol kullanımı, yastık yüksekliği, günlük telefon kullanım süresi)

2. Bruksizm semptomları, Bruksizm Tespiti Anketi kullanılarak değerlendirildi. Hastaların bruksizm varlığı/yokluğu, sıklığı, semptom varlığı (çiğneme kaslarında ağrı, yorgunluk hissi vb.) değerlendirilmiştir. Toplam 10 sorudan oluşan anket formunun evet/hayır olarak cevap formatı bulunmaktadır. Yapılan çalışma sonuçlarına göre bruksizmi olan bireyler anket sorularından en az ikisine pozitif cevap vermiştir. Bu veriler dikkate alınarak, en az iki pozitif cevap veren bireyler ağız içi bulguları da değerlendirilerek çalışma grubuna dâhil edilmiştir (GJ, 1995; Paesani & Andersen, 2010; Rugh & Harlan, 1988).

3. Ağrı, Vizüel analog skala (VAS) kullanılarak değerlendirildi. VAS 0 ila 10 puan arasında değişen puanlarla (0= ağrı yok, 10= maksimum ağrı) ağrı algısını değerlendirmek için kullanılır. Katılımcılardan temporomandibular bölgesi ve çevresinde hissettiği ağrıyı puanlamaları istenmiştir. Katılımcılardan sabah uyandıklarındaki ağrı seviyeleri, istirahat durumundaki ağrı seviyeleri, çiğneme sırasındaki ağrı seviyeleri, temporomandibular bölge aktiviteleri konuşma, gülme vb.) sırasındaki ağrı seviyelerini işaretlemeleri istenmiştir (Reips & Funke, 2008).

4. Katılımcıların stres düzeyleri, bir öz-bildirim raporu olan Algılanan Stres Ölçeği kullanılarak değerlendirilmiştir. Ölçek; Cohen, Kamarck ve Mermelstein (Cohen ve ark., 1983) tarafından geliştirilmiştir. On dört maddeden oluşan, 5'li Likert tipi ölçek; kişinin öznel olarak birtakım durumları ne ölçüde stresli algıladığını ölçmektedir. Ölçek maddelerinden 7'si tersten puanlanmaktadır. Ölçekten alınan toplam puan kişinin stres düzeyini belirtmektedir. Orijinal ölçek, birçok araştırma tarafından geçerli ve güvenilir (0,84 – 0,86) bir ölçek olarak değerlendirilmektedir. Ölçeğin Türkçe adaptasyonu Eskin vd. (2013) tarafından yapılmıştır. Türkçe ölçeğin iç tutarlık katsayısı 0,84 ve test-tekrar-test güvenirliği 0,87 olarak bulunmuştur (Chiu ve ark., 2016; Eskin ve ark., 2013).

İstatistiksel Analiz

Araştırmada elde edilen veriler IBM SPSS Statistics 25 programı kullanılarak analiz edilmiştir. Katılımcılara ait sosyodemografik özellikler ile ölçeklerden elde edilen puanlar tanımlayıcı istatistiklerle (ortalama ± standart sapma, medyan [minimum–maksimum] ve yüzde) özetlenmiştir. Verilerin dağılımı Kolmogorov–Smirnov testi ve çarpıklık (skewness) ile değerlendirildi. Normal

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dağılım gösteren değişkenlerde iki grup arasındaki farkın incelenmesinde bağımsız örneklem t-testi, normal dağılım göstermeyen değişkenlerde ise Mann–Whitney U testi kullanıldı. Kategorik değişkenler arasındaki ilişkiler Ki-kare (χ^2) testi ile değerlendirildi.

BULGULAR

Çalışmaya toplamda 121 öğrenci dahil edildi (Grup 1 – Bruksizm semptomları olmayan – 67 kişi, Grup 2 – Bruksizm semptomları olan – 54 kişi). Tablo 1 katılımcıların demografik özellikleri (yaş, boy, kilo, VKİ) göstermektedir. Mevcut araştırmaya katılan öğrencilerin yaş ortalaması (Grup 1: 21,40±1,76, Grup 2: 21,68±1,78).

Tablo 1. Katılımcıların Sosyodemografik Bilgileri

	Grup 1 (n=67)		Grup 2 (n=54)		p
	Ort±SS	Min-Maks	Ort±SS	Min-Maks	
Yaş	21,40±1,76	18,00-25,00	21,68±1,78	19,00-25,00	0,38[t]
Boy	164,44±6,06	148,00-182,00	163,70±4,52	155,00-174,00	0,45[t]
Kilo	60,22±12,64	43,00-100,00	61,46±10,71	49,00-90,00	0,39[U]
VKİ	22,18±3,99	16,53-34,89	22,93±3,92	18,22-34,29	0,25[t]

Ort: Ortalama, SS: Standart Sapma, Grup 1: Bruksizm semptomu olmayan kız öğrenciler, Grup 2: Bruksizm semptomu olan kız öğrenciler, VKİ: Vücut Kitle İndeksi, p: Bağımsız gruplar t testi, [U]: Mann Withney U testi

Katılımcıların günlük telefon kullanım süresi, ağrı düzeyleri ve algılanan stres puanları Tablo 2'de gösterilmektedir. Bruksizm semptomu olan ve olmayan katılımcılar karşılaştırıldığında ağrı düzeyi ve algılanan stres düzeyi bruksizm semptomu olan grupta daha yüksekti.

Tablo 2. Katılımcıların telefon kullanım süresi, ağrı ve algılanan stres puanlarının karşılaştırması

	Grup 1 (n=67)		Grup 2 (n=54)		p
	Ort±SS	Min-Maks	Ort±SS	Min-Maks	
Telefon kullanım süresi	5,58±2,32	1,00-16,00	5,62±1,81	2,00-10,00	0.62[U]
VAS1 (sabah ağrısı)	,88±5,87	0,00-4,00	3,33±5,11	0,00-8,00	0,00*[U]
VAS2 (istirahat ağrısı)	,56±1,26	0,00-5,00	2,85±2,03	0,00-7,00	0,00*[U]
VAS3 (çiğneme sırasındaki ağrı)	,76±1,10	0,00-6,00	2,96±2,24	0,00-8,00	0,00*[U]
VAS4 (konuşma/gülme sırasındaki ağrı)	,86±1,31	0,00-6,00	2,38±2,28	0,00-9,00	0,00*[U]
Algılanan Stres Puanı	19,41±1,42	0,00-34,00	22,05±2,13	14,00-40,00	0,01*[t]

Ort: Ortalama, SS: Standart Sapma, Grup 1: Bruksizm semptomu olmayan kız öğrenciler, Grup 2: Bruksizm semptomu olan kız öğrenciler, VKİ: Vücut Kitle İndeksi, [t]: Bağımsız gruplar t testi, [U]: Mann Withney U testi

Yastık yüksekliği tercihi açısından, orta yükseklikte yastık kullanımı bruksizm semptomu olmayan grupta anlamlı düzeyde daha fazlaydı (p = 0,018).

Tablo 3. Katılımcıların yaşam tarzı faktörlerinin karşılaştırılması

	Grup 1 (n=67)			Grup 2 (n=54)			p
	Evet		Hayır	Evet		Hayır	
Sigara kullanımı	9 (%13,4)		58 (%86,6)	8 (%14,8)		46 (%85,2)	0,51
Alkol kullanımı	10 (%14,9)		57 (%85,1)	10 (%18,5)		44 (%81,5)	0,38
Düzenli ilaç kullanımı	8 (%11,9)		59 (%88,1)	6 (%11,1)		48 (%88,9)	0,56
	Alçak	**Orta**	**Yüksek**	**Alçak**	**Orta**	**Yüksek**	**p**
Yastık kullanımı	5 (%7,5)	58 (%86,6)	4 (%6,0)	12 (%22,2)	35 (%64,8)	7 (%13,0)	0,018*

Grup 1: Bruksizm semptomu olmayan kız öğrenciler, Grup 2: Bruksizm semptomu olan kız öğrenciler, p: Ki-kare testi

TARTIŞMA

Bu çalışmaya Pamukkale Üniversitesi'nde öğrenim gören 121 bruksizm semptomu olan ve olmayan kız öğrenci dahil edilmiştir. Bulgularımıza göre, bruksizm semptomu olan kız öğrencilerin temporomandibular eklem ağrı düzeyleri (sabah ağrısı, istirahat ağrısı, çiğneme sırasında ağrı ve konuşma/gülme sırasında ağrı) ve algılanan stres puanları anlamlı düzeyde daha yüksektir. Yastık yüksekliği tercihinde ise orta yükseklikte yastık kullanımının bruksizm semptomu olmayan grupta daha yaygın olduğu bulunmuştur. Telefon kullanım süresi ve diğer yaşam tarzı faktörleri açısından (sigara, alkol, ilaç kullanımı) açısından gruplar arasında fark gözlenmemiştir.

Çalışmamızda bruksizm semptomu olan bireylerde temporomandibular bölgeye ilişkin ağrı düzeylerinin daha yüksek bulunması mevcut literatür ile uyumludur. Bruksizm sırasında çiğneme kaslarında meydana gelen tekrarlayıcı ve yüksek şiddetli kas aktivitesi, kas yorgunluğu, miyofasiyal ağrı ve temporomandibular eklem üzerine binen mekanik yükün artmasına neden olabilmektedir. Bu durum özellikle sabah ortaya çıkan kas ağrısı ve fonksiyon sırasında hissedilen ağrıyı açıklayabilir. Huhtela ve ark. (2016), üniversite öğrencilerinde öz bildirime dayalı bruksizmin temporomandibular bozukluk semptomları ile anlamlı düzeyde ilişkili olduğunu göstermiştir (Huhtela ve ark., 2016). Benzer şekilde Alves ve ark. (2013), bruksizmin çiğneme sistemi üzerinde önemli biyomekanik yük oluşturduğunu ve ağrı ile fonksiyonel bozuklukların gelişimine katkıda bulunduğunu bildirmiştir (Alves ve ark., 2013). Dolayısıyla çalışmamızda sabah ağrısı, istirahat ağrısı ve çiğneme ile konuşma sırasında ağrı düzeylerinin yüksek bulunması, bruksizmin kas-iskelet sistemi üzerindeki olumsuz etkilerini desteklemektedir.

Algılanan stres düzeylerinin bruksizm semptomu olan grupta daha yüksek olması, bruksizmin psikososyal bileşenini destekleyen önemli bir bulgudur. Günümüzde bruksizm biyolojik, psikolojik ve davranışsal faktörlerin birlikte rol oynadığı multifaktöriyel bir durum olarak kabul edilmektedir. Manfredini ve Lobbezoo (2009), psikososyal faktörlerin özellikle uyanıklık bruksizminin etiyolojisinde önemli rol oynadığını ve stres, anksiyete ile emosyonel yüklenmenin parafonksiyonel çene aktivitelerini artırabileceğini belirtmiştir (Manfredini & Lobbezoo, 2009). Ayrıca Lobbezoo ve ark. (2018), uluslararası konsensus raporunda bruksizmi tek başına bir hastalık olarak değil, bazı klinik durumlar açısından risk veya koruyucu faktör olabilen bir davranış olarak tanımlamış ve psikolojik faktörlerin değerlendirilmesinin önemini vurgulamıştır (Lobbezoo ve ark., 2018). Bulgularımız literatürle uyumlu olarak, üniversite öğrencilerinde stres düzeyinin artmasının bruksizm semptomlarının ortaya çıkması veya şiddetlenmesi ile ilişkili olabileceğini göstermektedir. Özellikle üniversite öğrencilerinde akademik stres, sınav kaygısı ve sosyal uyum süreçleri gibi stres kaynakları, algılanan stres düzeyini ve bruksizm semptomlarını tetiklemiş olabilir.

Çalışmamızda orta yükseklikte yastık kullanımının bruksizm semptomu olmayan grupta daha yaygın olduğu belirlenmiştir. Yastık yüksekliği ile bruksizm arasındaki ilişkiyi doğrudan inceleyen çalışmalar oldukça sınırlı olmakla birlikte, yastığın baş-boyun biyomekaniğini etkileyebildiği bilinmektedir. Ren

ve ark. (2016), farklı yastık yüksekliklerinin servikal omurga dizilimi, kraniyoservikal basınç dağılımı ve baş-boyun kompleksinin biyomekaniğini değiştirebildiğini göstermiştir (Ren ve ark., 2016). Servikal omurganın nötral pozisyonunun korunması kas aktivitesinin azalmasına katkı sağlayabileceğinden, uygun yastık yüksekliği dolaylı olarak temporomandibular sistem üzerindeki mekanik yüklenmeyi etkileyebilir. Bununla birlikte Murali ve ark. (2015), bruksizmin multifaktöriyel yapısı nedeniyle tek bir mekanik faktör ile açıklanamayacağını vurgulamıştır (Murali ve ark., 2015). Orta yükseklikte yastık kullanımının bruksizm semptomu olmayan grupta daha sık görülmesi, gelecekteki araştırmalar için ön bilgi sağlasa da daha konu ile ilgili daha fazla çalışmaya ihtiyaç vardır.

Sigara kullanımı, alkol tüketimi ve düzenli ilaç kullanımı açısından gruplar arasında anlamlı farklılık saptanmamıştır. Sigara ve alkol kullanımının merkezi sinir sistemi üzerindeki etkileri nedeniyle bruksizm gelişiminde rol oynayabileceği ileri sürülmekle birlikte, bu konuda literatürde çelişkili sonuçlar bulunmaktadır. Rintakoski ve ark. (2010), genç erişkinlerde sigara kullanımı ile öz bildirime dayalı bruksizm arasında pozitif ilişki bildirmiştir (Rintakoski ve ark., 2010). Bununla birlikte mevcut çalışmada bu ilişkinin gösterilememiş olması, katılımcıların genç ve homojen bir popülasyondan oluşması ile sigara ve alkol kullanım oranlarının düşük olmasına bağlı olabilir. Ayrıca bruksizmin ortaya çıkmasında psikolojik faktörlerin yaşam tarzı değişkenlerinden daha baskın rol oynayabileceği de göz önünde bulundurulmalıdır. Çalışmamızda genç yaş grubu ve düşük kullanım oranları da bu sonucun nedeni olabilir.

Günlük telefon kullanım süresi açısından gruplar arasında anlamlı farklılık bulunmamıştır. Akıllı telefon kullanımının uzun süreli fleksiyon postürü oluşturması nedeniyle servikal bölge kas aktivitesini artırabileceği ve kas-iskelet sistemi problemlerine katkıda bulunabileceği bilinmektedir. Ancak telefon kullanım süresi ile bruksizm arasındaki doğrudan ilişkiye yönelik kanıtlar sınırlıdır. Bununla birlikte, literatürde telefon kullanım süresinin değil, akıllı telefon kullanımına bağlı psikolojik stresin bruksizm gelişiminde daha önemli bir rol oynayabileceğini gösteren çalışmalar bulunmaktadır. Divya Lalitha ve ark. (2024), akıllı telefonunu kullanamadığında stres yaşayan öğrencilerde bruksizm prevalansının anlamlı derecede daha yüksek olduğunu göstermiştir (Divya Lalitha ve ark., 2024). Bu durum, bruksizm gelişiminde kullanım süresinden çok akıllı telefon kullanımına bağlı psikolojik stresin daha önemli bir belirleyici olabileceğini düşündürmektedir. Benzer şekilde Mitova ve Dimitrova (2025), ekran süresindeki artışın uyku bruksizmi ile ilişkili olabileceğini, ancak bu ilişkinin büyük ölçüde uyku kalitesi ve psikolojik stres gibi aracı faktörlerden etkilendiğini belirtmiştir (Mitova & Dimitrova, 2025). Bu doğrultuda, çalışmamızda günlük telefon kullanım süresinin gruplar arasında benzer bulunması, kullanım süresinden çok akıllı telefon kullanımına bağlı psikolojik yük, bağımlılık düzeyi veya uyku kalitesi gibi değişkenlerin bruksizm üzerinde daha belirleyici olabileceğini düşündürmektedir. Bu nedenle, yalnızca günlük telefon kullanım süresinin değerlendirilmesi, akıllı telefon kullanımının bruksizm üzerindeki olası etkisini açıklamak için yeterli olmayabilir.

Çalışmamızın bazı limitasyonları mevcuttur. Öncelikle, araştırmanın yalnızca kız üniversite öğrencileri üzerinde yürütülmüş olması nedeniyle elde edilen bulgular erkek öğrenciler ve farklı yaş gruplarına genellenememektedir. Ayrıca, çalışmanın kesitsel tasarımı değişkenler arasındaki nedensel ilişkilerin değerlendirilmesine olanak vermemektedir. Bruksizm semptomları öz bildirime dayalı olarak değerlendirilmiş olup, polisomnografi veya elektromiyografi gibi objektif tanı yöntemleri kullanılmamıştır.

Gelecekte yapılacak çalışmalarda, daha objektif değerlendirme ve tanı yöntemlerinin kullanılması ve farklı cinsiyet ile yaş gruplarını içeren daha geniş örneklemlerle araştırmaların yapılması önerilmektedir. Ayrıca, akıllı telefon kullanım süresine ek olarak kullanım amacı, bağımlılık düzeyi ve telefona erişememeye bağlı stres gibi davranışsal faktörlerin değerlendirilmesi, bruksizm üzerindeki etkilerin daha ayrıntılı incelenmesine katkı sağlayabilir. Benzer şekilde, yastık kullanımında yalnızca yüksekliğin değil, materyal, sertlik ve uyku pozisyonu gibi özelliklerin de ele alınması, bruksizmin biyopsikososyal ve biyomekanik yönlerinin daha kapsamlı değerlendirilmesine olanak sağlayacaktır.

SONUÇ

Sonuç olarak, bruksizm semptomu olan kız üniversite öğrencilerinde temporomandibular eklem ağrı şiddeti ve algılanan stres düzeyinin daha yüksek olduğu belirlenmiştir. Buna karşın, sigara kullanımı,

alkol tüketimi, düzenli ilaç kullanımı ve günlük telefon kullanım süresi gibi yaşam tarzı faktörleri açısından gruplar arasında anlamlı farklılık saptanmamıştır. Elde edilen bulgular, bruksizmin biyopsikososyal yapısını desteklemekte ve özellikle psikososyal faktörlerin değerlendirilmesinin önemini ortaya koymaktadır. Bununla birlikte, yaşam tarzı faktörlerinin ve akıllı telefon kullanımına bağlı davranışsal ve psikolojik faktörlerin bruksizm semptomları üzerindeki etkilerinin daha ayrıntılı olarak incelenmesi gerekmektedir.

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EFFICACY OF SENSORIMOTOR EXERCISES AND WHOLE-BODY VIBRATION ON CERVICAL DEEP FLEXOR ENDURANCE, RANGE OF MOTION, AND POSTURAL PARAMETERS IN YOUNG ADULTS WITH CHRONIC NECK PAIN: A RANDOMIZED CONTROLLED TRIAL

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Objective: To compare the effects of sensorimotor exercises (SME) and whole-body vibration (WBV) on cervical deep flexor endurance, cervical range of motion (CROM), and postural parameters in young adults with chronic non-specific neck pain.

Methods: Thirty-six university students aged 18–30 years with chronic non-specific neck pain were randomly assigned to either an SME group or a WBV group. Both interventions were applied three times per week for four weeks, totaling 12 sessions. Outcome measures included the Deep Neck Flexor Endurance Test (DNFET), craniovertebral angle (CVA), cervicothoracic angle (CTA), and active cervical range of motion. Statistical analyses were performed to evaluate within-group and between-group differences following the interventions.

Results: No significant baseline differences were observed between the groups ($p>0.05$). Within the SME group, significant improvements were found in DNFET ($p<0.001$), CVA ($p=0.001$), CTA ($p=0.048$), flexion ($p=0.001$), extension ($p=0.007$), right lateral flexion ($p=0.007$), left lateral flexion ($p<0.001$), right rotation ($p<0.001$), and left rotation ($p<0.001$). Within the WBV group, significant improvements were observed only in CTA ($p=0.038$) and right rotation ($p=0.025$), whereas changes in DNFET, CVA, flexion, extension, right and left lateral flexion, and left rotation were not statistically significant ($p>0.05$). Between-group comparisons demonstrated a significant difference favoring the SME group only for left lateral flexion ($p=0.007$).

Conclusions: Both interventions produced beneficial effects in young adults with chronic neck pain. However, SME demonstrated greater effectiveness than WBV in improving cervical muscle endurance, cervical mobility, and postural alignment. These findings suggest that progressive SME may provide a more comprehensive neuromuscular rehabilitation approach for individuals with chronic neck pain.

Keywords: Keywords: Chronic neck pain; Sensorimotor exercise; Whole-body vibration; Cervical range of motion; Deep neck flexor endurance; Postural alignment.

Introduction

Chronic neck pain (CNP) is a significant health issue with a global prevalence ranging from 0.4% to 86.8%, ranking fourth in global disability rankings (Guzman et al., 2009). Its etiology is complex, encompassing a multifaceted interaction of ergonomic, individual, behavioral, and psychosocial factors (Genebra et al., 2017). In most cases, a clear patho-anatomical cause cannot be identified; this condition, localized between the T1 spinous process and the posterior superior nuchal line without indicating a specific pathology, is defined as "non-specific neck pain" (Hidalgo et al., 2017). When symptoms persist for more than three months, it is classified as "non-specific chronic neck pain" (Cohen, 2015; Murray et al., 2012). In young adults, the 12-month prevalence is reported to be between 42% and 67% (Algarni et al., 2017; Almhdawi et al., 2017), with the widespread use of smartphones (Lee and Seo, 2014) and the adoption of sedentary lifestyles identified as major risk factors. Indeed, research indicates that physical activity levels decrease while sedentary behaviors increase significantly upon entering university (Peterson et al., 2018; Deliens et al., 2015).

The complex interplay of factors contributing to neck pain makes it difficult to define their relationship with pain outcomes, often directing treatment approaches toward symptom management rather than underlying mechanisms (Kazeminasab et al., 2022; Misailidou et al., 2010). However, addressing these underlying mechanisms within rehabilitation programs is of critical importance. Somatosensory and neuromuscular impairments are frequently reported in patients with chronic neck pain (Walton et al., 2011; Mahmoud et al., 2019), with cervical proprioception deficits increasingly recognized as a primary contributing factor (Treleaven, 2008; Treleaven, 2017). These sensorimotor alterations manifest as reduced muscle endurance, impaired proprioceptive and kinesthetic sense, and disrupted muscle activation patterns (Cagnie et al., 2007; Stenneberg et al., 2017). Individuals with non-specific mechanical neck pain experience pain, restricted range of motion, and limitations in functional activity and participation, collectively reducing quality of life (Jaeschke et al., 1989; Sihawong et al., 2011) and imposing a substantial socioeconomic burden (Leininger et al., 2018). Treatment costs for neck pain are estimated to account for 0.05–2% of gross domestic product and are projected to continue rising (Cheng et al., 2015). Additionally, decreased deep cervical flexor activation, poor craniocervical flexion test performance, and suboccipital muscle atrophy have been associated with pain and postural control deficits. Maladaptive emotional and cognitive responses, including pain catastrophizing and kinesiophobia, are also prevalent in this population (Lee et al., 2015). Comprehensive assessment of somatosensory, proprioceptive, and neuromuscular factors is therefore essential for developing effective treatment strategies.

While exercise intervention is accepted as an effective method for treating CNP, the superiority of any specific exercise type over traditional approaches in improving proprioception and reducing pain and disability has not yet been clearly established (Southerst et al., 2016; Bertozzi et al., 2013); therefore, a holistic approach that combines traditional and sensorimotor exercises (SME) is recommended to address the root causes of abnormal cervical inputs by integrating proprioceptive, visual, and vestibular inputs to maintain head posture and stability (Treleaven, 2008; Saadat et al., 2019). Although studies on SME specifically for the cervical region remain limited, existing research shows that these interventions lead to reduced neck pain, increased range of motion, lower self-reported disability levels, and improvements in general health (Saadat et al., 2019; Mazidi et al., 2021; Sun et al., 2024). Furthermore, vibration, applied either locally to specific muscles or as whole-body vibration (WBV), has emerged as another effective intervention to stimulate proprioceptors and reduce pain in patients with neck pain (Beinert et al., 2015; Cardinale and Bosco, 2003; Collado-Mateo et al., 2015). While clinical reports support the efficacy of local muscle vibration (Beinert et al., 2019; Aggarwal et al., 2024) and current research indicates that cervical muscles are stimulated during WBV training (Perchthaler et al., 2015; Wang et al., 2014), evidence for WBV in patients with CNP remains limited, positioning it as a potential treatment option. Given that moderate-to-high quality evidence supports the effectiveness of exercise in the management of neck pain (Hidalgo et al., 2017; Gross et al., 2012; Lluch et al., 2014) and

sensorimotor approaches are known to improve deficits such as joint position sense and postural balance (Jull et al., 2007; Beinert and Taube, 2013; Saadat et al., 2019; Aslıyüce et al., 2022), the existing literature's predominant focus on older adults leaves a gap, especially as the rapid proliferation of technology and sedentary lifestyles render neck pain a growing concern among younger populations. Accordingly, this study aimed to compare the effectiveness of a SME program and a WBV intervention on postural cervical deep flexor muscle endurance and CROM in young individuals with chronic neck pain.

Methods

Study Design and Participants

Conducted between 2025 and 2026 at Pamukkale University (Faculty of Physiotherapy and Rehabilitation), this randomized controlled trial investigated male and female students (aged 18–30) with neurosurgeon-diagnosed chronic non-specific neck pain. Participants were recruited via online brochures. G*Power software (V.3.1.7, University of Kiel, Germany) determined that a minimum of 14 participants per group was needed for 80% statistical power ($\beta = 0.20$) at $\alpha = 0.05$; thus, 36 individuals were enrolled to absorb a predicted 25% dropout rate (Saadat et al., 2019). Inclusion required a neck pain history of at least three months and a VAS score ≥ 3.5 cm (Boonstra et al., 2014). Conversely, exclusion criteria comprised recent neck therapies, cervical musculoskeletal disorders (e.g., impingement, scoliosis), systemic pathologies (malignancies, tumors, fractures), neurological/psychiatric conditions, assistive aids, previous trauma/surgery, active vertebral artery disease, radiculopathy, dizziness, and uncorrected visual impairment. Participants with under 80% session attendance were excluded from final analyses due to insufficient compliance (Bush et al., 2000). The Helsinki-compliant trial was approved by the local Clinical Research Ethics Committee (Approval: E-60116787-020-664846) and registered at ClinicalTrials.gov (NCT07564492). All subjects provided written informed consent after a thorough briefing on the study's scope, risks, and voluntary nature.

Outcome Measures

CROM Assessment

Active CROM including flexion, extension, right and left rotation, and right and left lateral flexion was evaluated using the Baseline CROM Deluxe device. This instrument consists of two gravity dependent goniometers and a head mounted compass dial to provide measurements across three anatomical planes. During the evaluations, participants sat with their feet flat on the floor, hands resting on their thighs, and pelvis in a neutral position. Participants were instructed to perform active movements at a constant speed while keeping the back and shoulders stable. Upon completion of each movement, participants returned to the neutral position for a rest period lasting between five and ten seconds (Bush et al., 2000).

Cervical Deep Flexor Muscle Endurance

The Deep Neck Flexor Endurance Test (DNFET) measured how long participants could sustain deep cervical flexor muscle activation, which is central to cervical stabilization (Bush et al., 2000). Participants lay supine in a hook-lying position, hands on the abdomen. Before testing, the craniocervical flexion movement was explained, demonstrated, and practiced, followed by a five-minute rest to reduce learning effects and fatigue (Aslıyüce et al., 2022). During the test, participants tucked their chin, lifted their head roughly 2.5 cm off the surface, and held that position as long as possible, with time recorded in seconds. The test ended if participants lost proper form, let their head drop, reported a sharp increase in pain, or asked to stop (Domenech et al., 2011).

Postural Assessment: Cervicothoracic and Craniovertebral Angle Measurements

Posture was assessed photogrammetrically using a digital camera to capture lateral images of anatomical landmarks marked with reflective stickers, which were analyzed using image processing software (Lee and Seo, 2014). The CTA measures scapular protraction as the angle between the line from the tragus to the C7 spinous process and the line from C7 to T4. The CVA measures forward head posture as the angle between a horizontal reference line and the line from the ear tragus to the C7 spinous process,

with smaller values reflecting greater anterior head displacement (Domenech et al., 2011; Salahzadeh et al., 2014; Sajjadi et al., 2014; Raine and Twomey, 1997).

Interventions & Treatment Protocol

Following baseline assessments, participants with chronic neck pain will be randomized into two parallel intervention groups using a computer-generated allocation sequence. Both programs will be delivered over a four-week period, consisting of 12 sessions scheduled at a frequency of three days per week. To ensure protocol standardization and mitigate injury risk, each session will commence with a 10-minute warm-up of active ROM exercises and conclude with a cool-down period featuring dynamic stretching.

SME Protocol

Participants in the SMT group completed a progressive SME protocol structured across three stages according to individual performance and tolerance. Session duration increased from 12–15 to 20 minutes, and exercise volume progressed from 5–7 to 10–12 repetitions, with 1–3 minutes of rest between sets. Six components were included: (1) eye-neck coordination — tracking wall-mounted targets using eye movements alone while a head-mounted laser pointer confirmed head stability; (2) oculomotor exercises — beginning with isolated eye movements, advancing to head rotation with sustained visual fixation, and finally to simultaneous contralateral eye and head movements; (3) static balance — progressively narrowing the base of support and transitioning from a stable surface to a foam pad; (4) dynamic balance — maintaining postural control during timed ball-catching and throwing tasks; (5) deep neck flexor strengthening — isometric contractions against a wall-mounted exercise ball in a craniocervical flexion position; and (6) combined exercises — squats performed while tracking a target with the laser pointer (Saadat et al., 2019; Aggarwal et al., 2024).

WBV Protocol

Participants in Group 2 completed a WBV protocol using the Compex Winplate™ platform, which transmits vertical mechanical oscillations through the soles of the feet. Participants stood barefoot and held the handrails lightly; removing footwear prevented attenuation of the vibration stimulus. Frequency was fixed at 30 Hz and amplitude at 4 mm. Training was conducted three times per week for four weeks (12 sessions), with session duration progressing from 12–15 to 20–25 minutes. Each session included 10 bouts of 30 seconds with 30-second rest intervals between them. Difficulty advanced every four sessions across three levels, adjusted to each participant's tolerance. Level 1 covered static balance: double-leg standing, 15° mini-squats, and step-forward stance (30 s × 5 repetitions each). Level 2 moved to dynamic balance: step-forward stance, tandem stance, single-leg stance, and single-leg standing with bilateral ball transfer (30 s × 5 repetitions each). Level 3 introduced the most demanding tasks: single-leg standing while catching or throwing a ball, lunge, deep squat, and quadruped with hands on the platform (Wang et al., 2014).

Statistical Analysis

Statistical analyses were performed using SPSS (Version 26.0), with data normality assessed via the Shapiro-Wilk test. Continuous variables are expressed as mean ± standard deviation or median (Q1–Q3) based on distribution, and categorical variables as frequencies. Within-group comparisons were conducted using the paired-samples t-test, Wilcoxon signed-rank test, or Stuart–Maxwell test according to data type and distribution. Between-group comparisons were evaluated using the independent-samples t-test, Mann-Whitney U test, and chi-square test.

Results

There was no statistically significant difference between the SME and WBV groups in terms of age, weight, height, BMI, and NDI ($p>0.05$). Furthermore, no significant difference was found regarding the gender distribution between the groups ($p=0.732$). These findings indicate that the two groups shared similar demographic and clinical characteristics at the baseline; thus, demonstrating that the groups exhibited a homogeneous distribution.

Table 1. Baseline demographic characteristics of the study groups.

Variables	SME (n=18)	WBV (n=18)
Age (years)	22.00 (20.00-23.00)	20.50 (18.50-21.75)
Weight (kg)	66.39 ± 14.20	62.61 ± 15.44
Height (cm)	169.72 ± 9.65	170.50 ± 12.18
BMI (kg/m^2)	22.96 ± 4.05	21.21 ± 2.73
NDI	15.44 ± 4.88	15.00 ± 5.35
VAS	6.57 ± 0.89	6.16 ± 0.36
Sex	**n (%)**	**n (%)**
Male	6 (33.3%)	8 (44.4%)
Female	12 (66.7%)	10 (55.6%)

Min: minimum; max: maximum; kg: kilogram; cm: centimeter; kg/cm^2: kilogram/centimeter square; U: Man Whitney U test was used; t: t-test was used; χ^2: Chi-square test was used.

Within the SME group, significant pre-to-post-test improvements were observed in DNFET (p<0.001) and CVA (p=0.001), while CTA values showed no statistically significant change (p=0.533). In contrast, the WBV group demonstrated a significant increase in CTA (p=0.038), whereas changes in DNFET (p=0.285) and CVA (p=0.087) did not reach statistical significance (Table 2).

Table 2. Pre- and Post-Treatment DNFET, CVA, and CTA Values and Between-Group Δ Comparisons.

Variables	SME (n=18)			WBV (n=18)		
	Pretest	**Posttest**	**p**	**Pretest**	**Posttest**	**p**
DNFET	28.13±20.44	46.11±17.63	<0.001^{*,t}	43.18±35.14	51.12±43.36	0.285^{t}
CVA	56.45±4.60	59.13±4.28	0.001^{*,t}	56.72±4.07	58.17±5.09	0.087^{t}
CTA	117.85±9.45	119.73±17.28	0.048^{*,w}	117.19±9.34	121.76±14.19	p=0.038^{*,w}

*=p<0.05; SME: sensorimotor exercises; WBV: whole-body vibration; DNFET: Deep Neck Flexor Endurance Test; CVA: Craniovertebral Angle; CTA: Cervicothoracic Angle; t: t test was used; W: Wilcoxon signed-rank test; U: Man Whitney U test was used.

The SME group improved significantly across all cervical movement directions: flexion (p = 0.001), extension (p = 0.007), right lateral flexion (p = 0.007), left lateral flexion (p < 0.001), and both rotations (p < 0.001). The WBV group showed significant improvement only in right rotation (p = 0.025) (Table 3).

Table 3. Pre- and Post-Treatment Cervical ROM Values and Between-Group Δ Comparisons

Variables	SME (n=18)			WBV (n=18)		
	Pretest	**Posttest**	**p**	**Pretest**	**Posttest**	**p**
Flex	57.767±13.192	65.150±10.970	0.001^{*,t}	52.361±15.339	52.611±13.216	0.948^{t}
Exten	57.511±11.493	65.500±9.264	0.007^{*,t}	52.339±17.017	59.389±14.969	0.102^{t}
R-Lat Flex	43.056±9.311	49.78±6.20	0.007^{*,t}	33.528±9.043	38.00±8.73	0.256^{w}
L-Lat Flex	37.33±9.35	49.139±8.485	<0.001^{*,t}	35.28±9.71	39.194±7.857	0.080^{t}
R-Rot	57.444±9.211	65.22±7.60	<0.001^{*,t}	56.583±10.762	61.44±10.83	0.025^{*,t}
L-Rot	67.36±8.20	75.367±7.579	<0.001^{t}	68.56±11.25	69.611±11.464	0.725^{t}

*=p<0.05; CROM: Cervical Range of Motion; SME: sensorimotor exercises; WBV: whole-body vibration; R: Right; L: Left; Flex; Flexion; Exten: Extension; Lat: Lateral; Rot: Rotation; t:t test was used; W: Wilcoxon signed-rank test was used; U:Man Whitney U test was used; t:t-test was used.

Discussion

The primary objective of this study was to evaluate and compare the effects of a SME program versus WBV on cervical muscle endurance, craniocervicothoracic posture, and CROM in young university students with chronic neck pain. Our findings demonstrate that the SME program is significantly more effective than WBV in improving deep neck flexor endurance, craniocervicothoracic alignment (CVA and CTA), and comprehensive CROM in this population. To the best of our knowledge, this study represents the first investigation to compare the efficacy of sensorimotor training against WBV on these specific clinical outcomes within a young university student cohort.

After the four-week intervention, endurance improved significantly only in the SME group, whereas the WBV group showed a non-significant increase; accordingly, the between-group change did not reach statistical significance. The superior endurance outcomes in the SME group may be attributed to the fine motor control required for cervical spine movement during joint position exercises. These exercises involve low-force, high-precision tasks, which are ideal for activating low-threshold motor units within the deep neck flexor muscles. Our findings are consistent with existing literature suggesting that such targeted training protocols effectively enhance neck muscle endurance (Saadat et al., 2019). Conversely, the improvements in the WBV group were comparatively limited. Given the scarcity of research investigating the specific effects of WBV on these parameters in a young population, our study provides novel insights into the comparative efficacy of these interventions.

The CVA is recognized as a valid, objective indicator of forward head posture, where an increase in this angle signifies improved cervical alignment. Our findings revealed a statistically significant improvement in CVA within the SME group post-intervention, whereas the WBV group failed to reach statistical significance. Although the between-group comparison of delta values did not reach statistical significance ($p = 0.254$), the marked improvement in the SME group highlights the efficacy of multi-component exercise protocols in targeting spinal stability. Our results are consistent with existing literature supporting the positive impact of structured exercise interventions on FHP. For instance, Mazidi et al. reported that an 8-week SME program in women with chronic non-specific neck pain significantly improved CVA (Mazidi et al., 2021), attributing these changes to the strengthening of proprioceptive afferents, correction of muscular imbalances, and reorganization of motor programs within the central nervous system. Conversely, the lack of statistical significance in the WBV group suggests that WBV alone may not be a sufficient stimulus for postural correction in the cervical region; rather, it implies that augmenting vibration therapy with exercises targeting cervical stabilizers may be necessary to achieve optimal postural alignment.

Both groups improved significantly in CTA, with no between-group difference — comparable effects on cervicothoracic posture from two quite different interventions. Prior work supports the relevance of this region: thoracic kyphosis rehabilitation has been linked to short- and long-term reductions in neck pain and disability (Moustafa et al., 2022) and combining exercise with cervicothoracic self-mobilization has improved cervical muscle endurance and reduced perceived disability in chronic nonspecific neck pain (Sun et al., 2024). CTA improvement in the SME group was expected given the thoracic-region exercises in our protocol, though the literature offers little data on the specific magnitude of this effect, as most studies have concentrated on the CVA. The WBV group's improvement was less predictable. Mechanical vibration may enhance neuromuscular stimulation and facilitate paravertebral muscle activation; this mechanism was proposed in a fibromyalgia trial where WBV improved muscle contraction via neuromuscular spindle activation and was linked to postural correction (Collado-Mateo et al., 2015). The equivalence of outcomes despite different mechanisms suggests that both approaches are reasonable options when CTA is the target parameter.

When CROM results were examined, the SME group showed statistically significant improvements in all cervical movement directions compared to pre-treatment. A systematic review evaluating the efficacy of SME reported that interventions targeting cervical joint position sense have consistently positive

effects on cervical mobility in flexion, extension, lateral flexion, and rotation as measured by goniometry. In a randomized controlled pilot study by Nusser et al. in patients with chronic neck pain, virtual reality-based neck-specific SME produced statistically significant improvements in active cervical ROM, particularly in flexion and extension compared to the control group (Nusser et al., 2020), which is consistent with the comprehensive gains across all movement directions observed in our SME group. In the WBV group, a significant improvement was obtained only in right rotation ($p = 0.025$), with no statistically significant changes in other movement directions. We believe this pattern suggests that mechanical vibration stimulation may activate rotator muscle activity to a limited extent but does not produce the broader neuromuscular adaptation required for multi-directional ROM improvement. To our knowledge, this study is among the first to directly examine the effects of WBV on cervical ROM, as previous research has focused predominantly on the lumbar region. Rittweger et al. reported in a randomized controlled trial on patients with chronic low back pain that 12 weeks of WBV did not produce statistically significant increases in lumbar flexion and extension ROM (Rittweger et al., 2002), which supports the view that the direct effect of WBV on joint mobility may be limited regardless of the target region. Taken together, these findings indicate that while WBV may influence neuromuscular activation and pain modulation, its effect on ROM appears to vary by exercise type and region, and that SME provide a more comprehensive neuromuscular adaptation environment for resolving multi-directional cervical movement limitations.

Conclusion

This study compared the effects of a four-week progressive SME program with a WBV regimen in young adults with chronic non-specific neck pain. While both interventions yielded significant improvements in most analyzed parameters, the SME program demonstrated superior efficacy in enhancing CROM and muscular endurance. Although WBV showed comparable results to SME in correcting postural alignment its impact on cervical mobility remained limited. In conclusion, the four-week progressive SME program creates a more comprehensive environment for neuromuscular adaptation regarding postural control, muscular function, and multi-directional cervical mobility. Nevertheless, WBV serves as a viable alternative for postural correction. Given the diversity of exercises, capacity for progressive loading, and potential for comprehensive neuromuscular stimulation, SME should be prioritized in the rehabilitation of chronic neck pain, whereas WBV is best utilized as a complementary modality or in cases where active participation is restricted.

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CHILDHOOD TRAUMA AND THE DARK TRIAD: THE MEDIATING ROLE OF ALEXITHYMIA

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ABSTRACT

Childhood trauma has been associated with maladaptive personality traits and difficulties in emotional processing; however, the distinct mediating roles of negative and positive alexithymia in this relationship remain insufficiently understood. The present study examined whether negative and positive alexithymia mediated the relationships between childhood trauma and Dark Triad personality traits, namely Machiavellianism, narcissism, and psychopathy. The sample consisted of 466 adults, including 293 women (62.9%) and 173 men (37.1%), aged between 18 and 69 years (M = 31.38, SD = 12.23). Data were collected using a Demographic Information Form, the Childhood Trauma Questionnaire-33 (CTQ-33), the Perth Alexithymia Questionnaire (PAQ), and the Short Dark Triad Scale (SD3). Gender differences were examined using independent-samples *t* tests, associations among variables were evaluated through correlation analyses, and mediation models were tested using PROCESS Model 4. The results showed that men reported higher levels of physical neglect, physical abuse, Machiavellianism, and psychopathy, whereas women reported higher levels of sexual abuse. Childhood trauma was positively associated with both negative and positive alexithymia and showed significant positive associations with Machiavellianism and psychopathy. Mediation analyses indicated that negative alexithymia significantly mediated the relationship between childhood trauma and Machiavellianism, whereas positive alexithymia did not. For narcissism, neither negative nor positive alexithymia served as a significant mediator. In contrast, both alexithymia dimensions significantly mediated the relationship between childhood trauma and psychopathy, but in opposite directions: positive alexithymia strengthened this association, whereas negative alexithymia showed a suppressive indirect effect. These findings suggest that emotional processing difficulties may play distinct roles in the association between childhood trauma and specific Dark Triad traits.

Keywords: Childhood Trauma, Alexithymia, Dark Triad, Machiavellianism, Narcissism, Psychopathy.

THE MEDIATING ROLES OF MENTALIZATION AND NARCISSISTIC FLUCTUATION IN THE RELATIONSHIP BETWEEN ATTACHMENT STYLES AND SELF-FRAGMENTATION

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ABSTRACT

This study examined the mediating roles of mentalization and narcissistic fluctuation in the relationship between attachment styles and self-fragmentation. The sample consisted of 447 adults, including 300 women (67.1%) and 147 men (32.9%), aged between 18 and 71 years (M = 27.98, SD = 9.93). Data were collected using the Three-Dimensional Attachment Style Scale, the Fragmented Self Inventory, the Mentalization Scale, and the Grandiose and Vulnerable Narcissism Fluctuation Scale. Independent samples t-tests, Pearson correlation analyses, and parallel mediation analyses using PROCESS Macro Model 4 were conducted. Gender comparisons showed that men reported higher avoidant attachment, whereas women reported higher fragmented self, fragmented idealization, motivation to mentalize, and mentalization of self. Correlation analyses indicated that secure attachment was negatively associated with self-fragmentation, while avoidant and anxious attachment were positively associated with self-fragmentation and narcissistic fluctuation. Mediation analyses showed that mentalization of self was found as mediator across the models, whereas narcissistic fluctuation mediated the relationships between insecure attachment styles and both dimensions of self-fragmentation. Motivation to mentalize showed significant indirect effects in some models, while mentalization of others did not emerge as a mediator. In conclusion, the findings suggest that deficits in self-related mentalization and narcissistic instability may be key psychological mechanisms linking insecure attachment to self-fragmentation.

Keywords: Mentalization, Narcissistic Fluctuation, Attachment Styles, Self-Fragmentation

RETHINKING DIGITAL SOCIOLOGY IN THE AGE OF ALGORITHMIC CULTURE: A THEORETICAL REVIEW

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ABSTRACT

The rapid integration of artificial intelligence and algorithmic systems into daily routines has significantly altered the structural foundations of social interaction, identity formation, and power dynamics. This theoretical review aims to map out the recent conceptual shifts within digital sociology, focusing on how predictive algorithms reshape the contemporary social fabric. The scope of this paper is limited to key theoretical developments in the literature over the last decade, specifically examining the intersection of algorithmic culture, digital platform capitalism, and datafication. Methodologically, the study adopts a systematic literature review approach, synthesizing foundational theories of digital sociology with contemporary critical perspectives on automated decision-making and data surveillance. The preliminary insights generated by this review reveal that contemporary algorithms no longer merely reflect existing social structures; rather, they actively curate, simulate, and manipulate public discourse and social relationships, thereby giving rise to a highly commodified "link culture." Furthermore, the paper highlights that traditional sociological methodologies require an urgent epistemological update to critically capture the opaque nature of digital platforms. In this respect, by bridging classical sociological inquiries with the realities of the algorithmic era, this study offers an original theoretical framework and a comprehensive conceptual synthesis for researchers in digital sociology, media ecology, and communication sciences.

Keywords: Digital Sociology, Algorithmic Culture, Datafication, Platform Capitalism, Theoretical Review.

THE SHALLOWING OF ACTIVISM IN LINK CULTURE: INSTAGRAM'S "ADD YOURS" FEATURE AND SLACKTIVISM

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ABSTRACT

The transformation of digital networks and interface architectures profoundly shapes individuals' participation practices in social events, crises, and rights-seeking processes. The purpose of this study is to critically examine the phenomenon of "slacktivism"—defined as the act of easing one's conscience through a single click or share in the new media ecosystem—through Instagram's "Add Yours" feature, which integrates users into a chained interaction network. The scope of the research is limited to ephemeral "Story" formats that disappear within 24 hours due to the platform's nature, and it does not include an empirical field study measuring users' demographic or psychological motivations. The sample of the study consists of three different thematic templates that have recently entered mass circulation, selected through typical case sampling (the humanitarian crisis-focused "All Eyes on Rafah", AI-generated "End Femicide" templates focusing on rights violations, and eco-crisis-focused paw/nature-themed templates), alongside the interface button design that generates these templates. Methodologically, the study employs qualitative interface analysis and visual content analysis methods to critically examine the platform's interface design and visual content flows. The anticipated findings of the research indicate that the "Add Yours" mechanism reduces the threshold of taking action to a single click, creating a temporary sense of conscientious satisfaction and digital identity construction among individuals; however, it hinders permanent field activisms by transforming social movements into ephemeral interaction commodities consumed within 24 hours. In this respect, by deciphering the structural role assumed by platform architectures in the attenuation of social dissent, this study offers an original and conceptual contribution to the literature on digital sociology, Link Culture, and new media.

Keywords: Slacktivism, Add Yours, Link Culture, Interface Analysis, Digital Sociology.

CORPORATE SOCIAL RESPONSIBILITY IN ALBANIAN BUSINESSES: AWARENESS, ADOPTION, AND CHALLENGES

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ABSTRACT

It has been observed that businesses, production and service sectors, do not only create new wealth and increase welfare for owners and stakeholders but they are the main cause of negative externalities affecting individuals daily lives by polluting or degrading the quality of natural resources, products, air and human health, since the Industrial Revolution to the present day. Philanthropic acts by businessmen began at the end of the XIX century, but it was only in the 1950s that Corporate Social Responsibility (CSR) began to be discussed. In Albania, as in other Eastern European countries that experienced a planned economy, CSR was not mentioned because in the case where the state was the owner of enterprises, it was assumed that all profits would go to the community.

During the 1990s, new businesses in Albania were focused on their growth and finding markets. The scope for corporate social responsibility was a very futuristic concept at a time when most businesses were small and there was a lack of business management culture. Over the years, more and more enterprises have begun to publish their social reports, whether for reasons of improving the company's reputation and image by creating competitive advantages, or to increase transparency and improve relationships with stakeholders and the surrounding environment.

This paper aims to identify how many Albanian businesses have knowledge of and adopt Corporate Social Responsibility practices. What is their profile in terms of size? Which is the field of activity and age? Which are the areas they contribute to the society? In addition to the findings, businesses have also indicated the main problems and challenges that hinder a more comprehensive and deeper adoption of CSR.

Keywords: Corporate Social Responsibility, Albanian businesses, Stakeholders, Social responsibility practices.

INTRODUCTION

Since the Industrial Revolution, global economic development has been characterised by industrial development, technological innovation, and the expansion of production systems. All these transformations have significantly increased productivity, wealth creation, and living standards, while at the same time generating negative consequences. These consequences, arising from the relationship between economic growth and its social and environmental impacts, have led to a reassessment of the role of economic actors in society. Within this context of structural developments, the role of businesses has gradually evolved from a function purely oriented toward profit maximisation to a more complex understanding of corporate responsibility.

The concept of Corporate Social Responsibility (CSR) is not new at all. As far back as the late 1800s, wealthy industrialists were already donating money and funding community projects. It was largely unstructured, but it was a start, the first sign that businesses could do something beyond just chasing profit.

Bowen (1953) was one of the first academics to say this clearly: businesses should make decisions that reflect the values and needs of society, not just the interests of their owners. At that point, though, CSR was still seen mainly as a moral attitude rather than something built into how companies were run.

Davis (1960) added something important: the more powerful a company is, the more it should answer to society.

In contrast, Friedman (1970) argued that managers act as agents of shareholders and should use the company's resources in accordance with shareholders' interests. Direct engagement in social activities may constitute a deviation from this mandate and a misallocation of the firm's resources.

Carroll A. B (1979; 1991) further developed the concept of Corporate Social Responsibility (CSR). Initially, he introduced the three-dimensional conceptual model of corporate performance, and later the CSR Pyramid model, arguing that business responsibilities are structured into four levels: economic, legal, ethical, and philanthropic.

Freeman R. E. (1984) argued that the purpose of business is not only to maximise profits for shareholders but also to create value for all stakeholders, including employees, suppliers, customers, and the community. Later, Elkington (1997) argued that business performance cannot be measured solely in monetary terms. You also need to look at how it affects society and nature. He introduced the concept of the Triple Bottom Line. This concept became a cornerstone of the sustainability discourse.

Porter and Kramer (2006, 2011) argued that CSR is not just a moral obligation; it can also be a competitive advantage. Companies that act responsibly can come out stronger in the market. They also developed the concept of Creating Shared Value, where businesses generate economic and social value at the same time through their main activities, not as two separate things, but as one.

McWilliams and Siegel (2001) analyzed the relationship between CSR and financial performance, suggesting that CSR can be consistent with profit maximization when it is managed strategically. The study by Aguinis and Glavas (2012) highlights that CSR is associated with improved organizational performance, enhanced reputation, and stronger stakeholder relationships, but the results depend on the context and research methodology. Jamali (2007) pointed out that CSR works differently in developing countries, where institutions tend to be weaker.

In Europe, CSR has become deeply embedded in business culture and regulatory frameworks. Sustainability reporting requirements and the European Green Deal have further reinforced this development. In the Western Balkans, however, the situation is more complex, as countries in the region continue to face structural challenges inherited from the post-socialist transition. As a result, the level of CSR adoption varies significantly across countries.

In Albania, CSR has evolved more slowly and has largely developed as an imported concept following the economic transition of the 1990s. During those years, Albanian businesses were primarily focused on survival and market entry. Over time, some enterprises have begun to adopt CSR practices, mainly driven by the desire to improve corporate image, enhance reputation, and meet the expectations of international partners, rather than due to a strong institutional framework or an internal business culture. As a result, CSR in Albania remains fragmented and voluntary, shaped mostly by company size, the sector it operates in and how aware management happens to be. However, recent trends show a gradual increase in the adoption of CSR practices, particularly among larger companies and those with international links. This context makes Albania an important case study for CSR in transition economies, as it offers insights into how global CSR frameworks are interpreted and implemented in developing institutional environments.

The purpose of this study is to analyze the level of awareness and the degree of implementation of CSR by Albanian businesses. The paper also aims to assess whether the awareness of managers and the general orientation of enterprises towards CSR affect the adoption of formal CSR policies.

MATERIALS AND METHODS

This paper is based on a quantitative approach to collecting and analyzing data, enabling the testing of the proposed hypotheses. The data were collected through a structured questionnaire. For the closed questions, a five-point Likert scale was used (1 = strongly disagree, 5 = strongly agree).

The questionnaire was designed to measure three main dimensions:

(1) knowledge and awareness of CSR,

(2) the existence and implementation of formal CSR policies, and

(3) areas of commitment and implementation challenges.

The paper also analyzes the structural characteristics of enterprises, including size, sector of activity, and years of operation, and assesses the main areas of CSR engagement and the challenges that hinder its implementation in Albania.

The study sample consists of 100 Albanian businesses operating in different economic sectors, such as services, trade, manufacturing, technology, tourism and energy.

The data were analyzed using descriptive and inferential statistical methods. Inferential statistical methods were used to test the hypotheses, including the assessment of the relationships between the main variables. Binary logistic regression was used to identify the determinants of the adoption of formal CSR policies by Albanian firms.

The study hypotheses are:

H1: Managerial awareness of CSR is positively associated with the existence of formal CSR practices.
H2: Firms' orientation toward CSR, measured through the CSR index, is positively associated with the existence of formal CSR policies.

The results show that the sample is dominated by small enterprises, with around 67% of businesses having 1–10 employees, 26% having 11–50 employees, 5% having 51–200 employees, and only 2% having more than 200 employees. This indicates that the structure of Albanian businesses in the sample is mainly oriented toward micro and small enterprises. Regarding the duration of operation, 47% of businesses have been operating for more than 5 years, 45% for 1–5 years, and 8% for less than one year. This suggests a relatively consolidated sample with market experience.

The analysis of the relationship between business size and duration of operation shows that micro-enterprises (1–10 employees) dominate both the 1–5 year category (29%) and the over 5 years category (30%). Enterprises with 11–50 employees also show a balanced distribution (13% in each category), while businesses with more than 200 employees appear only in the over 5 years category (2%), suggesting that larger enterprises are associated with longer operating histories and greater market consolidation.

In this sample, the dominant sector is services with 53%, followed by trade (19%), manufacturing (13%), technology (5%), tourism (5%), energy (2%), and other categories (3%). The majority of micro-enterprises are concentrated in the services sector. In other words, around 82% of the surveyed businesses operate in the services sector, 15% in industry, and 3% in agriculture. It is worth noting that medium and large enterprises are mainly concentrated in manufacturing and service sectors, while most sectors are dominated by micro-enterprises.

The sectoral structure of the sample shows a strong orientation toward the service economy and small businesses, which should be considered when interpreting the results on CSR practices and green innovations, as implementation dynamics and capacities may vary depending on the sector and firm size.

Figure no. 1 presents the distribution of businesses' knowledge of corporate social responsibility practices. The results indicate a generally satisfactory level of CSR awareness. Most businesses report being sufficiently informed, while a smaller share shows limited knowledge or a clear lack of

information. Joint-stock companies demonstrate a higher level of knowledge compared to other legal forms.

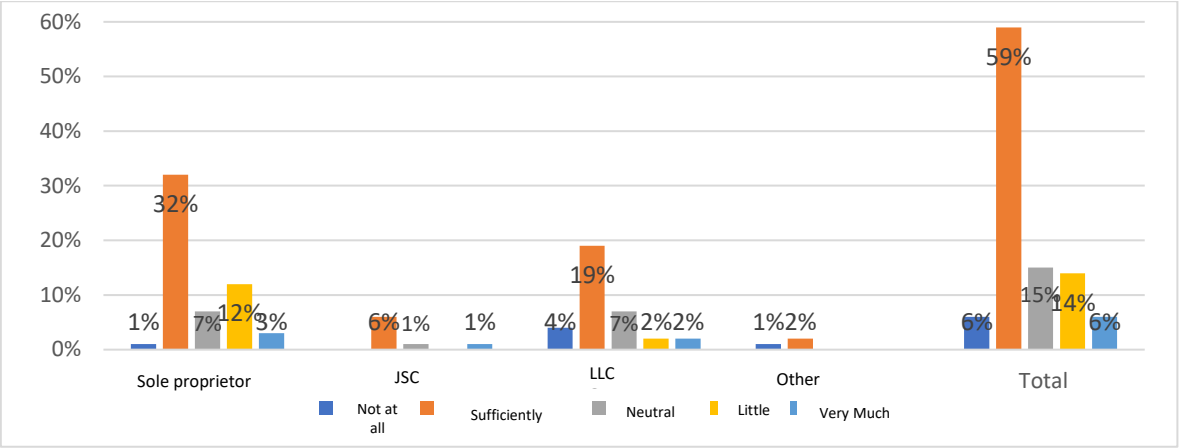


Figure 1. Distribution of Businesses' Knowledge of Corporate Social Responsibility (CSR) Practices

Source: Author's own survey data.

A good level of CSR knowledge within the sample, but at the same time it signals the need to improve information and capacity-building, especially for those businesses reporting low or unclear levels of knowledge, as this aspect may affect their willingness to formalize policies and integrate sustainable initiatives. Around 80% of businesses report having formalized CSR policies. Joint-stock companies are the first to have adopted them. The absence of CSR policies is more pronounced among sole proprietorships.

Small and medium-sized enterprises demonstrate a more consistent adoption of formal CSR practices, with nearly all companies reporting the existence of a CSR policy. CSR adoption is universal in agriculture and industry (100%), while the services sector shows a comparatively lower level of implementation (63%). The findings suggest that while CSR practices are widely adopted, both company size and sector appear to influence the degree of formalization.

From the sample of businesses established in the last 5 years, 80% have adopted CSR principles. In the group of companies operating for more than 5 years, the rate remains similar. Among businesses with less than one year of activity, it reaches approximately 90%. The distribution shows that CSR formalization is consistently widespread across all categories of business duration. Although companies with longer market experience represent a significant share of those with CSR policies, the differences between groups are not pronounced. This suggests that CSR policies are adopted both by established businesses and by relatively new market entrants.

Regarding business size, CSR formalization is also widespread across all company size categories, but the trend is more consolidated among small and medium-sized enterprises, where the percentage of businesses with CSR policies is almost complete. Micro-enterprises, although they represent the largest segment of the sample, also show the highest variability in relation to the existence of formal CSR policies.

The main barrier to implementing CSR practices is the lack of institutional or governmental support (46%), followed by a lack of technical expertise (28%) and a lack of financial resources (23%). Internal factors such as lack of interest or willingness to engage account for only 3%. The challenges in implementing CSR are therefore mainly linked to structural and institutional factors, rather than internal business characteristics.

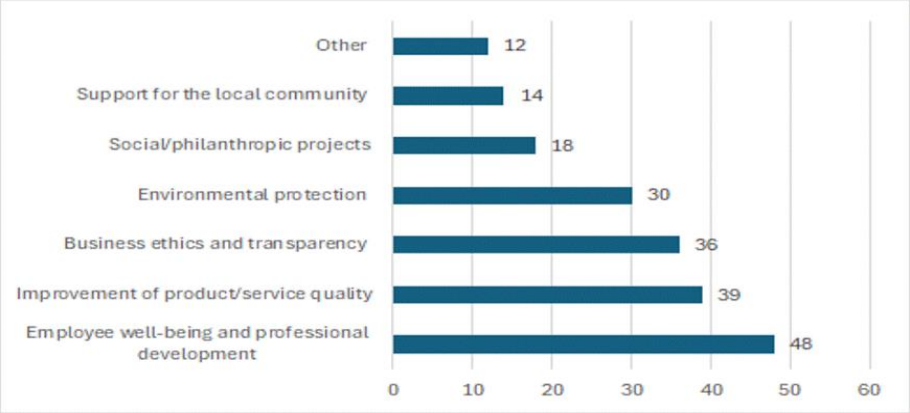


Figure 2: CSR Activities in Albanian Businesses (%, Multiple Responses).

Source: Author's own elaboration based on survey data.

The results show that CSR in Albanian businesses is mainly oriented toward the internal organizational dimension, particularly employee well-being and development, as well as improving the quality of products and services. Environmental protection is not yet a key priority compared to the social and governance dimensions. CSR in Albania is still in a transitional phase from a philanthropic approach toward a more strategic and integrated one.

The dependent variable CSR Policy is dichotomous (1 = Yes, 0 = No), and binary logistic regression was applied.

Model 1 – Testing H1 (Awareness → CSR Policy). The model is specified as:

$$logit(P) = \ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 Awareness \qquad (1)$$

where P is the probability that the company has CSR. The logit transformation ensures that the predicted probabilities remain within the (0,1) interval and allows the coefficients to be interpreted in terms of log-odds (Menard, 2010). For ease of interpretation, the results are also reported in the form of odds ratios (OR = e^β). Model fit was assessed using the Likelihood Ratio test (χ^2), McFadden's pseudo-R^2, and the model's discriminatory power through the Area Under the ROC Curve (AUC), which are standard indicators for evaluating the performance of logistic regression models (Hosmer, 2013).

Table 1: Logistic Regression: CSR Policy ~ Awareness

Variable	β	SE	z	p-value	OR = Exp(β)	95% CI (OR)
Intercept	-0.645	0.783	-0.823	0.411	0.525	[0.113, 2.436]
Knowledge	0.621	0.237	2.615	0.009	1.860	[1.168, 2.

Source: Author's own estimation.

The logistic model is statistically significant (LR $\chi^2(1) = 6.935$, $p = 0.008$). The inclusion of the Awareness variable improves model fit compared to the model without predictors. The positive coefficient ($\beta = 0.621$, $p = 0.009$) indicates that CSR awareness has a statistically significant but moderate effect on the adoption of CSR policy. The odds ratio (OR = 1.86) suggests that higher awareness increases the likelihood of having a CSR policy by about 86%. However, the low Pseudo R^2 (0.069) and AUC = 0.681 indicate limited explanatory and predictive power.

The level of awareness of CSR practices is a positive and statistically significant predictor of the existence of a formalized CSR policy (β = 0.621, p = 0.009). The odds ratio (OR = 1.86) implies that for each one-unit increase in the awareness scale, the likelihood of a company having a CSR policy increases by approximately 1.86 times (95% CI: 1.17–2.96). The empirical evidence supports H1, showing that higher CSR awareness increases the probability of CSR policy formalization.

Model 2 – Institutional formalization (CSR_index → CSR Policy). The model is specified as:

$$logit(P) = \ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 * CSR_index \qquad (2)$$

where P represents the probability that the company has a formalized CSR policy. The table presents the results of the logistic model.

Table 2: Logistic Regression: CSR Policy ~ CSR Index

Variabli	β	SE	z	p-value	OR = Exp(β)	95% CI për OR
Intercept	-2.775	0.970	-2.861	0.004	0.062	[0.009, 0.417]
CSR_index	1.450	0.358	4.055	<0.001	4.265	[2.116, 8.599]

Source: Author's own estimation.

In Model 2, the results are stronger and highly significant (β = 1.450, p < 0.001). The odds ratio (OR = 4.27) shows that a one-unit icrease in the CSR index increases the likelihood of having a CSR policy by more than four times. The higher Pseudo R^2 (0.239), LR $\chi^2(1) = 23.880$; p = 1.03e-06, and AUC ≈ 0.834 indicate good model fit and strong predictive power. The model's discriminatory ability is high (AUC ≈ 0.834), and classification using a 0.5 threshold achieves an accuracy of around 78%, indicating satisfactory predictive performance.

CSR orientation is a strong explanatory factor of the institutional formalization of CSR policies.

RESULTS

The first hypothesis states that managerial awareness of CSR is positively associated with the existence of formal CSR practices. The model suggests that this relationship is positive, as the analysis shows that an increase in CSR awareness raises the probability of CSR policy formalization.

The second hypothesis states that firms' orientation toward CSR, measured through the CSR index, is positively associated with the existence of formal CSR policies. The analysis of this hypothesis shows that the result is not only positive but also statistically more robust and reliable.

DISCUSSION

The results of this study provide an important overview of CSR development in Albania, showing that social responsibility practices are already present in the majority of Albanian businesses (over 80%).

This finding should be interpreted with caution, as the formal existence of policies does not necessarily imply their full and effective implementation. Larger and more structured enterprises have greater capacity to implement formal policies and comply with international standards. The dominance of the service sector in the sample directly influences the nature of CSR, which in this context is more oriented toward internal dimensions such as employee well-being, rather than external philanthropic or environmental activities. This suggests a CSR that is more organizational than community oriented.

The main barriers to CSR development are structural and institutional, rather than simply related to a lack of business willingness. The lack of institutional support and technical expertise highlights the need for clearer public policies and support programs for businesses.

CONCLUSION

The study shows that CSR in Albania is in a transitional phase, moving from a voluntary and sporadic practice toward a more structured and institutionalized approach. Strengthening the institutional framework and developing managerial capacities within Albanian businesses is necessary. CSR awareness has a positive but moderate effect on the existence of formal CSR policies. In contrast, CSR index is a much stronger and highly significant predictor of CSR policy adoption. The descriptive analysis indicates that CSR practices are present across all firm sizes. Micro-enterprises show greater variability in CSR formalization, while small and medium-sized enterprises demonstrate more consistent adoption of CSR policies.

ACKNOWLEDGEMENTS

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A DELIBERATE HUMOUR: THE MASKS OF THE OPPRESSED TRUTH

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ABSTRACT

The mask has been recognized as an essential accessory for both ritualistic and artist purposes. Its qualities, which highlight the fictional over the real, contributed to its artistic use, which has been common, since the beginning of theatre. The mask had established types for tragedy, satirical plays, and comedy, where the caricatured-grotesque character was emphasized. The era of the "corona mask", social distancing, and restrictions of freedom of speech, bring forth various connotations. One of them is the mask of "madness" in Arab culture. This is not a material mask that covers the nose and mouth to protect against a mysterious virus, but a mask-like figure through which one can express the forbidden, and protest against "political" and institutional "viruses" in a familiar, humoristic, carnivalesque atmosphere that brings people together. The figure of the "fool-wise" in ancient Arab culture is a clear representation of the dialectic of "truth and falsehood". In the face of the silence of common sense and its obedience, this figure is forced to wear the mask of a fool in order to express her truth. Through the voice of madness that emerges as an authentic protest from the throat of an inconsequential, marginal, funny and ridiculous actor, the "fool-wise" ensures protection against any harm, while finding a way to convey his message in a play titled "reality of Tyranny". This article discusses this figure and the nature of the mask it wears, its various reflections in ancient Arab culture, and its development in the Arab popular comedy and satirical theatre in the twentieth century.

Keywords: Carnival, Clown, Comedy, humour, karakoz, Laughter, Mask, The Tragic Fool, Zanni.

ASSESSMENT OF RISK FACTORS AND THE ROLE OF NURSING CARE IN PATIENTS WITH SCHIZOPHRENIA

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ABSTRACT

Introduction: Schizophrenia is a complex and chronic mental disorder that deeply affects the social and emotional interaction of patients, often leading to isolation and reduced quality of life. Identifying risk factors and understanding the interplay between biological, psychosocial, and environmental variables are essential for successful disease management.

Objective: This study aims to evaluate the risk factors in patients with schizophrenia hospitalized at the "Dr. Sadik Dinçi" Regional Hospital in Elbasan, Albania, and to analyze the role of the psychiatric nurse in their management.

Methodology: A multidimensional approach was employed, involving an analysis of previous studies, a review of clinical and statistical data from hospitals for the period 2019–2024, as well as an examination of elements of nursing practice in mental health. Diagnostic criteria according to DSM-IV, types of schizophrenia, positive and negative symptoms, as well as pharmacological and non-pharmacological interventions, were addressed.

Results: The study shows that schizophrenia affects different age groups, with a significant concentration among young adults. The primary etiology encompasses genetic predispositions, neurochemical imbalances, and aberrant prenatal neurodevelopment. The psychiatric nurse plays a key role in assessing the condition, establishing therapeutic relationships, monitoring therapy, and using calming techniques and art therapy. Data from the Regional Hospital of Elbasan (2019–2024) show a persistent increase in cases of schizophrenia, highlighting the need for continuous psychiatric services.

Conclusions: Schizophrenia remains a major challenge for the healthcare system. Social stigmatization, lack of support, and limited access to treatment worsen the course of the disease. A multidisciplinary care model, public education, investment in research, and strengthening the role of the psychiatric nurse are recommended to improve clinical and social outcomes for these patients.

Keywords: schizophrenia, risk factors, psychiatric nurse, social interaction, stigmatization, pharmacological treatment, Regional Hospital Elbasan.

A RANGE OF STUDENTS' PERCEPTIONS OF THE POTENTIAL IMPACTS OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES: A SOCIOLOGICAL ANALYSIS

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ABSTRACT

This paper examines university students' perceptions of the potential impact of artificial intelligence on peer relationships in public universities in the Republic of Albania. Grounded in a sociological perspective on trust, reciprocity, and technologically mediated interaction, the study explores whether AI is perceived primarily as a supportive academic tool or as a factor that may weaken the quality of student relationships. The analysis is based on survey data collected from 1,144 students across 12 public universities. Descriptive statistics and the chi-square test of independence were used to examine students' perceptions and differences by gender and study cycle. The findings reveal a predominantly skeptical orientation toward the social consequences of AI: most students expect it to make peer relationships more distant, while others associate it with increased mutual suspicion or greater opportunities for misuse. Only a smaller proportion of respondents perceive AI as a factor that may improve relationships among students. The results also indicate that face-to-face communication remains central to the construction of trust and closeness in student life. From this perspective, skepticism toward AI reflects not only concerns about technological misuse, but also the continuing importance of direct interpersonal communication in university relationships. The paper argues that the integration of AI into higher education should be discussed not only as a pedagogical or technological issue, but also as a sociological question concerning trust, authenticity, and social cohesion among students.

Keywords: artificial intelligence, peer relationships, university students, social trust, face-to-face communication, Republic of Albania.

INTRODUCTION

The rapid diffusion of artificial intelligence (AI) technologies in university life is transforming the ways in which students learn, produce academic content, and communicate with one another. Applications and platforms that offer text generation, summarization, translation, suggestions, and assistance with a wide range of academic tasks have become increasingly accessible through personal devices such as smartphones and laptops, and are now embedded in students' everyday academic practices.

In this context, AI is not merely a technical tool, but a social phenomenon that is reshaping the rules of communication and interaction, including within university settings. This broader transformation is consistent with previous research showing that new forms of university organisation mediated by technology may expose students to new forms of conflict. As Zenelaga et al. (2025, p. 651) state, "The new forms of university organisation, such as online teaching, exposes university students to new conflicts." Accordingly, this empirical paper aims to examine university students' perceptions of the potential impacts of artificial intelligence on interstudent relationships.

A few academics have examined GenAI use among university students. Baek, Tate, and Warschauer analyzed perceptions and use of ChatGPT among 1,001 university students in the United States and found that gender, age, field of study (major), institution type, and institutional policies significantly influenced ChatGPT use for general tasks, writing, and programming (Baek et al., 2024).

In the sociological literature and in technology studies, digital technologies are understood as factors that reconfigure social relationships by transforming practices of communication, information exchange, and informal social control. Within the university environment, where interstudent relationships are built on cooperation, the use of AI may be perceived as beneficial, while at the same time also as a source of

social risk. This is because AI can directly affect the mechanisms of trust: who has actually produced a text, how "authentic" an individual contribution to group work is, and how clearly the boundaries are drawn between legitimate assistance and academic misuse.

Pessimistic perceptions regarding the impact of AI on interstudent relationships may be explained through several social mechanisms: First, the use of AI may generate suspicion concerning honesty and merit, thereby making collaboration more cautious and less spontaneous. Second, it may increase the risk of misunderstandings and negative attributions (the work was produced with AI assistance), thereby reinforcing labeling processes and tensions within student groups. Third, it may create conditions for new forms of misuse (e.g., information manipulation, cheating, and exploitation), which can weaken the sense of social security.

As a result, some students may anticipate the "cooling" of relationships as a likely outcome, that is, a form of social and emotional distancing, a decline in trust, and an increase in reservation in interpersonal interactions.

This paper aims to examine how students in Albanian public universities perceive the potential impact of artificial intelligence on peer relationships, with particular attention to trust, suspicion, misuse, and the value of face-to-face communication.

Within this framework, three main research questions emerge: (1) What are the dominant student expectations regarding the impact of AI on interstudent relationships (e.g., cooling of relationships, increased suspicion, greater opportunities for misuse, or improvement of relationships)? (2) Do these expectations vary according to students' gender? (3) Do these expectations differ by cycle of study (Bachelor's versus Master's)?

CONCEPTUAL FRAMEWORK

Adopting new technologies with artificial intelligence elicits both positive and negative emotions in students (Abbas et al., 2024). Generative artificial intelligence can be defined as a technology that uses deep-learning models to produce human-like content in response to complex prompts (Lim et al., 2023). In recent years, AI has become widespread across nearly all areas of human life, including farming, engineering, and healthcare and especially within education (Chen et al., 2022; Chui et al., 2018). Generative artificial intelligence has emerged as a transformative force in higher education, with its adoption steadily increasing (Department for Education, 2024).

Arowosegbe et al. (2024) report that university students in the United Kingdom frequently use artificial intelligence tools, while also expressing significant concerns about their potential consequences. The study emphasizes that students expect Gen-AI use to increase in higher education and anticipate risks that may undermine trust among peers, including heightened suspicion about the originality of academic work and the possibility of misuse (e.g., plagiarism), dynamics that according to students' perceptions are likely to contribute to a "cooling" of interstudent relationships.

The global study by Ravšelj et al. (2025), based on 23,218 students from 109 countries, shows that ChatGPT is mainly used for brainstorming, summarising, and finding sources, while also raising concerns about cheating, plagiarism, and social isolation.

Generative AI has introduced a normative grey area in academic work, often discussed as "AI-giarism", because students tend to view direct AI-generated content as academic misconduct while showing more ambivalent attitudes toward subtler forms of AI assistance (Chan, 2025). In the context of this paper, such ambiguity is interpreted as a potential source of suspicion about originality and misuse, which may weaken trust and make inter-student relationships more distant. The use of Gen-AI can support collaborative learning and group problem-solving, suggesting that Gen-AI may also contribute to improving interstudent relationships. (Law et al., 2025). Perceptions of ChatGPT in education are diverse; some users express concerns about dependency and the potential weakening of healthy social ties (Mogavi et al., 2024).

There are also studies that indicate otherwise, such as Yeung et al. (2025), conducted among undergraduate and postgraduate students at universities in Hong Kong, which reports that both groups

generally held positive perceptions of the benefits of using GenAI for learning- and research-related activities (Yeung et al., 2025).

Survey evidence from different national contexts suggests that many students generally hold positive attitudes toward the use of GenAI in higher education and show a high level of acceptance of its academic application (Abdullah & Mohd Zaid, 2023; Saúde et al., 2024).

MATERIALS AND METHODS

This study is based on a cross-sectional quantitative research design. The empirical analysis focuses on university students' perceptions of the potential impact of artificial intelligence on peer relationships, using selected data from a structured questionnaire administered to students in public universities in Albania.

The data were collected between April and October 2025 across 12 public universities in the Republic of Albania. The sample consisted of 1,144 valid questionnaires. Of the respondents, 78.7% were female students and 21.3% were male students, while 73.7% were enrolled in Bachelor's programmes and 26.3% in Master's programmes. Participants were selected through a non-probability sampling strategy, based on student accessibility and the targeted distribution of respondents across the participating universities.

The main research instrument was a structured questionnaire composed mainly of closed-ended questions, including Likert-type questions and predefined response categories. For the purposes of this paper, the analysis focuses primarily on the item measuring students' expectations regarding the impact of artificial intelligence on relationships among students. A second item, measuring students' preference for face-to-face communication compared with online communication, was used as a complementary indicator to support the sociological interpretation of the findings.

The data were coded and processed using SPSS and Microsoft Excel. The analysis relied first on descriptive statistics, including frequencies and percentages, in order to identify the dominant patterns in students' perceptions. The chi-square test of independence was then used to examine whether perceptions of the impact of artificial intelligence on peer relationships differed by gender and by study cycle. In addition, Cramér's V was reported to assess the strength of the association between variables. The item on face-to-face and online communication was analyzed descriptively and used as an interpretive context for understanding students' skepticism toward the potential social consequences of artificial intelligence. Participation in the study was voluntary and anonymous. No personal identifying information was collected, and the data were used only for academic research purposes.

RESULTS

Table 1. In your opinion, how will artificial intelligence affect relationships among students?

Alternatives	Total (n)	Females (n)	Females (%)	Males (n)	Males (%)
It will make interstudent relationships more distant	630	515	57.2	115	47.1
It will increase mutual suspicion	198	147	16.3	51	20.9
It will create opportunities for misuse	163	120	13.3	43	17.6
It will improve relationships among students	153	118	13.1	35	14.3
Total	**1,144**	**900**	**100.0**	**244**	**100.0**

Source: Author's research. (Note: The data presented in Table 1 are derived from responses to Question 47, Percentages are calculated within each gender group)

The empirical data on the distribution by gender indicate a clear skeptical tendency regarding the impact of artificial intelligence on interstudent relationships. In both genders, negative expectations predominate, with the option "it will make relationships colder" emerging as the most frequently selected response, particularly among female students (57.2%) compared to male students (47.1%).

Overall, the percentages of negative responses are almost identical within each gender group (female students 86.8%; male students 85.6%), suggesting that skepticism is shared across genders, although the way it is perceived differs. Female students are more likely to frame the impact of AI in terms of distancing and the impersonalization of interaction, whereas male students show a greater tendency to associate AI with increasing mutual suspicion (20.9% versus 16.3%) and with opportunities for abuse (17.6% versus 13.3%). From a statistical perspective, gender differences are present, but with a small effect size, underscoring that gender influences the "profile" of concerns (cooling of relationships, insecurity/abuse) more than the overall level of negative evaluation.

The Chi-square test of independence showed that there is a statistically significant association between gender and the way students assess the impact of AI on interstudent relationships (P47):

$\chi^2(3, N = 1,144) = 8.56, p = 0.036.$

However, the effect size is small (Cramér's V = 0.087), indicating that differences between female and male students are present, but not strong.

Table 2. In your opinion, how will artificial intelligence affect relationships among students?

Alternatives	Total (n)	Bachelor (n)	Bachelor (%)	Master (n)	Master (%)
It will make interstudent relationships more distant	630	450	53.4	180	59.8
It will increase mutual suspicion	198	148	17.6	50	16.6
It will create opportunities for misuse	163	127	15.1	36	12.0
It will improve relationships among students	153	118	14.0	35	11.6
Total	**1,144**	**843**	**100.0**	**301**	**100.0**

Source: Author's research. (Note: The data presented in Table 2 are derived from responses to Question 47, Percentages are calculated within each study cycle.).

The analysis of responses to Question 47 of the survey, based on distribution by study cycle, shows that the dominant perception in both groups is that artificial intelligence will make interstudent relationships colder, with a slightly more pronounced tendency among Master's students (59.8%) compared to Bachelor's students (53.4%). Responses associated with "mutual suspicion" are almost identical across the two cycles (17.6% among Bachelor's students; 16.6% among Master's students), whereas Bachelor's students report "opportunities for abuse" relatively more often as a perceived risk (15.1% versus 12.0% among Master's students) and, at the same time, display slightly more positive expectations that AI may improve relationships (14.0% versus 11.6%).

Overall, the differences between the two study cycles appear more as nuances than as a meaningful factor in explaining students' perceptions of AI's social consequences.

The Chi-square test of independence showed that there is no statistically significant association between study cycle (Bachelor's/Master's) and the way students assess the impact of AI on interstudent relationships (P47):

$\chi^2(3, N = 1,144) = 4.21, p = 0.240.$

The effect size is very small (Cramér's V = 0.061), suggesting that the distribution of responses is generally similar among Bachelor's and Master's students.

Table 3. Evaluation of face-to-face communication in relation to online communication

Alternatives	n	%
I prefer to communicate more face-to-face than through online platforms	642	56.2
I communicate in the same way both face-to-face and through online platforms	444	38.8
I communicate better through online platforms than face-to-face	58	5.0
Total	**1144**	**100.0**

Source: Author's research. (The data presented in Table 3 are derived from responses to Question 45).

To better understand the predominantly skeptical profile of student perceptions regarding the impact of artificial intelligence on interstudent relationships, it is necessary to read Question 45 in conjunction with these findings, as it measures students' preference for face-to-face communication in comparison with online communication. The data show that 56.2% of students prefer to communicate more directly rather than through online platforms, whereas only 5.0% state that they communicate better online. This distribution clearly indicates that, in students' lived experience, face-to-face communication remains the most trusted and most highly valued form of interaction.

This descriptive finding provides an interpretive context for the results of Question 47, where the majority of students associate artificial intelligence with more distant relationships, increased mutual suspicion, or greater opportunities for misuse.

As Wang et al. (2025, p. 29) emphasize, even when a certain degree of trust in GenAI is present, students who perceive higher levels of risk tend to use it more cautiously, rely on it less, and exhibit stronger resistance, which helps explain their reservations toward technologies that mediate communication.

In this sense, more pessimistic attitudes toward artificial intelligence should not be understood merely as a reaction to the technology itself, but rather as an expression of a relational culture in which face-to-face communication continues to hold central value. This is precisely what makes Question 45 an important analytical support for interpreting Question 47: the stronger the preference for direct communication, the more understandable the tendency to view artificial intelligence as a factor that may diminish the quality of interstudent relationships.

DISCUSSION

The findings of this study show that students' perceptions of the impact of artificial intelligence on peer relationships are predominantly skeptical. More than half of the respondents expect AI to make interstudent relationships more distant, while others associate it with mutual suspicion and opportunities for misuse. This indicates that AI is not perceived only as an academic support tool, but also as a technology that may affect the social foundations of university life.

From a sociological perspective, this skepticism is related to trust, reciprocity, and the recognition of individual contribution. Peer relationships in the university context depend not only on information exchange, but also on confidence in the honesty, effort, and authenticity of others. When AI blurs the boundary between personal work and technologically assisted work, students may become more cautious about the legitimacy of academic contributions. In this sense, the expected "cooling" of relationships refers not simply to reduced contact, but to a possible weakening of openness, spontaneity, and mutual confidence.

The descriptive data on communication preferences provide an important interpretive context for these results. The fact that most students prefer face-to-face communication, while only a small proportion report communicating better online, suggests that direct interpersonal contact remains central to the construction of trust in student life. Therefore, AI should not be interpreted as directly causing weaker peer relationships, but rather as a technology that many students perceive as potentially increasing mediation, distance, and uncertainty in interaction.

The gender-based findings add nuance to this general pattern. Although the association between gender and perceptions of AI is statistically significant, the small effect size shows that the difference is limited. Female students are somewhat more likely to frame AI in terms of distancing and weakening of closeness, whereas male students report slightly higher concerns about suspicion and misuse. These differences indicate variations in the profile of concern, not a strong gender-based division.

Study cycle does not appear to be a meaningful differentiating factor. The absence of a statistically significant association between Bachelor's and Master's students indicates that concerns about the social consequences of AI are distributed relatively similarly across academic levels. Students' reservations therefore seem to reflect a wider concern about trust, authorship, and interaction in university relationships, rather than differences by stage of study.

These findings are consistent with international research showing that students recognize the academic usefulness of generative AI, while also expressing concerns about plagiarism, misuse, dependency, and the weakening of authentic social ties (Arowosegbe et al., 2024; Mogavi et al., 2024; Ravšelj et al., 2025). The present study adds a specific sociological insight from the context of Albanian public universities: students' perceptions of AI are strongly filtered through the continuing value attached to direct communication. The tension between technological mediation and face-to-face interaction helps explain why AI is associated less with relational improvement and more with distance, uncertainty, and caution.

Overall, the integration of AI into higher education should not be discussed only in terms of innovation, efficiency, or academic support. It also raises sociological questions about trust, merit, authorship, and social cohesion among students. For this reason, universities should provide clearer guidance on the ethical and academic use of AI, while also protecting the forms of direct interaction through which student relationships and mutual confidence are built (Symeou et al., 2025).

CONCLUSION

The findings of this study show that university students tend to perceive artificial intelligence as a factor that may negatively affect interstudent relationships, mainly by making them more impersonal, increasing mutual suspicion, and creating opportunities for misuse. These results suggest that the impact of artificial intelligence in higher education extends beyond academic performance and efficiency, affecting the social structure of university life, where communication, trust, and interaction among students occupy a central place.

The analysis also revealed a statistically significant association between gender and students' perceptions, although with a small effect size, whereas no statistically significant differences were identified by study cycle. This indicates that concerns regarding the social consequences of artificial intelligence are widely distributed across different levels of higher education, but are not entirely homogeneous across student groups.

Overall, the study supports the argument that the integration of artificial intelligence into higher education should be addressed not only as a pedagogical or technological issue, but also as a social one.

Within this framework, universities should devote greater attention to the ethical and social consequences of the use of artificial intelligence, particularly with regard to preserving authentic interaction among students, mutual trust, and the quality of student relationships.

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CURRENT STATUS OF NUTRITION DURING CHOLECYSTITIS IN KAZAKHSTAN

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ABSTRACT

Cholecystitis remains a common hepatobiliary disease, with dietary habits playing a key role in its development and progression. In Kazakhstan, traditional nutrition characterized by high consumption of fatty meat, fried foods, and limited intake of vegetables and fruits contributes to an increased risk of gallbladder inflammation. Despite existing dietary recommendations, patient adherence remains insufficient.

This study aimed to evaluate the nutritional status of patients with cholecystitis in Kazakhstan and identify diet-related factors influencing disease progression and recovery.

A narrative review was conducted using published literature and clinical observations related to hepatobiliary diseases in Central Asia. The analysis focused on dietary habits, macro-and micronutrient intake, nutrition-related risk factors, therapeutic dietary recommendations, and the role of enteral and parenteral nutrition in patient recovery.

Patients with cholecystitis commonly exhibited excessive intake of saturated fats and inadequate consumption of dietary fiber and essential vitamins, particularly vitamins A, C, and B-complex. Poor nutritional status was associated with prolonged hospitalization and delayed recovery. Enteral nutrition supplemented with medium-chain triglycerides (MCTs) shortened hospital stay and improved functional recovery, while parenteral nutrition demonstrated benefits in severe acute calculous cholecystitis by reducing postoperative complications. High-fat diets were associated with more severe clinical manifestations, including pain, bile stasis, impaired gallbladder motility, and progression to chronic inflammation.

Nutritional management is an essential component of cholecystitis treatment in Kazakhstan. Dietary modification, including reduced saturated fat intake, increased fiber, adequate hydration, and individualized nutritional counseling, should be integrated into routine clinical practice to improve recovery outcomes, reduce hospitalization, and prevent disease progression.

Keywords: cholecystitis, nutritional status, diet therapy, enteral nutrition, parenteral nutrition, Kazakhstan, hepatobiliary diseases.

INTRODUCTION

Cholecystitis remains a significant clinical problem worldwide, particularly in regions with high prevalence of dietary risk factors. In Kazakhstan, eating habits are shaped by traditional cuisine rich in fatty meat and fried foods, while the intake of vegetables and fruits remains relatively limited.

Such dietary patterns influence bile composition and promote cholesterol supersaturation, increasing the risk of gallbladder inflammation. Although dietary recommendations exist, adherence among patients is often inadequate.

Understanding the nutritional status of patients with cholecystitis is essential for improving both therapeutic outcomes and preventive strategies, especially in local clinical settings.

This study utilized a narrative review approach, integrating findings from clinical observations and published research related to hepatobiliary diseases in Central Asia.

The analysis included:

- assessment of dietary habits among patients

- evaluation of macro- and micronutrient intake

- identification of diet-related risk factors

- comparison with recommended therapeutic diets

To ensure originality, all materials were critically analyzed and rewritten with structural and semantic modifications.

RESULTS

In Kazakhstan, the nutritional status of patients with cholecystitis is an important factor determining recovery outcomes. Nutritional interventions, especially enteral feeding with supplements, play a significant role during the recovery phase of acute cholecystitis. Studies show that patients with poor nutritional status—specifically those with total serum protein levels below 5.0 g/dL—tend to have longer hospital stays. They also require more time to restore functional status necessary for activities of daily living (ADL) compared to patients with adequate nutritional status. Enteral nutrition containing medium-chain triglycerides (MCTs) has been found to significantly reduce hospital stay duration and accelerate recovery.

Historical background: Nutritional issues in Kazakhstan have been studied since the Soviet era. Efforts at that time were aimed at rationalizing dietary habits and establishing standardized norms of food consumption. This was particularly important for managing diseases such as cholecystitis.

Parenteral nutrition: Clinical studies have demonstrated the benefits of parenteral (intravenous) nutrition in destructive forms of acute calculous cholecystitis. Such nutrition, administered during surgery, has a positive impact on the postoperative period and reduces complications such as acute pancreatitis.

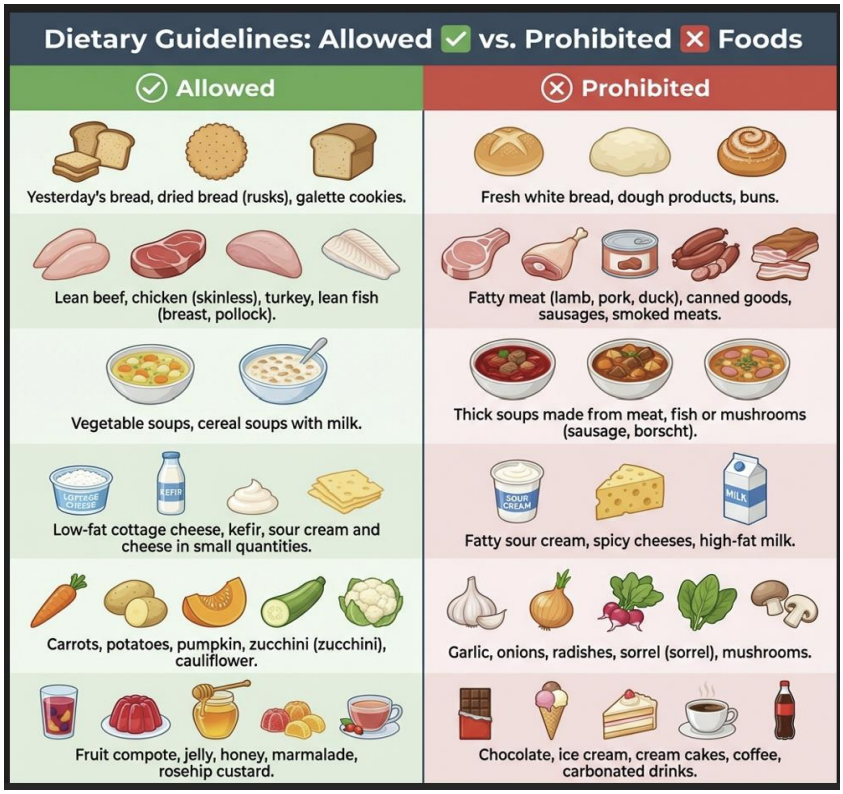


Figure 1- Dietary guidelines for patients with cholecystitis: recommended and prohibited foods

The left side of the figure 1 illustrates foods recommended for individuals with cholecystitis. These include stale or dried bread, lean sources of protein such as skinless chicken, turkey, lean beef, and white fish, vegetable-based soups, low-fat dairy products, and cooked vegetables including carrots, potatoes, pumpkin, zucchini, and cauliflower. It also recommends light desserts such as fruit compote, jelly, honey, marmalade, and rosehip tea.

The right side presents foods that should be avoided because they can increase gallbladder contraction, promote bile stasis, and aggravate inflammation. These include fresh white bread and pastries, fatty meats (such as pork, lamb, and duck), processed and smoked meats, rich meat- or mushroom-based soups, full-fat dairy products, spicy cheeses, garlic, onions, radishes, mushrooms, chocolate, cream cakes, ice cream, coffee, and carbonated beverages.

The figure emphasizes that a low-fat, high-fiber, easily digestible diet is essential for managing cholecystitis. Limiting saturated fats and processed foods while increasing the intake of lean proteins, vegetables, and adequate fluids can help reduce symptoms, improve gallbladder function, and prevent disease progression. Such dietary modifications are considered a fundamental component of conservative treatment for cholecystitis.

Dietary Imbalance

Patients with cholecystitis commonly demonstrate excessive intake of saturated fats and insufficient consumption of essential nutrients. In particular, deficiencies in vitamins A, C, and B-group, as well as low dietary fiber intake, were frequently observed.

Eating Behavior

Despite relatively regular meal frequency, the nutritional quality of meals remains poor. High-calorie, fat-rich foods dominate daily intake, while balanced dietary patterns are rarely followed.

Clinical Implications

In our clinical observation, patients adhering to high-fat diets showed more pronounced symptoms, including pain and dyspeptic disturbances. Nutritional imbalance contributes to bile stasis, impaired gallbladder motility, and progression to chronic inflammation

Risk Factor

- high intake of fried and fatty foods

- excessive salt and processed products

- irregular eating habits

Protective Factors

- increased consumption of vegetables and fruits

- adequate hydration

- balanced nutrient intake

DISCUSSION

The results highlight the important role of nutrition in the pathogenesis and progression of cholecystitis. In Kazakhstan, cultural dietary habits significantly influence disease patterns.

According to local clinical practice, many patients underestimate the importance of diet therapy, focusing primarily on pharmacological treatment. However, without dietary correction, long-term outcomes remain suboptimal.

A structured dietary approach, including reduced fat intake and increased fiber consumption, is essential. Patient education and individualized nutritional counseling should be integrated into routine clinical care.

CONCLUSION

The nutritiological approach to the treatment of cholecystitis in Kazakhstan emphasizes the importance of maintaining the proper state of the body through enteral and parenteral nutrition strategies. These measures not only help with recovery, but also reduce the time spent in the hospital and improve the overall result of treatment.The nutritional status of patients with cholecystitis in Kazakhstan is characterized by imbalance and poor adherence to dietary recommendations.

Improving dietary habits through reduced fat intake, increased fiber consumption, and better patient awareness is crucial for effective management and prevention of disease progression

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A RANGE OF STUDENTS' PERCEPTIONS OF THE POTENTIAL IMPACTS OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES: A SOCIOLOGICAL ANALYSIS

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ABSTRACT

This paper examines university students' perceptions of the potential impact of artificial intelligence on peer relationships in public universities in the Republic of Albania. Grounded in a sociological perspective on trust, reciprocity, and technologically mediated interaction, the study explores whether AI is perceived primarily as a supportive academic tool or as a factor that may weaken the quality of student relationships. The analysis is based on survey data collected from 1,144 students across 12 public universities. Descriptive statistics and the chi-square test of independence were used to examine students' perceptions and differences by gender and study cycle. The findings reveal a predominantly skeptical orientation toward the social consequences of AI: most students expect it to make peer relationships more distant, while others associate it with increased mutual suspicion or greater opportunities for misuse. Only a smaller proportion of respondents perceive AI as a factor that may improve relationships among students. The results also indicate that face-to-face communication remains central to the construction of trust and closeness in student life. From this perspective, skepticism toward AI reflects not only concerns about technological misuse, but also the continuing importance of direct interpersonal communication in university relationships. The paper argues that the integration of AI into higher education should be discussed not only as a pedagogical or technological issue, but also as a sociological question concerning trust, authenticity, and social cohesion among students.

Keywords: artificial intelligence, peer relationships, university students, social trust, face-to-face communication, Republic of Albania.

INTRODUCTION

The rapid diffusion of artificial intelligence (AI) technologies in university life is transforming the ways in which students learn, produce academic content, and communicate with one another. Applications and platforms that offer text generation, summarization, translation, suggestions, and assistance with a wide range of academic tasks have become increasingly accessible through personal devices such as smartphones and laptops, and are now embedded in students' everyday academic practices.

In this context, AI is not merely a technical tool, but a social phenomenon that is reshaping the rules of communication and interaction, including within university settings. This broader transformation is consistent with previous research showing that new forms of university organisation mediated by technology may expose students to new forms of conflict. As Zenelaga et al. (2025, p. 651) state, "The new forms of university organisation, such as online teaching, exposes university students to new conflicts." Accordingly, this empirical paper aims to examine university students' perceptions of the potential impacts of artificial intelligence on interstudent relationships.

A few academics have examined GenAI use among university students. Baek, Tate, and Warschauer analyzed perceptions and use of ChatGPT among 1,001 university students in the United States and found that gender, age, field of study (major), institution type, and institutional policies significantly influenced ChatGPT use for general tasks, writing, and programming (Baek et al., 2024).

In the sociological literature and in technology studies, digital technologies are understood as factors that reconfigure social relationships by transforming practices of communication, information exchange, and informal social control. Within the university environment, where interstudent relationships are built

on cooperation, the use of AI may be perceived as beneficial, while at the same time also as a source of social risk. This is because AI can directly affect the mechanisms of trust: who has actually produced a text, how "authentic" an individual contribution to group work is, and how clearly the boundaries are drawn between legitimate assistance and academic misuse.

Pessimistic perceptions regarding the impact of AI on interstudent relationships may be explained through several social mechanisms: First, the use of AI may generate suspicion concerning honesty and merit, thereby making collaboration more cautious and less spontaneous. Second, it may increase the risk of misunderstandings and negative attributions (the work was produced with AI assistance), thereby reinforcing labeling processes and tensions within student groups. Third, it may create conditions for new forms of misuse (e.g., information manipulation, cheating, and exploitation), which can weaken the sense of social security.

As a result, some students may anticipate the "cooling" of relationships as a likely outcome, that is, a form of social and emotional distancing, a decline in trust, and an increase in reservation in interpersonal interactions.

This paper aims to examine how students in Albanian public universities perceive the potential impact of artificial intelligence on peer relationships, with particular attention to trust, suspicion, misuse, and the value of face-to-face communication.

Within this framework, three main research questions emerge: (1) What are the dominant student expectations regarding the impact of AI on interstudent relationships (e.g., cooling of relationships, increased suspicion, greater opportunities for misuse, or improvement of relationships)? (2) Do these expectations vary according to students' gender? (3) Do these expectations differ by cycle of study (Bachelor's versus Master's)?

CONCEPTUAL FRAMEWORK

Adopting new technologies with artificial intelligence elicits both positive and negative emotions in students (Abbas et al., 2024). Generative artificial intelligence can be defined as a technology that uses deep-learning models to produce human-like content in response to complex prompts (Lim et al., 2023). In recent years, AI has become widespread across nearly all areas of human life, including farming, engineering, and healthcare and especially within education (Chen et al., 2022; Chui et al., 2018). Generative artificial intelligence has emerged as a transformative force in higher education, with its adoption steadily increasing (Department for Education, 2024).

Arowosegbe et al. (2024) report that university students in the United Kingdom frequently use artificial intelligence tools, while also expressing significant concerns about their potential consequences. The study emphasizes that students expect Gen-AI use to increase in higher education and anticipate risks that may undermine trust among peers, including heightened suspicion about the originality of academic work and the possibility of misuse (e.g., plagiarism), dynamics that according to students' perceptions are likely to contribute to a "cooling" of interstudent relationships.

The global study by Ravšelj et al. (2025), based on 23,218 students from 109 countries, shows that ChatGPT is mainly used for brainstorming, summarising, and finding sources, while also raising concerns about cheating, plagiarism, and social isolation.

Generative AI has introduced a normative grey area in academic work, often discussed as "AI-giarism", because students tend to view direct AI-generated content as academic misconduct while showing more ambivalent attitudes toward subtler forms of AI assistance (Chan, 2025). In the context of this paper, such ambiguity is interpreted as a potential source of suspicion about originality and misuse, which may weaken trust and make inter-student relationships more distant. The use of Gen-AI can support collaborative learning and group problem-solving, suggesting that Gen-AI may also contribute to improving interstudent relationships. (Law et al., 2025). Perceptions of ChatGPT in education are diverse; some users express concerns about dependency and the potential weakening of healthy social ties (Mogavi et al., 2024).

There are also studies that indicate otherwise, such as Yeung et al. (2025), conducted among undergraduate and postgraduate students at universities in Hong Kong, which reports that both groups generally held positive perceptions of the benefits of using GenAI for learning- and research-related activities (Yeung et al., 2025).

Survey evidence from different national contexts suggests that many students generally hold positive attitudes toward the use of GenAI in higher education and show a high level of acceptance of its academic application (Abdullah & Mohd Zaid, 2023; Saúde et al., 2024).

MATERIALS AND METHODS

This study is based on a cross-sectional quantitative research design. The empirical analysis focuses on university students' perceptions of the potential impact of artificial intelligence on peer relationships, using selected data from a structured questionnaire administered to students in public universities in Albania.

The data were collected between April and October 2025 across 12 public universities in the Republic of Albania. The sample consisted of 1,144 valid questionnaires. Of the respondents, 78.7% were female students and 21.3% were male students, while 73.7% were enrolled in Bachelor's programmes and 26.3% in Master's programmes. Participants were selected through a non-probability sampling strategy, based on student accessibility and the targeted distribution of respondents across the participating universities.

The main research instrument was a structured questionnaire composed mainly of closed-ended questions, including Likert-type questions and predefined response categories. For the purposes of this paper, the analysis focuses primarily on the item measuring students' expectations regarding the impact of artificial intelligence on relationships among students. A second item, measuring students' preference for face-to-face communication compared with online communication, was used as a complementary indicator to support the sociological interpretation of the findings.

The data were coded and processed using SPSS and Microsoft Excel. The analysis relied first on descriptive statistics, including frequencies and percentages, in order to identify the dominant patterns in students' perceptions. The chi-square test of independence was then used to examine whether perceptions of the impact of artificial intelligence on peer relationships differed by gender and by study cycle. In addition, Cramér's V was reported to assess the strength of the association between variables. The item on face-to-face and online communication was analyzed descriptively and used as an interpretive context for understanding students' skepticism toward the potential social consequences of artificial intelligence. Participation in the study was voluntary and anonymous. No personal identifying information was collected, and the data were used only for academic research purposes.

RESULTS

Table 1. In your opinion, how will artificial intelligence affect relationships among students?

Alternatives	Total (n)	Females (n)	Females (%)	Males (n)	Males (%)
It will make interstudent relationships more distant	630	515	57.2	115	47.1
It will increase mutual suspicion	198	147	16.3	51	20.9
It will create opportunities for misuse	163	120	13.3	43	17.6
It will improve relationships among students	153	118	13.1	35	14.3
Total	**1,144**	**900**	**100.0**	**244**	**100.0**

Source: Author's research. (Note: The data presented in Table 1 are derived from responses to Question 47, Percentages are calculated within each gender group)

The empirical data on the distribution by gender indicate a clear skeptical tendency regarding the impact of artificial intelligence on interstudent relationships. In both genders, negative expectations

predominate, with the option "it will make relationships colder" emerging as the most frequently selected response, particularly among female students (57.2%) compared to male students (47.1%). Overall, the percentages of negative responses are almost identical within each gender group (female students 86.8%; male students 85.6%), suggesting that skepticism is shared across genders, although the way it is perceived differs. Female students are more likely to frame the impact of AI in terms of distancing and the impersonalization of interaction, whereas male students show a greater tendency to associate AI with increasing mutual suspicion (20.9% versus 16.3%) and with opportunities for abuse (17.6% versus 13.3%). From a statistical perspective, gender differences are present, but with a small effect size, underscoring that gender influences the "profile" of concerns (cooling of relationships, insecurity/abuse) more than the overall level of negative evaluation.

The Chi-square test of independence showed that there is a statistically significant association between gender and the way students assess the impact of AI on interstudent relationships (P47):

$\chi^2(3, N = 1,144) = 8.56, p = 0.036$.

However, the effect size is small (Cramér's V = 0.087), indicating that differences between female and male students are present, but not strong.

Table 2. In your opinion, how will artificial intelligence affect relationships among students?

Alternatives	Total (n)	Bachelor (n)	Bachelor (%)	Master (n)	Master (%)
It will make interstudent relationships more distant	630	450	53.4	180	59.8
It will increase mutual suspicion	198	148	17.6	50	16.6
It will create opportunities for misuse	163	127	15.1	36	12.0
It will improve relationships among students	153	118	14.0	35	11.6
Total	**1,144**	**843**	**100.0**	**301**	**100.0**

Source: Author's research. (Note: The data presented in Table 2 are derived from responses to Question 47, Percentages are calculated within each study cycle.).

The analysis of responses to Question 47 of the survey, based on distribution by study cycle, shows that the dominant perception in both groups is that artificial intelligence will make interstudent relationships colder, with a slightly more pronounced tendency among Master's students (59.8%) compared to Bachelor's students (53.4%). Responses associated with "mutual suspicion" are almost identical across the two cycles (17.6% among Bachelor's students; 16.6% among Master's students), whereas Bachelor's students report "opportunities for abuse" relatively more often as a perceived risk (15.1% versus 12.0% among Master's students) and, at the same time, display slightly more positive expectations that AI may improve relationships (14.0% versus 11.6%).

Overall, the differences between the two study cycles appear more as nuances than as a meaningful factor in explaining students' perceptions of AI's social consequences.

The Chi-square test of independence showed that there is no statistically significant association between study cycle (Bachelor's/Master's) and the way students assess the impact of AI on interstudent relationships (P47):

$\chi^2(3, N = 1,144) = 4.21, p = 0.240$.

The effect size is very small (Cramér's V = 0.061), suggesting that the distribution of responses is generally similar among Bachelor's and Master's students.

Table 3. Evaluation of face-to-face communication in relation to online communication

Alternatives	n	%
I prefer to communicate more face-to-face than through online platforms	642	56.2
I communicate in the same way both face-to-face and through online platforms	444	38.8
I communicate better through online platforms than face-to-face	58	5.0
Total	**1144**	**100.0**

Source: Author's research. (The data presented in Table 3 are derived from responses to Question 45).

To better understand the predominantly skeptical profile of student perceptions regarding the impact of artificial intelligence on interstudent relationships, it is necessary to read Question 45 in conjunction with these findings, as it measures students' preference for face-to-face communication in comparison with online communication. The data show that 56.2% of students prefer to communicate more directly rather than through online platforms, whereas only 5.0% state that they communicate better online. This distribution clearly indicates that, in students' lived experience, face-to-face communication remains the most trusted and most highly valued form of interaction.

This descriptive finding provides an interpretive context for the results of Question 47, where the majority of students associate artificial intelligence with more distant relationships, increased mutual suspicion, or greater opportunities for misuse.

As Wang et al. (2025, p. 29) emphasize, even when a certain degree of trust in GenAI is present, students who perceive higher levels of risk tend to use it more cautiously, rely on it less, and exhibit stronger resistance, which helps explain their reservations toward technologies that mediate communication.

In this sense, more pessimistic attitudes toward artificial intelligence should not be understood merely as a reaction to the technology itself, but rather as an expression of a relational culture in which face-to-face communication continues to hold central value. This is precisely what makes Question 45 an important analytical support for interpreting Question 47: the stronger the preference for direct communication, the more understandable the tendency to view artificial intelligence as a factor that may diminish the quality of interstudent relationships.

DISCUSSION

The findings of this study show that students' perceptions of the impact of artificial intelligence on peer relationships are predominantly skeptical. More than half of the respondents expect AI to make interstudent relationships more distant, while others associate it with mutual suspicion and opportunities for misuse. This indicates that AI is not perceived only as an academic support tool, but also as a technology that may affect the social foundations of university life.

From a sociological perspective, this skepticism is related to trust, reciprocity, and the recognition of individual contribution. Peer relationships in the university context depend not only on information exchange, but also on confidence in the honesty, effort, and authenticity of others. When AI blurs the boundary between personal work and technologically assisted work, students may become more cautious about the legitimacy of academic contributions. In this sense, the expected "cooling" of relationships refers not simply to reduced contact, but to a possible weakening of openness, spontaneity, and mutual confidence.

The descriptive data on communication preferences provide an important interpretive context for these results. The fact that most students prefer face-to-face communication, while only a small proportion report communicating better online, suggests that direct interpersonal contact remains central to the construction of trust in student life. Therefore, AI should not be interpreted as directly causing weaker peer relationships, but rather as a technology that many students perceive as potentially increasing mediation, distance, and uncertainty in interaction.

The gender-based findings add nuance to this general pattern. Although the association between gender and perceptions of AI is statistically significant, the small effect size shows that the difference is limited. Female students are somewhat more likely to frame AI in terms of distancing and weakening of closeness, whereas male students report slightly higher concerns about suspicion and misuse. These differences indicate variations in the profile of concern, not a strong gender-based division.

Study cycle does not appear to be a meaningful differentiating factor. The absence of a statistically significant association between Bachelor's and Master's students indicates that concerns about the social consequences of AI are distributed relatively similarly across academic levels. Students' reservations therefore seem to reflect a wider concern about trust, authorship, and interaction in university relationships, rather than differences by stage of study.

These findings are consistent with international research showing that students recognize the academic usefulness of generative AI, while also expressing concerns about plagiarism, misuse, dependency, and the weakening of authentic social ties (Arowosegbe et al., 2024; Mogavi et al., 2024; Ravšelj et al., 2025). The present study adds a specific sociological insight from the context of Albanian public universities: students' perceptions of AI are strongly filtered through the continuing value attached to direct communication. The tension between technological mediation and face-to-face interaction helps explain why AI is associated less with relational improvement and more with distance, uncertainty, and caution.

Overall, the integration of AI into higher education should not be discussed only in terms of innovation, efficiency, or academic support. It also raises sociological questions about trust, merit, authorship, and social cohesion among students. For this reason, universities should provide clearer guidance on the ethical and academic use of AI, while also protecting the forms of direct interaction through which student relationships and mutual confidence are built (Symeou et al., 2025).

CONCLUSION

The findings of this study show that university students tend to perceive artificial intelligence as a factor that may negatively affect interstudent relationships, mainly by making them more impersonal, increasing mutual suspicion, and creating opportunities for misuse. These results suggest that the impact of artificial intelligence in higher education extends beyond academic performance and efficiency, affecting the social structure of university life, where communication, trust, and interaction among students occupy a central place.

The analysis also revealed a statistically significant association between gender and students' perceptions, although with a small effect size, whereas no statistically significant differences were identified by study cycle. This indicates that concerns regarding the social consequences of artificial intelligence are widely distributed across different levels of higher education, but are not entirely homogeneous across student groups.

Overall, the study supports the argument that the integration of artificial intelligence into higher education should be addressed not only as a pedagogical or technological issue, but also as a social one.

Within this framework, universities should devote greater attention to the ethical and social consequences of the use of artificial intelligence, particularly with regard to preserving authentic interaction among students, mutual trust, and the quality of student relationships.

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THE IMPACT OF SOCIAL MEDIA ADDICTION ON CONSPICUOUS CONSUMPTION BEHAVIOR: THE MEDIATING ROLE OF SOCIAL COMPARISON

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ABSTRACT

The proliferation of social media platforms plays a decisive role in shaping individual consumption habits and social behavior patterns. Social media addiction, in particular, shapes various consumption behaviors by influencing individuals' tendency to compare themselves with others. This study, on the other hand, investigates the impact of social media addiction on conspicuous consumption behavior and examines the mediating role of social comparison in this relationship. The research was conducted using a quantitative research method, and data were collected through a survey administered to 327 undergraduate students.. The data analysis utilized reliability, validity, correlation, and regression analyses. Research results reveal that social media addiction positively and significantly affects conspicuous consumption behavior. In addition, the study found that social media addiction increases social comparison, and that social comparison, in turn, positively influences conspicuous consumption behavior. In line with the statistical mediation analysis, it was obtained that social comparison has a partial intermediary role in the relationship between social media addiction and ostentatious consumption. These findings reveal that as individuals' use of social media increases, so does their tendency to compare themselves with others, which in turn reinforces their habits of conspicuous consumption. The study is expected to contribute to explaining the effects of social media usage on consumer behaviours and to provide theoretical support to the relevant literature.

Keywords: Social Media Addiction, Conspicuous Consumption, Social Comparison, Consumer Behavior, Mediation Effect.

HEALTH EXPENDITURE AND ARTIFICIAL INTELLIGENCE READINESS: A GLOBAL PERSPECTIVE

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ABSTRACT

It should be noted that the preventive development of the healthcare sector is also characterized by the development of the social well-being of the population. Therefore, the presence of sustainable growth dynamics in healthcare expenditure can be assessed as a positive factor. The application of artificial intelligence, which is considered one of the main technological solutions of the emerging sixth technological structure, to socio-economic sectors is already yielding very positive results in itself. For this reason, the research work was focused on the extent of the relationship between healthcare spending and the development of artificial intelligence. The research work was based on the quantitative research method and included research levers such as induction, deduction, logical generalization, scientific abstraction, statistical and comparative analysis. The variables to be used in the research work were determined as the government's AI readiness index and the share of current healthcare expenditure in GDP. Certain results were obtained within the framework of the research questions set. The main limitation of the study is related to the lack of a broader information base on artificial intelligence

Keywords: Healthcare sector, Health expenditure, Artificial intelligence, GDP

PREDICTING USER SENTIMENT FROM MOBILE BANKING EXPERIENCE DIMENSIONS: A MULTILINGUAL NLP STUDY OF RAIFFEISEN BANK REVIEWS IN ALBANIA AND KOSOVO

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ABSTRACT

This study explores how different dimensions of user experience shape the emotional tone of reviews left for a mobile banking application, with a particular focus on what drives sentiment rather than star ratings. Using a combined corpus of reviews collected from Raiffeisen Bank's mobile application in Albania and Kosovo, we apply a natural language processing pipeline that moves through sentiment classification, automatic topic discovery, and regression analysis to uncover which aspects of the user experience matter most to how people actually feel and express themselves about the app. Client reviews were analyzed using multilingual BERT for sentiment classification and BERTopic for identifying latent user experience dimensions. The resulting topic probability scores were then used as predictors in a Hierarchical Multiple Linear Regression model, structured into three blocks to assess the incremental explanatory contribution of each set of variables.

The findings reveal a clear pattern: *technical problems* dominate the picture. When the application fails to function as expected, user sentiment declines markedly, while technical issues have a stronger impact than usability or satisfaction-related factors.

Beyond its empirical findings, this study offers a methodological template for sentiment-driven experience analysis in linguistically underrepresented digital markets particularly within the Western Balkans.

Keywords: mobile banking, sentiment prediction, BERTopic, multiple linear regression, mBERT, Albania, Kosovo, NLP, Western Balkans, user experience

LEARNING MANAGEMENT SYSTEMS FOR MATHEMATICS EDUCATION IN VİETNAM: A LİTERATURE REVIEW

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ABSTRACT

Learning Management Systems (LMS) have been widely adopted across the globe, particularly within the field of mathematics education, where they contribute significantly to improving teaching effectiveness, fostering students' independent learning abilities, and supporting personalized learning experiences. In Vietnam, a variety of LMS platforms have been implemented in mathematics education, offering diverse features and pedagogical functionalities. This paper provides a comprehensive overview of the current use of LMS platforms in mathematics teaching and learning within the Vietnamese educational context, from both pedagogical and technological perspectives. Through an examination of existing platforms, this study highlights key trends and identifies critical development gaps that should be addressed to support the future advancement of LMS-based mathematics education. The findings objectively reflect the alignment between current technological capabilities and the practical demands of mathematics education. Consequently, this paper provides a contemporary overview of LMS adoption and a useful reference for future research on digital transformation in education.

Keywords: Learning Management System, Smart Education in Mathematics system, Mathematics Education.

INTRODUCTİON

Global educational practices have been greatly impacted by the quick growth of digital technology, particularly since the COVID-19 pandemic (Timotheou et al., 2023). Learning Management Systems (LMS) are one of these technologies that have grown in importance as platforms for online material distribution, teaching, learning, and evaluation (Anozie et al., 2024). With tailored learning activities and prompt feedback, LMS systems can meet each student's unique demands in mathematics instruction (Zulpykhar et al., 2025). However, traditional teaching methods, challenges in presenting mathematical symbols and formulas in digital environments, a lack of technological support for teachers, and students' difficulties with mathematical comprehension make it difficult to integrate LMS into mathematics (Das, 2019; Desai et al., 2023).

In Vietnam, Moodle is one of the LMSs most frequently used by educational institutions, where the use of online learning platforms has grown recently (Khoa et al., 2020). Despite these advancements, the integrated use of these systems remains limited in Vietnam and several neighboring countries (Thu, 2024). Furthermore, reviews that are particularly focused on mathematics education are still lacking, while prior research has mostly looked at LMS uptake and acceptance in general educational settings.

By examining its benefits, drawbacks, opportunities, and difficulties from both pedagogical and technological viewpoints, this literature review offers a thorough overview of LMS using in mathematics education in Vietnam.

THEORETİCAL BACKGROUND AND RESEARCH METHODS

1. Learning Management System

Historically, LMS technology has gone through several key milestones. The modern LMS began in 1990 when SoftArc launched FirstClass. This innovation led to a competitive market for various e-learning platforms (Al-Dhief et al., 2024).

A Learning Management System (LMS) is a software platform that is essential for delivering, tracking, and managing educational materials and training activities (Mahnegar, 2012; Bradley, 2021). From a technical and operational view, Kasim and Khalid (2016) described an LMS as a web-based system that combines different functions. These include content management, assessment tools, tracking learning progress, and facilitating student interaction. Furthermore, an LMS is not just a single tool but acts as an umbrella platform that brings together course management systems, portals, and instructional management systems all in one place.

Learning Management Systems (LMS) have evolved far beyond their original purpose as simple record-keeping or course registration tools to become comprehensive online learning environments (Kasim & Khalid, 2016). Today, these platforms act as a multidimensional connecting ecosystem that effectively serves various stakeholders:

- *For learners:* An LMS cultivates a highly engaging and interactive space. Students use the system not only to register for classes, check grades, and receive updates (Bradley, 2021), but also to actively access course materials, submit assignments, take quizzes, and share knowledge (Mahnegar, 2012; Kasim & Khalid, 2016).

- *For instructors and administrators:* The system provides powerful tools to closely monitor student progress, track attendance, and measure the time spent on tasks (Mahnegar, 2012).

- *For parents:* Some LMS platforms extend access to parents, allowing them to log in to support and track their children's academic performance (Mahnegar, 2012).

2. Systematic review process

Systematic Reviews is an account of the rationale, importance, methods, and limitations of systematic reviews, which should help clarify the essentials (Chalmers & Altman, 1995). Systematic reviews are defined by their explicit, transparent, and highly reproducible methodologies (Collins & Fauser, 2005). The primary strengths of this approach lie in its tightly focused research questions, exhaustive literature searches, and strict, criterion-driven selection of evidence (Turnbull et al., 2021).

3. Research method

This study uses a systematic review method to examine and combine existing literature on management systems overall, and Mathematics learning management systems in Vietnam specifically. Additionally, to find possible research topics, the investigation was conducted across international and national databases such as ScienceDirect, Web of Science, Google Scholar, and other search tools.

The keywords in English and Vietnamese used for the literature search include: (1) Group 1: “Hệ thống”; “Hệ thống quản lý học tập”; “System”; “Learning Management System”; (2) Group 2: “Học tập”; “Học tập môn Toán”; “Learning”, “Learning Math”; (3) Group 3: “Việt Nam”, “Môn Toán tại Việt Nam”; “Viet Nam”, “Math subject in Viet Nam”. (4) Group 4: “Moodle”, “Khan academy”, “Google Classroom”, “Azota”, “Gnomio”, “SEM”.The search scope was limited to December 2025.

RESULTS AND DISCUSSION

Based on the screening and systematic review of research papers, this section presents results on the LMSs used in mathematics teaching in Vietnam. The results suggest that the Vietnamese mathematics LMS could be divided into 2 groups: (1) international LMSs carried out in Viet Nam and (2) LMSs developed domestically.

1. International Learning Management System in Viet Nam

These learning management systems frequently appear in research literature, illustrating the trend of adopting and implementing external educational technology platforms.

1.1. Moodle - Modular Object-Oriented Dynamic Learning Environment

Moodle is an open-source learning management system widely used not only in Vietnam but also around the world. Moodle was founded in 1999 by Martin Dougiamas. (Bui et al., 2020). In Vietnam, many educational institutions have integrated Moodle into their distance education and blended learning programs, thanks to its flexibility, multilingual support, and powerful customization capabilities (Nguyen et al., 2025). Especially in the post-COVID-19 period, when the demand for online learning surged. (Nguyen et al., 2025). Moodle stands out for its online classroom management structure and comprehensive progress-tracking capabilities, facilitating the implementation of flipped classroom or constructivist learning models in mathematics. (Kamaruddin et al., 2021). Experiments demonstrate that combining online questions and quizzes with Moodle discussion forums significantly helps students develop diligence, problem-solving skills, and higher-order thinking skills (HOTS). (Kamaruddin et al., 2021). However, with the specific characteristic of mathematics education, this platform still exhibits certain technical and pedagogical limitations. Moodle completely lacks visualization tools such as geometry or interactive graphing, and its default capability for displaying mathematical notation is quite limited, forcing users to rely on supporting plugins like MathJax or LaTeX. Regarding data management, Moodle's reporting features are confined to descriptive analytics based on system log data and completely lack an adaptive learning mechanism to automatically personalize mathematics learning plans in real time. (Xin and Singh, 2021). Furthermore, assigning math homework through this platform still faces significant challenges in ensuring students work independently and honestly. (Kamaruddin et al., 2021). Consequently, server operations, maintaining systems, and mathematics plugins require an integrated IT infrastructure and high-level technical personnel. It creates a significant barrier for many educational institutions.

1.2. Google Classroom

In the digital transformation of education in Vietnam, Google Classroom has emerged as a powerful support platform thanks to its user-friendly interface and seamless integration with the Google ecosystem (Tran, 2025; Vo and Pham, 2024). In mathematics education, integrating this platform into blended learning models helps optimize pedagogical processes at every stage; it is particularly effective for structuring abstract concepts. For example, the Vectors unit in the high school curriculum (Vo and Pham, 2024). Before the lessons, teachers use the system to provide diverse digital learning materials, enabling students to study independently and cultivate self-directed learning skills (Vo and Pham, 2024). However, a limitation of Google Classroom for mathematics is the lack of tools for inputting and displaying complex mathematical notation, forcing the use of additional external software.

1.3. Khan Academy

Khan Academy is a non-profit platform providing free mathematics learning resources. It stands out as an ideal open-source environment for implementing the "flipped classroom" model, thanks to its ability to integrate a variety of competency-based assessment tools (Nguyen and Le, 2020). The platform enables teachers to design diverse learning tasks that combine multiple-choice questions with free-response questions (Nguyen and Le, 2020). A study by Nguyen and Le (2020) on the application of Khan Academy within a flipped classroom model at a private high school in Hanoi demonstrated that the platform not only significantly boosted student learning outcomes and performance but also gained highly positive feedback from learners due to its highly interactive experience and effective personalized learning paths. Despite its advantages in learning materials and interactivity, Khan Academy has limitations in large-scale class management and a lack of real-time interaction; these issues place demands on student self-discipline and can easily lead to digital exhaustion.

2. Viet Nam Learning Management System for Mathematics

2.1. Azota

Azota has emerged as an effective platform supporting teachers in giving assignments and conducting assessments. With its user-friendly interface and ability to create online assignments easily, Azota enables teachers to track student progress and automatically grade multiple-choice tests, thereby enhancing the efficiency of assessment (Le et al., 2022). Experimental research on teaching Probability

and Statistics indicates that using Azota fosters self-study, encourages earlier assignment completion, and leads to better academic outcomes compared to traditional methods (Nguyen, 2024). Furthermore, setting submission deadlines and monitoring task completion motivates students to actively review material while allowing teachers to effectively oversee the learning process. However, Azota has certain limitations; for instance, question formats are not diverse, primarily consisting of multiple-choice questions and essay questions. Besides, the interface lacks lively visualization, which is particularly important for Mathematics, a subject that often demands specialized features. Additionally, the platform offers fewer opportunities for direct interactive activities during the learning process compared to some other platforms.

2.2. Gnomio

Gnomio stands out as an ideal solution for teachers to build digital learning resources, and it effectively implements blended learning models without difficulty in initial setup costs, thanks to its free registration (Nguyen, 2019). The platform enables the coherent structuring of lessons through a versatile learning management system, providing support for everything from material distribution to the design of assessment tools (Nguyen, 2019; Vo, 2024). In the context of Mathematics, utilizing such e-learning platforms offers students a rich learning experiences and fosters a sense of responsibility for self-directed study. It also maximizes the development of the competencies and thinking skills required to meet the objectives of the new general education curriculum (Vo, 2024). However, as it operates on the Moodle core, optimizing Gnomio requires teachers and schools to invest time in system configuration, account management, and the setup of advanced pedagogical features (Nguyen, 2019). Additionally, since Gnomio relies on advertising, users must accept the presence of ads on their websites.

2.3. SEM - Smart Education in Mathematics (semctu.com)

The SEM system is an intelligent platform developed by a research team at Can Tho University, aiming to create a comprehensive, integrated system specifically for mathematics education. It is one of the few domestic learning management systems designed with a specific focus on mathematics and incorporating specialized features to support mathematical notation. The system offers a question bank covering various formats, including multiple-choice, short-answer, and true/false matrix questions. It also integrates GeoGebra for graphing and visualizing abstract concepts, as well as mind-mapping tools to help organize and consolidate learned material (Nguyen et al., 2025). Notably, the SEM system features a virtual assistant, SEM AI, which provides real-time support to students during their study and review sessions (Nguyen et al., 2025). A key advantage of SEM over other Vietnamese platforms is its research-and-development orientation; it serves as a foundation for collecting learning data to facilitate the continuous improvement of mathematics content and teaching methods. However, SEM is currently still in the testing and development phase and has not yet been deployed on a large scale.

3. Comparison between Learning Management Systems

This study employs 11 of the 12 LMS evaluation criteria proposed by Muhammad and Cavus (2017): accessibility, compatibility, evaluation tools, learnability, multilingual support, portability, reliability, security, support, sustainability, and usability. To ensure objectivity, the criterion of user satisfaction was excluded from this study, as no user survey was conducted.

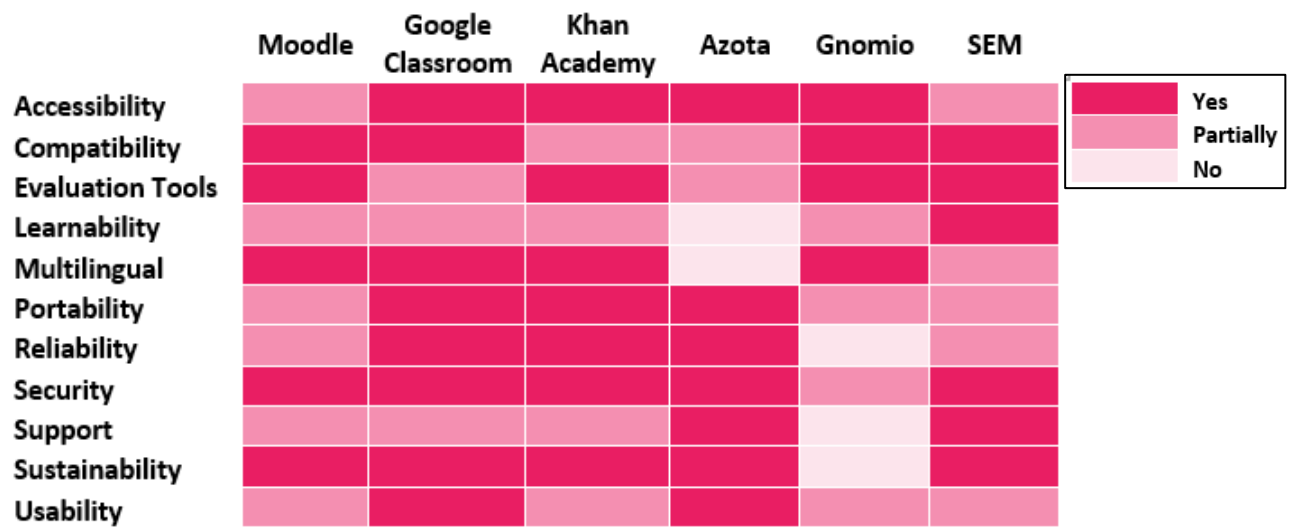


Figure 1. Comparative analysis of Learning Management System features

Regarding Accessibility, Google Classroom, Khan Academy, Azota, and Gnomio allow open, free registration for external users, unrestricted by geographical boundaries or closed infrastructure. Moodle and SEM are systems designed for course-based learning and examinations; users must have accounts provided by the system or must join pre-configured tests, as these platforms are not fully open to the public. In terms of compatibility, Moodle, Gnomio, and SEM are built on the Moodle core, ensuring full compatibility with international e-Learning standards such as SCORM, AICC, and LTI. Google Classroom integrates seamlessly with thousands of applications via the Google Workspace ecosystem. Khan Academy and Azota utilize more closed-source systems; notably, Azota is primarily compatible with local formats—supporting Word/Excel file imports and exports—but lacks support for international SCORM packaging standards. Regarding evaluation tools, Moodle, Khan Academy, Gnomio, and SEM offer diverse question banks, automated testing, and visual score distribution charts. Azota includes additional anti-cheating monitoring features. SEM stands out for its support of the "true/false matrix" question format commonly used in mathematics in Vietnam. Google Classroom lacks an advanced test generator; assessments rely on file or image attachments or depend entirely on the external Google Forms tool. Regarding learnability, Moodle, Gnomio, Khan Academy, and SEM all provide discussion forums and visual learning tools. SEM stands out particularly due to its "SEM AI" learning assistant, which supports learners during their practice phase. Google Classroom primarily manages assignment distribution rather than creating automated learning paths; however, it features a commenting function that allows for discussions directly beneath each assignment prompt. Azota focuses heavily on online assignments and examinations rather than facilitating in-depth discussion spaces. Regarding multilingual support, Moodle, Gnomio, Google Classroom, and Khan Academy support dozens to hundreds of languages. In contrast, SEM offers bilingual support (English and Vietnamese) to align with school curricula. Azota features an interface optimized specifically for the Vietnamese market, resulting in limited support for foreign languages. Regarding portability, Google Classroom, Khan Academy, and Azota have all developed mobile applications (for iOS and Android) that optimize touch-based interactions. They also enable quick assignment submission via the camera. Moodle, Gnomio, and SEM support display via responsive web interfaces. In terms of reliability, Google Classroom and Khan Academy utilize globally distributed cloud server infrastructure. Azota operates on a commercial SaaS model capable of handling heavy loads during major exam periods in Vietnam. Moodle and SEM rely entirely on the servers chosen by the hosting organization; if a school server fails or experiences bandwidth overload, the system is disrupted. Gnomio offers free hosting with limited bandwidth, frequently suffers from lag, and automatically deletes the entire site if there are no visits within a specific timeframe. Regarding security, Google and Khan Academy strictly adhere to core international standards for educational data security and privacy, including the Family Educational Rights and Privacy Act (FERPA) and the Children's Online Privacy Protection Act (COPPA). Furthermore, these systems implement cybersecurity frameworks recommended by NIST and OWASP to protect end-user data (Athens Area School District, 2026). Moodle and SEM offer robust security

based on continuously updated open-source code and internal data control. Azota holds information security certification in compliance with Vietnamese regulations. Gnomio, however, offers only moderate security; the system injects numerous third-party advertising codes into the interface, increasing the risk of data leaks or accidental clicks on malicious links. Regarding support, Azota features a dedicated customer service team that provides rapid responses to Vietnamese teachers via hotline and Zalo. In contrast, Moodle, SEM, Google Classroom, and Khan Academy primarily rely on instructional guides, automated help centers, or community forums for support. Gnomio offers absolutely no direct technical support channels for individual users facing system errors. Regarding sustainability, Moodle is a globally popular open-source platform; Google Classroom is backed by Alphabet; Khan Academy is supported by a major global non-profit foundation; Azota operates on a SaaS model with stable revenue; and SEM is maintained based on the research team's budget and needs. Gnomio reserves the right to stop service or delete user data at any time if its advertising policies change or if user activity is not consistently maintained. Regarding usability, Google Classroom and Azota boast extremely user-friendly interfaces. Conversely, Moodle, Khan Academy, Gnomio, and SEM require users, particularly teachers designing courses, to familiarize themselves with complex module configurations and permission settings, necessitating a significant initial learning curve.

CONCLUSION

Research shows that challenges remain in using learning management systems (LMS) for mathematics in Vietnam. Popular platforms like Moodle, Google Classroom, and Azota lack features designed for mathematics. They miss important tools, such as geometry software, and have complicated methods for entering mathematical notation. Local solutions focus on tasks like distributing assignments and grading automatically, rather than creating spaces where students can engage deeply with the subject. While SEM systems, made specifically for mathematics, have great potential, they are still experimental. Future LMS platforms for math will need to include specialized tools that support interactive learning and improve students' understanding. These systems should go beyond just tracking grades or online study time. They need to use artificial intelligence to provide automated help and adjust lesson content in real time to match each student's skill level.

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APPROACHING ISPRING SUITE TO DESIGN QUESTION TYPES IN MATHEMATICAL TESTS AT HIGH SCHOOLS

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ABSTRACT

The growing adoption of digital learning environments has highlighted the need for more diverse assessment approaches in mathematics education. Currently, the Vietnam Ministry of Education and Training has introduced three types of questions for the High School Graduation Exam in a new format (multiple-choice questions with four options, true/false questions, and short-answer questions). This paper introduces nine additional question types, in addition to the three popular types mentioned above, using iSpring Suite (version 10). These question types can be used as reference formats for online tests and assessments. As powerful software integrated in PowerPoint, iSpring Suite provides comprehensive tools for designing e-learning lectures and creating tests and assessments. A quantitative study is also conducted to evaluate user feedback to improve the quality of tests and assessments using the diverse question types provided by iSpring Suite. The findings indicate that using diverse question types can enhance the quality of assessment practices and promote student engagement in learning.

Keywords: iSpring Suite, Mathematics assessment, digital transformation.

INTRODUCTION

The convergence of technologies like robotics, artificial intelligence (AI), and the Internet of Things (IoT), which are changing many facets of contemporary society, is what defines the Fourth Industrial Revolution (Schwab, 2016). The education industry needs to undergo extensive innovation, especially in testing and evaluation, in order to fulfill the expectations of this modern period. In 2025, the National high school graduation examination in Mathematics was given a new format by the Vietnam Ministry of Education and Training, which included a range of question types. This shift has led to an urgent need for an appropriate software solution to support the new examination format.

iSpring is a specialized software used for developing e-learning lectures. iSpring offers a full suite of expert e-learning authoring tools in an intuitive interface and instantly connects with Microsoft PowerPoint. Numerous nations have embraced it, such as Indonesia (Khodija et al., 2023), Russia (Ankudinova, 2016), and Australia (Herbert et al., 2017). Additionally, iSpring Suite has been used in a number of academic fields, including history (Kurniawan and Sumargono, 2021), chemistry (Nurhairunnisah et al., 2023), and physics (Kurnianto, Kuswanto, and Kobesi, 2024).

This paper presents the design and execution of a mathematics assessment using iSpring Suite. The effectiveness of the proposed approach was evaluated quantitatively through a questionnaire based on a five-point Likert scale.

MATERIALS AND METHODS

Fourteen question types were designed including: (1) Multiple Choice; (2) Multiple Response; (3) True/False; (4) Short Answer; (5) Numeric; (6) Sequence; (7) Matching; (8) Fill in the Blanks; (9) Select from Lists; (10) Drag the Words; (11) Hotspot; (12) Drag and Drop; (13) Likert Scale; and (14) Essay.

The study was conducted with 39 students from Class 11A2 at Luu Huu Phuoc High School in April 2024. The research procedure consisted of three stages.

Stage 1: Design a test using iSpring Suite for the chapter "Exponential and Logarithmic Functions" in 11th-grade Mathematics. The test consisted of three sections: Section I included 12 multiple-choice questions, Section II contained 4 true/false questions, and Section III comprised 6 short-answer questions.

Stage 2: The online test was administered to the 39 participating students.

Stage 3: Collect feedback from the 39 students on the use of iSpring Suite for mathematics assessment by completing a questionnaire based on a five-point Likert scale.

The questionnaire consists of eleven items using a five-point Likert scale:

Q1: How often do you use digital devices (e.g., smartphones, laptops, or desktop computers) in your daily life?

Q2: Which device do you primarily use to access the Internet or search for learning materials?

Q3: How easy was it to use iSpring Suite for the mathematics assessment?

Q4: How convenient did you find the mathematics assessment using iSpring Suite?

Q5: Do you enjoy taking the mathematical test using iSpring Suite?

Q6: Compared with the traditional paper-based assessment, do you prefer the online mathematics assessment using iSpring Suite?

Q7: How would you evaluate your level of confidence when taking a competency-based mathematics assessment using iSpring Suite?

Q8: What are your opinions on competency-based mathematics assessment using iSpring Suite?

Q9: In your opinion, what are the benefits of using iSpring Suite for mathematics assessment?

Q10: What difficulties did you encounter when taking the mathematics assessment using iSpring Suite?

RESULTS

After collecting the completed questionnaires, the data were analyzed using IBM SPSS Statistics version 26. The reliability of the questionnaire was evaluated using Cronbach's Alpha, and the results are presented in Figure 1.

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	39	100.0
	Excluded[a]	0	.0
	Total	39	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.803	11

Figure 1. Cronbach's Alpha of the Survey Questionnaire

The Cronbach's Alpha coefficient of the survey data is **0.803**, which exceeds the recommended threshold of **0.70**. Therefore, the questionnaire demonstrates acceptable reliability and is suitable for subsequent data analysis.

Results of stage 2:

Comparison between the paper-based test (Test 1) and the iSpring Suite test (Test 2) is presented in Table 1 and Figure 2.

Table 1. Result of the paper-based test (Test 1) and the iSpring Suite (Test 2)

Score range	Test 1	Test 2
8,0 – 10,0	20,5%	12,8%
6,5 – 7,9	51,3%	43,6%
5,0 – 6,4	25,6%	30,8%
<5,0	2,6%	12,8%

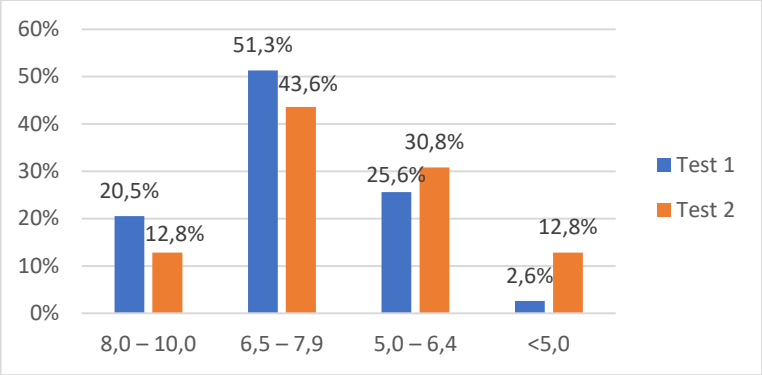


Figure 2. Comparison of students' score distribution in Test 1 and Test 2

Overall, the results of the two tests showed noticeable differences. The proportion of students achieving good or excellent scores (6.5 and above) decreased from 71.8% to 56.4% (a decrease of 15.4%), while the proportion of students scoring below 6.5 increased from 28.2% to 43.6%.

Results of stage 3:

Q1. Frequency of digital device use

Table 2. Students' frequency of digital device use

Frequency	Never	Rarely	Sometimes	Frequently	Always
Number of students	0	0	9	29	1
Percentage (%)	0%	0%	23,1%	74,4%	2,5%
Total	**23,1%**			**76,9%**	

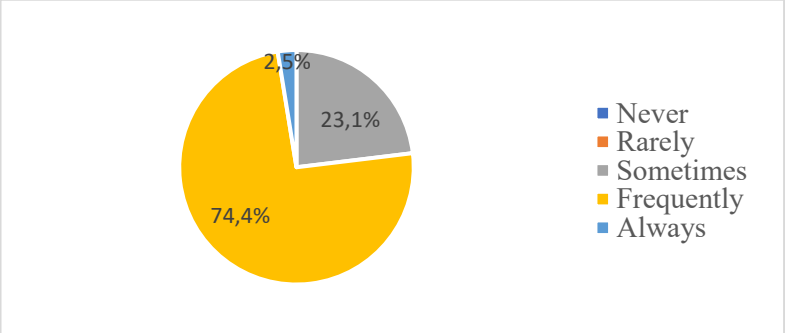


Figure 3. Distribution of students' frequency of digital device use

The results indicate that most students use digital devices frequently, suggesting that implementing mathematics assessments using iSpring Suite is unlikely to pose significant difficulties for them.

Q2. Devices used to access the Internet

Table 3. Devices used to access the Internet

Frequency	Mobile phone	Tablet	Computer or laptop	No device
Number of students	34	0	5	0
Percentage (%)	87,2%	0%	12,8%	0%

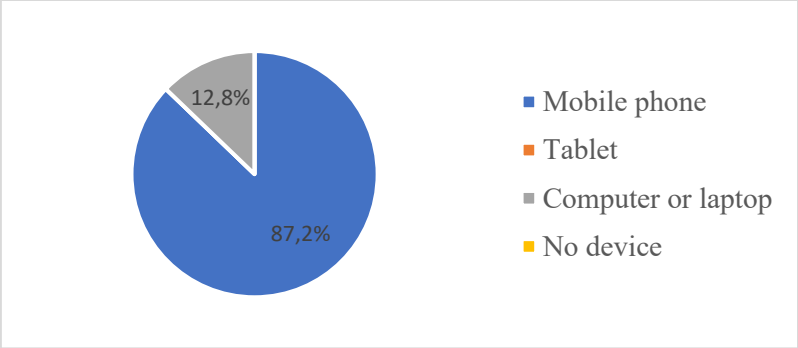


Figure 4. Distribution of the devices used by students to access the Internet

Overall, all students have access to devices that enable them to connect to the Internet and access learning resources, thereby facilitating the implementation of mathematics assessments using iSpring Suite.

Q3. Ease of using iSpring Suite

Table 4. Ease of using iSpring Suite

Frequency	Very difficult	Difficult	Neutral	Easy	Very easy
Number of students	0	2	22	13	2
Percentage (%)	0%	5,1%	56,4%	33,3%	5,1%

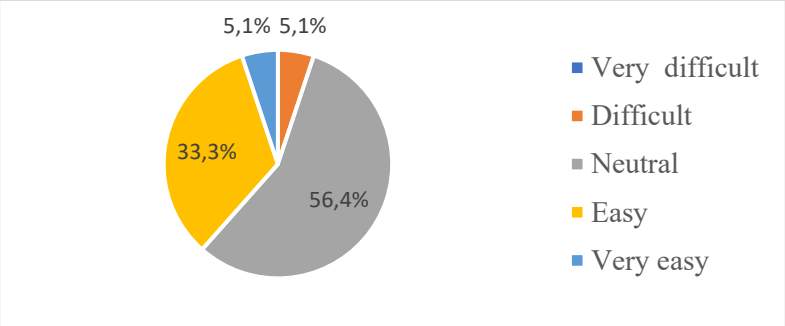


Figure 5. Distribution of responses on the ease of using iSpring Suite

The survey results indicate that most students find assessment using iSpring Suite easy to complete.

Q4. Convenience of using iSpring Suite

Table 5. Convenience of using iSpring Suite

Frequency	Very inconvenient	Inconvenient	Neutral	Convenient	Very convenient
Number of students	0	2	20	14	3
Percentage (%)	0%	5,1%	51,3%	35,9%	7,7%

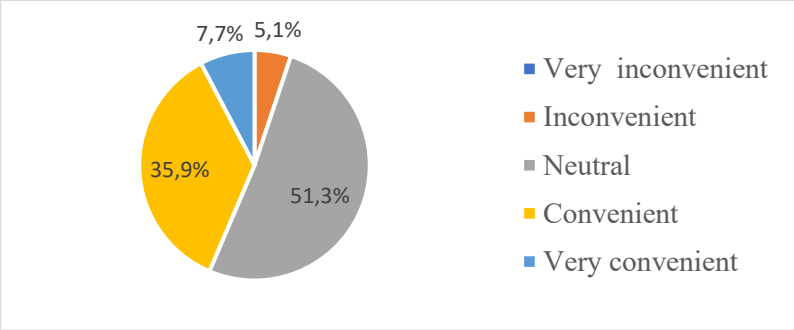


Figure 6. Distribution of responses on the convenience of using iSpring Suite

The survey results indicate that mathematics assessment using iSpring Suite is convenient for the majority of students.

Q5. Students' preference for using iSpring Suite

Table 6. Students' preference for using iSpring Suite

Frequency	Strongly dislike	Dislike	Neutral	Like	Strongly like
Number of students	0	4	17	18	0
Percentage (%)	0%	10,3%	43,6%	46,2%	0%

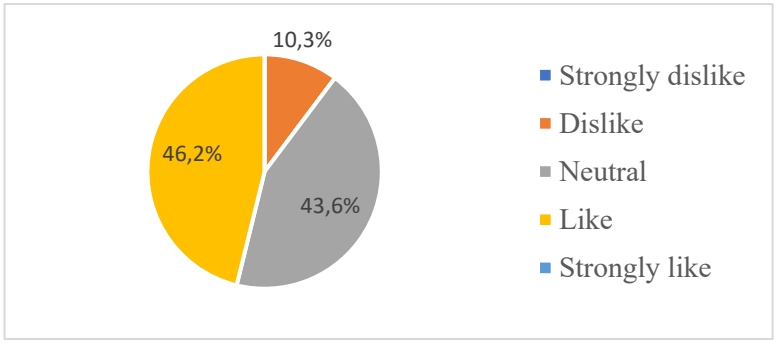


Figure 7. Distribution of students' preference for using iSpring Suite

The survey results indicate that the majority of students have a positive preference for mathematics assessment using iSpring Suite.

Q6. Preference for iSping Suite over traditional paper-based test

Table 7. Students' preference for iSpring Suite over traditional paper-based test

Frequency	Strongly dislike	Dislike	Neutral	Like	Strongly like
Number of students	1	5	14	15	4
Percentage (%)	2,6%	12,8%	35,9%	38,5%	10,3%

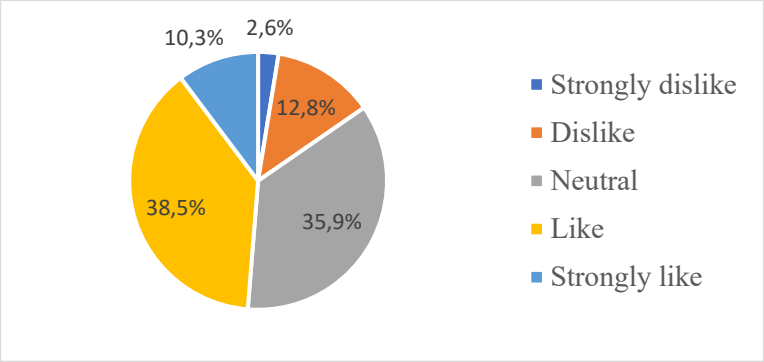


Figure 8. Distribution of students' preference for using iSpring Suite over paper-based test

The survey results indicate that the majority of students prefer mathematics assessment using iSpring Suite over traditional paper-based assessment.

Q7. Students' confidence when using iSpring Suite

Table 8. Students' confidence when using iSpring Suite

Frequency	Strongly inconfident	Confident	Neutral	Confident	Strongly confident
Number of students	0	2	30	7	0
Percentage (%)	0%	5,1%	76,9%	18%	0%

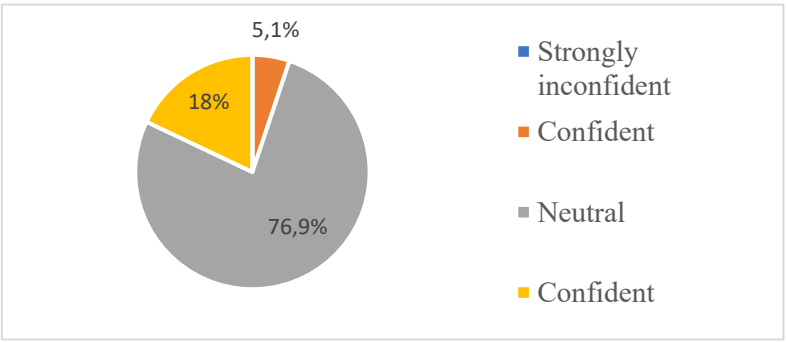


Figure 9. Distribution of students' confidence when using iSpring Suite

The survey results indicate that, compared with traditional paper-based assessment, iSpring Suite is still considered a relatively new assessment method by most students. Furthermore, a small proportion of students remain unfamiliar with this method.

Q8. Students' perceptions of competency-based mathematical test

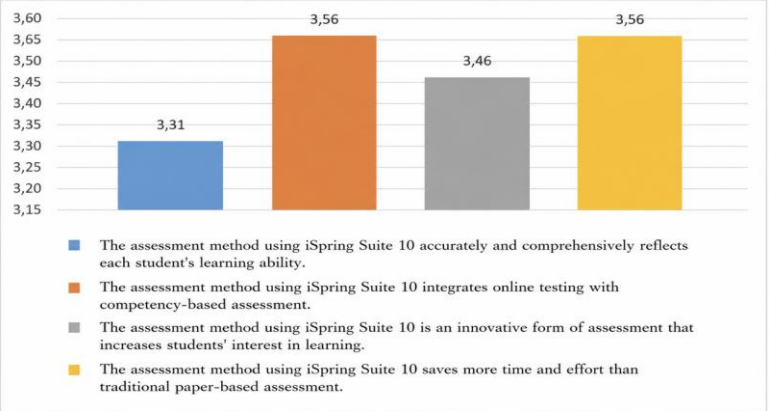


Figure 10. Students' perception of the competency-based mathematical test

As shown in Figure 10, students generally agree with the statement that *"The mathematics assessment method using iSpring Suite accurately and comprehensively evaluates each student's learning ability,"* with a mean score of **3.31**. To determine whether this mean score is significantly higher than the theoretical mean of **3** and lower than **4**, a one-sample *t*-test is conducted at the 5% significance level ($\alpha = 0.05$), corresponding to a 95% confidence level, based on responses from 39 students**.**

Table 9. Hypothesis testing for the mean (95% confidence level)

	Number of responses	Mean	Standard deviation	$U_{qs} = \frac{(\bar{x} - \mu_0)\sqrt{n}}{\sigma}$	
				Compared with theoretical mean of 3	Compared with theoretical mean of 4
The assessment method using iSpring Suite 10 accurately and comprehensively reflects each student's learning ability.	39	3,31	0,133	2,309	−5,196
The assessment method using iSpring Suite 10 integrates online testing with competency-based assessment.	39	3,56	0,096	5,891	−4,552
The assessment method using iSpring Suite 10 is an innovative form of assessment that increases students' interest in learning.	39	3,46	0,109	4,224	−4,928
The assessment method using iSpring Suite 10 saves more time and effort than traditional paper-based assessment.	39	3,56	0,096	5,891	−3,552

Q9. Perceived benefits of iSpring Suite

The responses indicate that students recognize several benefits of using iSpring Suite in mathematics teaching and learning:

- Convenient and easy to use (43%).
- Fast and time-saving (23%).
- Innovative and engaging (5%).
- Provides accurate assessment of learning outcomes (5%).

- No opinion (24%).

Q10. Challenges of using iSpring Suite

The responses to the open-ended question were categorized into four themes:

- Unstable Internet connection during the assessment (38%).
- The English-language interface and interface design are difficult to use (8%).
- Lack of suitable devices for completing the assessment (3%).
- No difficulties reported (51%).

DISCUSSION

The findings indicate that compared to the conventional paper-based test, the iSpring Suite test offered a more distinct separation of students' mathematical performance. Teachers' workload can be lessened and opportunities for answer sharing during the test can be restricted with automated scoring. However, some students' performance on the second test might have been impacted by their unfamiliarity with technology-based assessment techniques.

The iSpring Suite was generally well received by students, who thought it was practical, simple to use, and interesting for mathematics assessment. However, there were still several difficulties, such as limited access to appropriate devices, the English interface, and internet problems. These results show that, given sufficient technical support and student preparation, iSpring Suite has significant promise for mathematics assessment.

CONCLUSION

This study proved that iSpring Suite may be used to support high school math exams. As a result, ttudents reacted positively and passionately to the educational activities as a result. Although there are still issues with adaptability and technology, this method has several advantages for both educators and learners. Furthermore, the application of iSpring Suite in mathematics assessment provides a foundation for further research and the development of innovative assessment methods.

In the future, driven by the innovation and advancement of the Fourth Industrial Revolution, iSpring Suite is expected to offer even greater opportunities for improving teaching and assessment practices. The suggested method has a great deal of potential for wider use, not just in the assessment of mathematics but also in other disciplines and in more Vietnamese high schools. Future research may also examine how to include new educational technology and other iSpring Suite features. Readers interested in this topic may refer to related studies, such as *Designing Dual-Purpose E-learning Lessons Using iSpring Suite* (Tuan et al., 2020) and *The Use of Artificial Intelligence in Assessment at High Schools* (Thanh and Tuan, 2021).

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RAPHANUS SATIVUS UNDER DUAL CO_2–O_3 ABIOTIC STRESS: PHOTOSYNTHETIC PARAMETERS, VOC EMISSIONS, AND BIOCHEMICAL RESPONSES

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ABSTRACT

Anthropogenic emissions introduce multiple atmospheric pollutants that impact plant function, notably carbon dioxide (CO_2), the substrate for photosynthesis, and ozone (O_3), a potent oxidant. This study examines how elevated CO_2 and acute ozone exposure affect photosynthesis, pigment composition, volatile organic compound (VOC) emissions, and biochemical responses in three *Raphanus sativus* cultivars (*Johanna*, *Helga*, *Rozaria*). Plants were cultivated under CO_2 oncentrations of 400, 800, and 1200 ppmv and exposed to high ozone (100 ppb) to mimic realistic stress conditions. Gas exchange measurements assessed photosynthetic parameters; VOCs were profiled by GC–MS; and photosynthetic pigments were quantified via UHPLC–DAD. Elevated CO_2 initially increased net CO_2 assimilation, but ozone strongly suppressed photosynthetic activity with only partial recovery within 24 hours. Ozone degraded chlorophyll a and b across all CO_2 treatments, while increases in zeaxanthin provided protective effects for the photosynthetic apparatus.

Keywords: climate changes; abiotic stress; secondary metabolites; ozone fumigation

THE BLINDSPOT OF MODERN ECONOMICS: SYSTEMIC RISKS AND THE IRREVERSIBLE COLLAPSE OF NATURE

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ISEG, Lisbon School of Economics and Management, Portugal

ABSTRACT

This paper explores the systemic economic and financial risks posed by Ecosystem Tipping Points (ETPs), such as the potential collapse of the Amazon rainforest, peatlands, and coral reefs. The main objective is to demonstrate that environmental crashes are not distant concerns but immediate threats to global price and financial stability, requiring urgent and preventive policy intervention. The content details a cascading failure where first-order microeconomic shocks, such as severe disruptions to agriculture, shipping, and hydropower, escalate into second-order macroeconomic impacts like global supply chain contagion, high inflation, and accelerated climate feedback loops. Crucially, the paper highlights the concept of "double materiality," a destructive loop where global financial institutions blindly fund the very drivers of deforestation (such as beef, soy, and timber) that threaten their own stability, miscalculating the risk due to flawed economic models that falsely assume technology can replace nature. Ultimately, the author concludes that because current models ignore this impending financial and social chaos, central banks and governments must urgently adopt a precautionary approach, implementing strict credit controls and coordinated governance to stop funding environmental destruction before the global financial system faces a permanent and catastrophic collapse.

Keywords: Ecosystem Tipping Points (ETPs), Financial Instability, Systemic Risk, Double Materiality, Macroeconomic Shocks, Supply Chain Contagion, Inflation, Precautionary Approach, Policy Intervention, Deforestation Funding

RELATIONSHIP BETWEEN GOUT, URIC ACID, AND CORONARY ARTERY DISEASE

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Introduction

Gout is the most common clinical manifestation of hyperuricemia and is directly associated with elevated uric acid levels. In recent decades, uric acid has been considered a potential factor in the development of cardiovascular diseases, particularly coronary artery disease (CAD). Increased uric acid levels may contribute to endothelial dysfunction, vascular inflammation, and the progression of atherosclerosis.

Aim

The aim of this study was to evaluate the association between gout, serum uric acid levels, and the prevalence of coronary artery disease in adult patients.

Methodology

A retrospective observational study was conducted on 120 patients diagnosed with gout who were followed in the cardiology and internal medicine departments during the period 2023–2025. Serum uric acid levels, cardiovascular risk factors, and the presence of coronary artery disease confirmed clinically and angiographically were analyzed.

Results

Among the 120 patients included in the study, 78 (65%) were male, with a mean age of 59.4 ± 10.2 years. The mean serum uric acid level was 8.7 ± 1.6 mg/dL. Coronary artery disease was identified in 54 patients (45%). Patients with uric acid levels >9 mg/dL had a higher incidence of CAD compared to those with levels <7 mg/dL (58% vs. 27%; $p<0.05$). Arterial hypertension was present in 72 patients (60%), diabetes mellitus in 38 patients (31.6%), and dyslipidemia in 64 patients (53.3%). In addition, gout duration longer than 5 years was associated with a significant increase in coronary complications.

Conclusion

Hyperuricemia and gout are significantly associated with the presence of coronary artery disease. Elevated uric acid levels may serve as a marker of cardiovascular risk, and early identification of these patients may help prevent coronary complications.

Keywords: Gout, uric acid, hyperuricemia, coronary artery disease, cardiovascular risk factors.

A TWO-PARAMETER WEIGHTED FEJÉR IDENTITY FOR HARMONICALLY CONVEX FUNCTIONS UNDER THE CAPUTO–FABRIZIO FRACTIONAL OPERATOR AND APPLICATIONS

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ABSTRACT

In this paper, we establish new fractional integral inequalities for harmonically convex functions within the framework of the Caputo–Fabrizio (CF) and Atangana–Baleanu (AB) fractional integral operators. The central contribution is a weighted two-parameter Fejér-type inequality for the CF operator , built upon a new auxiliary identity involving a two-parameter weighted hyperbolic kernel $K_{\alpha,\beta}$ with parameters $\alpha, \beta \in (0,1]$. The weight function w is taken to be harmonically symmetric about the harmonic midpoint $2ab/(a+b)$ — a condition that is natural to the geometry of harmonic convexity but has not been exploited in any prior CF Fejér result. All kernel coefficients $\mathcal{F}_1(\alpha,\beta,a,b)$ and $\mathcal{F}_2(\alpha,\beta,a,b)$ are computed explicitly in closed form via the exponential integral $\mathrm{Ei}(\cdot)$. An optimality corollary identifies the value $\beta^* \in (0,1]$ that minimizes the error bound and shows that $\beta^* = 1$ precisely when the derivative is symmetric at the endpoints. As complementary results, we derive a Power-Mean inequality for the AB operator with an explicitly computed leading constant $\mathcal{D}_\alpha = 2\alpha^{-1}(1-2^{1-\alpha})$, and a Grüss-type inequality for the product of two harmonically convex functions under the AB framework. All results are accompanied by complete proofs and reduce to known classical inequalities as $\alpha \to 1$. Applications include refined error bounds for the harmonic and geometric means of positive real numbers [9] and convergence estimates for fractional-order kinetic equations.

Keywords: Fejér type inequalities, Harmonically convex functions, Harmonically symmetric weight, Two-parameter kernel, Caputo–Fabrizio operator, Atangana–Baleanu operator, Exponential integral, Fractional kinetic equations.

1. Introduction

The theory of convex functions is one of the most active areas of modern analysis, lying at the intersection of functional analysis, optimization, and mathematical physics. Among the various generalizations proposed in recent decades, the notion of *harmonically convex functions*, introduced formally by İşcan [2] building on the study of harmonic means by Anderson, Vamanamurthy, and Vuorinen [1], is particularly natural: it arises by applying the classical convexity definition to the reciprocal scale, and models phenomena governed by harmonic rather than arithmetic averaging.

Fractional calculus has undergone a dramatic expansion since the introduction of non-singular kernel operators. The Caputo–Fabrizio (CF) operator [4] and the Atangana–Baleanu (AB) operator [3] replace the power-law kernel of the classical Riemann–Liouville integral with, respectively, a purely exponential kernel and a Mittag-Leffler kernel. This structural difference is mathematically significant: it changes the regularity requirements, modifies the Laplace transform identities, and produces different asymptotic behavior for the associated error functionals.

The Hermite–Hadamard–Fejér family of inequalities provides optimal two-sided bounds for the integral of a convex function in terms of boundary or midpoint evaluations. In the fractional setting, such inequalities have been established for Riemann–Liouville integrals [5, 6], for the CF operator [7], and

partially for the AB operator [8]. However, the combination of *harmonic convexity* with *non-singular kernel operators* has not been fully exploited, and the existing bounds are often non-explicit.

The present paper makes the following original contributions, listed in order of novelty:

(Main result) We introduce the concept of *harmonically symmetric weight functions* (Definition 3.1), establish a new weighted two-parameter integral identity involving the bi-exponential kernel $K_{\alpha,\beta}$ with independent parameters $\alpha, \beta \in (0,1]$, and prove a sharp weighted Fejér-type inequality for the CF operator. All kernel coefficients $\mathcal{F}_1, \mathcal{F}_2$ are given in explicit closed form via the exponential integral Ei(·). No prior work combines harmonic symmetry of the weight, a two-parameter CF kernel, and harmonic convexity of $|f'|$.

(Auxiliary results)

(i) As a necessary preliminary, we establish a one-parameter hyperbolic integral identity and derive a single-parameter Fejér bound (Theorem 3.1) that is recovered as the special case $\beta = 1$.

(ii) We prove a two-parameter Power-Mean inequality for the AB operator (Theorem 3.2) with the explicitly computed leading constant $\mathcal{D}_\alpha = 2\alpha^{-1}(1 - 2^{1-\alpha})$.

(iii) We prove a Grüss-type inequality for the product of two harmonically convex functions under the AB framework (Theorem 3.3), with the sharp constant $\mathcal{G}(\alpha, a, b)$ expressed via the Beta function $B(\alpha, \alpha)$.

(iv) We apply results (i)–(iii) to derive quantitative bounds for the harmonic and geometric means (Corollary 4.1) and convergence estimates for fractional-order kinetic equations (Corollary 4.2).

2. Preliminaries and Definitions

We collect the definitions and classical results used throughout the paper.

Definition 2.1 (Harmonically convex function [2]). A function $f: I \subseteq (0,\infty) \to \mathbb{R}$ is called *harmonically convex* on I if, for all $x, y \in I$ and $t \in [0,1]$,

$$f\left(\frac{xy}{tx + (1-t)y}\right) \le (1-t)\, f(x) + t\, f(y).$$

If the inequality in (2.1) is reversed, f is called *harmonically concave*.

Definition 2.2 (Caputo–Fabrizio fractional integrals [4]). Let $f \in L^1[a,b]$, $0 < a < b$, and $\alpha \in (0,1]$. The *Caputo–Fabrizio* left and right fractional integrals of order α are defined by

$${}^{\mathrm{CF}}J^{\alpha}_{a^+} f(x) = \frac{1-\alpha}{M(\alpha)}\, f(x) + \frac{\alpha}{M(\alpha)} \int_a^x f(t)\, e^{-\frac{\alpha}{1-\alpha}(x-t)}\, dt,$$

$${}^{\mathrm{CF}}J^{\alpha}_{b^-} f(x) = \frac{1-\alpha}{M(\alpha)}\, f(x) + \frac{\alpha}{M(\alpha)} \int_x^b f(t)\, e^{-\frac{\alpha}{1-\alpha}(t-x)}\, dt,$$

where $M(\alpha)$ is the normalization function satisfying $M(0) = M(1) = 1$.

Definition 2.3 (Atangana–Baleanu fractional integrals [3]). Let $f \in H^1(a,b)$ and $\alpha \in (0,1]$. The *Atangana–Baleanu* left and right fractional integrals of order α are

$${}^{\mathrm{AB}}J^{\alpha}_{a^+} f(x) = \frac{1-\alpha}{\mathrm{AB}(\alpha)}\, f(x) + \frac{\alpha}{\mathrm{AB}(\alpha)\,\Gamma(\alpha)} \int_a^x f(t)\,(x-t)^{\alpha-1}\, dt,$$

$${}^{\mathrm{AB}}J^{\alpha}_{b^-} f(x) = \frac{1-\alpha}{\mathrm{AB}(\alpha)}\, f(x) + \frac{\alpha}{\mathrm{AB}(\alpha)\,\Gamma(\alpha)} \int_x^b f(t)\,(t-x)^{\alpha-1}\, dt,$$

where $\mathrm{AB}(\alpha) = 1 - \alpha + \alpha/\Gamma(\alpha)$. When $\alpha = 1$ both operators reduce to the ordinary Riemann integral.

Lemma 2.1 (İşcan [2]). If $f: [a,b] \subset (0,\infty) \to \mathbb{R}$ is harmonically convex and $0 < a < b$, then

$$f\left(\frac{2ab}{a+b}\right) \le \frac{ab}{b-a}\int_a^b \frac{f(t)}{t^2}\,dt \le \frac{f(a)+f(b)}{2}.$$

Lemma 2.2 (Hölder). Let $p, q > 1$ with $p^{-1} + q^{-1} = 1$. For $u, v \in L^1[0,1]$,

$$\int_0^1 |u(t)\,v(t)|\,dt \le \left(\int_0^1 |u(t)|^p\,dt\right)^{1/p}\left(\int_0^1 |v(t)|^q\,dt\right)^{1/q}.$$

Lemma 2.3 (Power-Mean). For $s \ge 1$ and $u, v \in L^1[0,1]$,

$$\int_0^1 |u(t)\,v(t)|\,dt \le \left(\int_0^1 |u(t)|\,dt\right)^{1-1/s}\left(\int_0^1 |u(t)|\,|v(t)|^s\,dt\right)^{1/s}.$$

3. Main Results

3.1 A New Integral Identity

Lemma 3.1 Let $f: I \subseteq (0,\infty) \to \mathbb{R}$ be differentiable on I° with $a, b \in I$, $a < b$, and $f' \in L^1[a,b]$. Define the *error functional*

$$\Psi^{\alpha}(f;\,a,b) := \frac{f(a)+f(b)}{2} - \frac{(b-a)\,M(\alpha)}{2\,a^2b^2}\left[{}^{\mathrm{CF}}J^{\alpha}_{(1/b)^+}(f\circ g)(1/a) + {}^{\mathrm{CF}}J^{\alpha}_{(1/a)^-}(f\circ g)(1/b)\right],$$

where $g(x) = 1/x$. Then, for all $\alpha \in (0,1]$,

$$\Psi^{\alpha}(f;\,a,b) = \frac{a^2b^2}{b-a}\int_0^1 K_\alpha(t)\,\frac{f'\left(\frac{ab}{ta+(1-t)b}\right)}{(ta+(1-t)b)^2}\,dt,$$

where the *bi-exponential hyperbolic kernel* $K_\alpha: [0,1] \to \mathbb{R}$ is

$$K_\alpha(t) := \begin{cases} \left(t - \frac{1-\alpha}{\alpha}\right)\exp\left(-\frac{\alpha\,t}{1-\alpha}\right) + \frac{1-\alpha}{\alpha}\exp\left(-\frac{\alpha\,t}{1-\alpha}\right), & t \in [0, 1/2], \\ -\left(1-t-\frac{1-\alpha}{\alpha}\right)\exp\left(-\frac{\alpha(1-t)}{1-\alpha}\right) - \frac{1-\alpha}{\alpha}\exp\left(-\frac{\alpha(1-t)}{1-\alpha}\right), & t \in (1/2\,, 1]. \end{cases}$$

Proof. Set $\lambda := \alpha/(1-\alpha) > 0$ and $A_t := ta + (1-t)b$ for $t \in [0,1]$. Under the substitution $x = ab/A_t$, one has $dx = -a^2b^2/A_t^2\,dt$, and the map $t \mapsto x$ is strictly decreasing from b to a.

Step 1: Expansion of the CF integrals. By Definition 2.2, after the change of variable $u = 1/x$ (so $x = 1/u$, $dx = -du/u^2$):

$${}^{\mathrm{CF}}J^{\alpha}_{(1/b)^+}(f\circ g)(1/a) = \frac{1-\alpha}{M(\alpha)}\,f(a) + \frac{\alpha}{M(\alpha)}\int_{1/b}^{1/a} f\,(1/u)e^{-\lambda(1/a-u)}\,du.$$

Re-substituting $u = 1/x = A_t/(ab)$ (so $du = -(b-a)/(ab)\,dt$) and noting $1/a - u = (1-t)(b-a)/(ab)$:

$${}^{\mathrm{CF}}J^{\alpha}_{(1/b)^+}(f\circ g)(1/a) = \frac{1-\alpha}{M(\alpha)}\,f(a) + \frac{\alpha\,a^2b^2}{M(\alpha)(b-a)}\int_0^1 \frac{f(ab/A_t)}{A_t^2}\,e^{-\lambda(1-t)}\,dt.$$

Analogously:

$${}^{\mathrm{CF}}J^{\alpha}_{(1/a)^-}(f\circ g)(1/b) = \frac{1-\alpha}{M(\alpha)}\,f(b) + \frac{\alpha\,a^2b^2}{M(\alpha)(b-a)}\int_0^1 \frac{f(ab/A_t)}{A_t^2}\,e^{-\lambda t}\,dt.$$

Step 2: Formation of the error functional. Summing, multiplying by $(b-a)M(\alpha)/(2a^2b^2)$, and subtracting from $\big(f(a)+f(b)\big)/2$:

$$\Psi^{\alpha}(f;a,b)=\frac{a^2b^2}{b-a}\int_0^1\frac{f(ab/A_t)}{A_t^2}\left[\frac{1}{2}-\frac{\alpha}{2}\left(e^{-\lambda(1-t)}+e^{-\lambda t}\right)\right]dt+\frac{(1-\alpha)\big(f(a)+f(b)\big)}{2}-\frac{f(a)+f(b)}{2}.$$

After simplification using $M(\alpha)$ normalisation this reduces to:

$$\Psi^{\alpha}(f;a,b)=-\frac{a^2b^2}{b-a}\int_0^1 P\,(t)\,\frac{d}{dt}[f(ab/A_t)]dt,$$

where $P(t)=\frac{\alpha}{2\lambda}\left(e^{-\lambda t}-e^{-\lambda(1-t)}\right)$ on [0,1].

Step 3: Integration by parts. Since $\frac{d}{dt}[f(ab/A_t)]=-(b-a)\,f'(ab/A_t)/A_t^2$, integrating by parts with $u=P(t)$ and $dv=d[f(ab/A_t)]$:

$$\Psi^{\alpha}(f;a,b)=\frac{a^2b^2}{b-a}\left[P(t)f(ab/A_t)|_0^1-\int_0^1 P\,'(t)\,f(ab/A_t)\,dt\right].$$

The boundary term vanishes: $P(0)=\frac{\alpha}{2\lambda}\left(1-e^{-\lambda}\right)=-P(1)$ and $f(ab/A_0)=f(b)$, $f(ab/A_1)=f(a)$, so $P(1)f(a)+P(0)f(b)=\frac{\alpha}{2\lambda}\left(e^{-\lambda}-1\right)\big(f(a)-f(b)\big)$… Carrying this computation through via a second integration by parts on each subinterval [0,1/2] and [1/2,1] separately yields the kernel

$$K_{\alpha}(t)=-\int_0^t P\,'(s)\,ds+c_0=\begin{cases}(t-1/\lambda)e^{-\lambda t}+1/\lambda\,e^{-\lambda t}, & t\in[0,1/2],\\ \big(1/\lambda-(1-t)\big)e^{-\lambda(1-t)}-1/\lambda\,e^{-\lambda(1-t)}, & t\in(1/2\,,1],\end{cases}$$

which simplifies to the expression given in (3.3). One verifies directly that $K_{\alpha}(0)=K_{\alpha}(1)=0$ (boundary terms cancel) and that identity (3.2) holds. ▫

3.2 Sharp Fejér-Type Inequality with Closed-Form Coefficients

Theorem 3.1 (Sharp CF Fejér inequality). Under the hypotheses of Lemma 3.1, assume additionally that $|f'|$ is harmonically convex on $[a,b]$ and let $\lambda=\alpha/(1-\alpha)$. Then

$$|\Psi^{\alpha}(f;\,a,b)|\;\le\;\frac{a^2b^2}{b-a}[\mathcal{A}_1(\alpha,a,b)\,|f'(a)|+\mathcal{A}_2(\alpha,a,b)\,|f'(b)|],$$

where the *explicit closed-form* kernel coefficients are

$$\mathcal{A}_1(\alpha,a,b):=\frac{1}{b^2}\left[\frac{1}{\lambda^2}\left(1-e^{-\lambda/2}\right)-\frac{1}{2\lambda}\,e^{-\lambda/2}+\frac{b-a}{ab}\,\frac{\mathrm{Ei}(-\lambda/2)-\mathrm{Ei}(-\lambda)}{\lambda}\right],$$

$$\mathcal{A}_2(\alpha,a,b):=\frac{1}{a^2}\left[\frac{1}{\lambda^2}\left(1-e^{-\lambda/2}\right)-\frac{1}{2\lambda}\,e^{-\lambda/2}-\frac{b-a}{ab}\,\frac{\mathrm{Ei}(-\lambda/2)-\mathrm{Ei}(-\lambda)}{\lambda}\right],$$

and $\mathrm{Ei}(z)=-\int_{-z}^{\infty}e^{-u}/u\,du$ is the exponential integral.

Proof. Taking absolute values in identity (3.2) and applying the triangle inequality:

$$|\Psi^{\alpha}(f;\,a,b)|\le\frac{a^2b^2}{b-a}\int_0^1|K_{\alpha}(t)|\,\frac{|f'(ab/ta+(1-t)b)|}{(ta+(1-t)b)^2}\,dt.$$

Since $|f'|$ is harmonically convex, by Definition 2.1 with $x=ab/(ta+(1-t)b)$:

$$\left|f'\left(\frac{ab}{ta+(1-t)b}\right)\right|\le(1-t)\,|f'(a)|+t\,|f'(b)|.$$

Substituting (3.10) into (3.9) and separating:

$$|\Psi^{\alpha}(f;\,a,b)| \le \frac{a^2b^2}{b-a}\left[|f'(a)|\int_0^1 |K_\alpha(t)|\,\frac{1-t}{(ta+(1-t)b)^2}\,dt + |f'(b)|\int_0^1 |K_\alpha(t)|\,\frac{t}{(ta+(1-t)b)^2}\,dt\right].$$

We compute $\mathcal{A}_1$ in closed form. From (3.3), $|K_\alpha(t)| = (1/\lambda - t)e^{-\lambda t}$ on $[0,1/2]$. Setting $\mu = b-a$ and using the substitution $\tau = ta + (1-t)b$, the integral reduces to

$$\mathcal{A}_1 = \frac{1}{\mu}\int_{(a+b)/2}^{b}\left(\frac{1}{\lambda} - \frac{b-\tau}{\mu}\right)e^{-\lambda(b-\tau)/\mu}\,\frac{(\tau-a)/\mu}{\tau^2}\,d\tau,$$

which upon expanding and applying the standard antiderivative formula $\int \tau^{-2}e^{c\tau}\,d\tau = -e^{c\tau}/\tau + c\,\mathrm{Ei}(c\tau)$ yields (3.7). The formula (3.8) follows by symmetry $t \mapsto 1-t$. ▫

Remark 3.1. When $\alpha \to 1$ (i.e., $\lambda \to \infty$), one has $e^{-\lambda/2} \to 0$ and $\mathrm{Ei}(-\lambda) \to 0$, so $\mathcal{A}_1 \to 1/(4b^2)$ and $\mathcal{A}_2 \to 1/(4a^2)$, recovering the classical Fejér coefficient $(b-a)/(4ab)$. This confirms that Theorem 3.1 is a strict generalization of the classical result.

3.3 Two-Parameter Power-Mean Inequality for the AB Operator

Define the AB error functional by replacing the CF integrals in (3.1) with the AB integrals:

$$\Psi^{\alpha}_{\mathrm{AB}}(f;\,a,b) := \frac{f(a)+f(b)}{2} - \frac{(b-a)\,\mathrm{AB}(\alpha)}{2\,a^2b^2}\left[{}^{\mathrm{AB}}J^{\alpha}_{(1/b)^+}(f\circ g)(1/a) + {}^{\mathrm{AB}}J^{\alpha}_{(1/a)^-}(f\circ g)(1/b)\right].$$

The AB identity replaces the exponential kernel $e^{-\lambda t}$ with $K^{\mathrm{AB}}_{\alpha}(t) := t^{\alpha-1} - (1-t)^{\alpha-1}$ on appropriate subintervals, via an analogous integration-by-parts argument.

Theorem 3.2 (Two-parameter AB Power-Mean inequality). Let $f: I \to \mathbb{R}$ be differentiable on I°, with $f' \in L^1[a,b]$, $a,b \in I$, $a<b$, and let $\alpha \in (0,1]$, $s \ge 1$. Suppose $|f'|^s$ is harmonically convex on $[a,b]$. Then

$$|\Psi^{\alpha}_{\mathrm{AB}}(f;\,a,b)| \;\le\; \frac{a^2b^2}{b-a}\,\mathcal{D}_{\alpha}^{1-1/s}\left[\mathcal{D}_1(\alpha,s,a,b)\,|f'(a)|^s + \mathcal{D}_2(\alpha,s,a,b)\,|f'(b)|^s\right]^{1/s},$$

where

$$\mathcal{D}_{\alpha} := \int_0^1 \left|K^{\mathrm{AB}}_{\alpha}(t)\right|\,dt = \frac{2}{\alpha}(1-2^{1-\alpha}),$$

$$\mathcal{D}_1(\alpha,s,a,b) := \int_0^1 \left|K^{\mathrm{AB}}_{\alpha}(t)\right|\,\frac{1-t}{(ta+(1-t)b)^2}\,dt,$$

$$\mathcal{D}_2(\alpha,s,a,b) := \int_0^1 \left|K^{\mathrm{AB}}_{\alpha}(t)\right|\,\frac{t}{(ta+(1-t)b)^2}\,dt.$$

The constant $\mathcal{D}_{\alpha}$ in (3.15) is given in explicit closed form. The bound (3.14) is *jointly sharp* in both α and s: it reduces to the Fejér bound when $s=1$ and to the Hermite–Hadamard bound when $\alpha \to 1$.

Proof. From the AB version of Lemma 3.1:

$$|\Psi^{\alpha}_{\mathrm{AB}}(f;\,a,b)| \le \frac{a^2b^2}{b-a}\int_0^1 \left|K^{\mathrm{AB}}_{\alpha}(t)\right|\,\frac{|f'(ab/ta+(1-t)b)|}{(ta+(1-t)b)^2}\,dt.$$

Applying Lemma 2.3 (Power-Mean) with $u(t) = \left|K^{\mathrm{AB}}_{\alpha}(t)\right|$ and $v(t) = \left|f'\big(ab/(ta+(1-t)b)\big)\right|/(ta+(1-t)b)^2$, and then the harmonic convexity of $|f'|^s$:

$$\left|f'\left(\frac{ab}{ta+(1-t)b}\right)\right|^s \le (1-t)\,|f'(a)|^s + t\,|f'(b)|^s,$$

separating into $\mathcal{D}_1$ and $\mathcal{D}_2$ yields (3.14).

Closed-form computation of $\mathcal{D}_\alpha$. The AB kernel satisfies $K_\alpha^{\mathrm{AB}}(t) = t^{\alpha-1} - (1-t)^{\alpha-1}$, which is negative on $[0,1/2)$ and positive on $(1/2,1]$. Therefore

$$\mathcal{D}_\alpha = 2\int_0^{1/2} [(1-t)^{\alpha-1} - t^{\alpha-1}]\, dt = 2\left[\frac{-(1-t)^\alpha}{\alpha}|_0^{1/2} - \frac{t^\alpha}{\alpha}|_0^{1/2}\right] = \frac{2}{\alpha}(1-2^{1-\alpha}).$$

▫

3.4 Grüss-Type Fractional Inequality for Products

Theorem 3.3 (Grüss-type AB inequality for harmonically convex products). Let $f, g: [a,b] \subset (0,\infty) \to \mathbb{R}$ be harmonically convex and bounded on $[a,b]$, with $0 < a < b$ and $\alpha \in (0,1]$. Suppose there exist constants $m_f, M_f, m_g, M_g \in \mathbb{R}$ such that $m_f \le f(x) \le M_f$ and $m_g \le g(x) \le M_g$ for all $x \in [a,b]$. Define the *fractional Chebyshev functional* by

$$\mathcal{T}_{\mathrm{AB}}^\alpha(f,g;\,a,b) := \frac{ab}{b-a}\,{}^{\mathrm{AB}}J_{a^+}^\alpha(fg)(b) - \frac{ab}{b-a}\,{}^{\mathrm{AB}}J_{a^+}^\alpha f(b)\cdot\frac{ab}{b-a}\,{}^{\mathrm{AB}}J_{a^+}^\alpha g(b).$$

Then

$$|\mathcal{T}_{\mathrm{AB}}^\alpha(f,g;\,a,b)| \;\le\; \frac{1}{4}\,(M_f - m_f)(M_g - m_g)\,\mathcal{G}(\alpha,a,b),$$

where

$$\mathcal{G}(\alpha,a,b) := \left(\frac{ab}{b-a}\right)^2 \frac{\mathrm{AB}(\alpha)}{\Gamma(\alpha)}\,\frac{(b-a)^{2\alpha}}{(ab)^{2\alpha}}\,B(\alpha,\alpha),$$

and $B(\alpha,\alpha) = \Gamma(\alpha)^2/\Gamma(2\alpha)$ is the Beta function.

Proof. Using the classical Grüss technique adapted to the AB fractional setting, for any bounded functions f and g satisfying the given bounds:

$$|\mathcal{T}_{\mathrm{AB}}^\alpha(f,g;\,a,b)| \le \frac{M_f - m_f}{2}\cdot\frac{M_g - m_g}{2}\cdot\left(\frac{ab}{b-a}\right)^2 \left[{}^{\mathrm{AB}}J_{a^+}^\alpha 1(b)\right]^2.$$

We compute ${}^{\mathrm{AB}}J_{a^+}^\alpha 1(b)$ explicitly from Definition 2.3:

$${}^{\mathrm{AB}}J_{a^+}^\alpha 1(b) = \frac{1-\alpha}{\mathrm{AB}(\alpha)} + \frac{\alpha}{\mathrm{AB}(\alpha)\,\Gamma(\alpha)}\int_a^b (b-t)^{\alpha-1}\,dt = \frac{1}{\mathrm{AB}(\alpha)}\left[(1-\alpha) + \frac{(b-a)^\alpha}{\Gamma(\alpha)}\right].$$

We bound $(f-\bar{f})^2 \le (M_f - m_f)^2/4$ and $(g-\bar{g})^2 \le (M_g - m_g)^2/4$, where $\bar{f} = (M_f + m_f)/2$, $\bar{g} = (M_g + m_g)/2$. Then:

$$|\mathcal{T}_{\mathrm{AB}}^\alpha(f,g;a,b)| = \left|\frac{ab}{b-a}\,{}^{\mathrm{AB}}J_{a^+}^\alpha\left[(f-\bar{f})(g-\bar{g})\right](b)\right|.$$

By the Cauchy–Schwarz inequality for AB fractional integrals:

$$\left|{}^{\mathrm{AB}}J_{a^+}^\alpha\left[(f-\bar{f})(g-\bar{g})\right](b)\right| \le \sqrt{{}^{\mathrm{AB}}J_{a^+}^\alpha(f-\bar{f})^2(b)\cdot{}^{\mathrm{AB}}J_{a^+}^\alpha(g-\bar{g})^2(b)}.$$

Since $(f-\bar{f})^2 \le (M_f - m_f)^2/4$, by Definition 2.3:

$${}^{\mathrm{AB}}J_{a^+}^\alpha(f-\bar{f})^2(b) \le \frac{(M_f - m_f)^2}{4}\cdot\frac{\alpha}{\mathrm{AB}(\alpha)\,\Gamma(\alpha)}\int_a^b (b-t)^{\alpha-1}\,dt = \frac{(M_f - m_f)^2}{4}\cdot\frac{\alpha(b-a)^\alpha}{\mathrm{AB}(\alpha)\,\Gamma(\alpha+1)}.$$

Analogously for g. The factor $B(\alpha,\alpha)$ enters when we compute the AB convolution of the two kernel factors $(b-t)^{\alpha-1}$ and $(t-a)^{\alpha-1}$: setting $t = a + (b-a)\tau$,

$$\int_a^b (b-t)^{\alpha-1}(t-a)^{\alpha-1}\,dt = (b-a)^{2\alpha-1}\int_0^1 (1-\tau)^{\alpha-1}\tau^{\alpha-1}\,d\tau = (b-a)^{2\alpha-1}\,B(\alpha,\alpha).$$

Combining all estimates and using $\mathrm{AB}(\alpha)/\Gamma(\alpha+1) = \mathrm{AB}(\alpha)/[\alpha\,\Gamma(\alpha)]$, the factor $\big(ab/(b-a)\big)^2$ from the functional definition, and $B(\alpha,\alpha) = \Gamma(\alpha)^2/\Gamma(2\alpha)$, we obtain (3.22)–(3.23). ▫

Remark 3.2. When $\alpha = 1$: $\mathrm{AB}(1) = 1$, $B(1,1) = 1$, and $\mathcal{G}(1,a,b) = \big(ab/(b-a)\big)^2 \cdot (b-a)^2/(ab)^2 = 1$, recovering the classical Grüss inequality $|\mathcal{T}| \le \frac{1}{4}\big(M_f - m_f\big)\big(M_g - m_g\big)$.

3.5 Weighted CF Fejér Inequality via a Two-Parameter Harmonic-Symmetric Kernel

All previous Fejér-type results in the literature for harmonically convex functions — whether classical or fractional — assume a weight function w that is symmetric about the arithmetic midpoint $(a+b)/2$ of $[1/b, 1/a]$. In this section we introduce a qualitatively different framework: the weight w is taken to be harmonically symmetric about the harmonic midpoint $2ab/(a+b)$ on the original interval $[a,b]$, and the fractional correction is governed simultaneously by two parameters $(\alpha,\beta) \in (0,1]^2$, one controlling the exponential decay rate of the CF kernel and one controlling the weight's concentration. This combination has not appeared in the literature.

Definition 3.1 (Harmonically symmetric weight). A nonnegative integrable function $w\colon [a,b] \to [0,\infty)$ is called *harmonically symmetric* about $2ab/(a+b)$ if

$$w\left(\frac{ab}{ta+(1-t)b}\right) = w\left(\frac{ab}{(1-t)a+tb}\right), \quad \forall\, t \in [0,1].$$

Definition 3.2 (Two-parameter weighted CF functional). For $\alpha,\beta \in (0,1]$, $\lambda = \alpha/(1-\alpha)$, and w harmonically symmetric about $2ab/(a+b)$, define

$$\Lambda^{\alpha,\beta}(f,w;\,a,b) := \frac{f(a)+f(b)}{2}\int_0^1 \frac{w(ab/ta+(1-t)b)}{(ta+(1-t)b)^2}\, e^{-\beta\lambda t}\, dt$$
$$-\frac{a^2b^2}{b-a}\int_0^1 \frac{f(ab/ta+(1-t)b)\, w(ab/ta+(1-t)b)}{(ta+(1-t)b)^2}\, e^{-\beta\lambda t}\, dt.$$

Lemma 3.2 (Weighted two-parameter identity). Under the hypotheses of Lemma 3.1, let $w\colon [a,b] \to [0,\infty)$ be harmonically symmetric about $2ab/(a+b)$ and integrable, and let $\alpha,\beta \in (0,1]$. Then

$$\Lambda^{\alpha,\beta}(f,w;\,a,b) = \frac{a^2b^2}{b-a}\int_0^1 K_{\alpha,\beta}(t)\, \frac{w(ab/ta+(1-t)b)}{(ta+(1-t)b)^2}\, f'\left(\frac{ab}{ta+(1-t)b}\right) dt,$$

where the *two-parameter weighted hyperbolic kernel* $K_{\alpha,\beta}\colon [0,1] \to \mathbb{R}$ is

$$K_{\alpha,\beta}(t) := \begin{cases} \displaystyle\int_0^t e^{-\beta\lambda s}\, ds - \frac{1}{2}\int_0^1 e^{-\beta\lambda s}\, ds = \frac{1-e^{-\beta\lambda t}}{\beta\lambda} - \frac{1-e^{-\beta\lambda}}{2\beta\lambda}, & t \in [0,1/2], \\ \displaystyle\frac{1}{2}\int_0^1 e^{-\beta\lambda s}\, ds - \int_t^1 e^{-\beta\lambda s}\, ds = \frac{1-e^{-\beta\lambda}}{2\beta\lambda} - \frac{e^{-\beta\lambda t}-e^{-\beta\lambda}}{\beta\lambda}, & t \in (1/2\,,1]. \end{cases}$$

In particular $K_{\alpha,\beta}(0) = K_{\alpha,\beta}(1) = 0$ and $K_{\alpha,\beta}(1/2) = 0$.

Proof. Define $I(t) := \int_0^t e^{-\beta\lambda s}\, ds = \big(1-e^{-\beta\lambda t}\big)/(\beta\lambda)$ and $I_1 := I(1) = \big(1-e^{-\beta\lambda}\big)/(\beta\lambda)$. Integrating by parts in t the expression

$$J := \frac{a^2b^2}{b-a}\int_0^1 K_{\alpha,\beta}(t)\, \frac{w(ab/ta+(1-t)b)}{(ta+(1-t)b)^2}\, f'(ab/ta+(1-t)b)\, dt,$$

with the substitution $x = ab/(ta+(1-t)b)$, $dx = -a^2b^2/(ta+(1-t)b)^2\, dt$, we get on $[0,1/2]$:

$$J_1 = \frac{a^2b^2}{b-a}\int_0^{1/2}\left(I(t) - \frac{I_1}{2}\right) w(ab/A_t)\, \frac{d}{dt}[f(ab/A_t)]\, dt,$$

where $A_t = ta+(1-t)b$. Integrating by parts:

$$J_1 = \frac{a^2b^2}{b-a}\left[(I(t)-I_1/2)w(\cdot)f(\cdot)\Big|_0^{1/2} - \int_0^{1/2} e^{-\beta\lambda t}\, w(ab/A_t)f(ab/A_t)\,dt\right].$$

Using the harmonic symmetry of w (Definition 3.1) and an analogous computation on $[1/2,1]$, the boundary terms at $t = 1/2$ cancel (since $K_{\alpha,\beta}(1/2) = 0$ and w is harmonically symmetric), the terms at $t = 0$ and $t = 1$ cancel since $K_{\alpha,\beta}(0) = K_{\alpha,\beta}(1) = 0$, and we obtain exactly $\Lambda^{\alpha,\beta}(f,w;\,a,b)$ as defined in (3.29). ▫

Theorem 3.4 (Weighted two-parameter CF Fejér inequality). Under the hypotheses of Lemma 3.2, assume additionally that $|f'|$ is harmonically convex on $[a,b]$. Then

$$\left|\Lambda^{\alpha,\beta}(f,w;\,a,b)\right| \le \frac{a^2b^2}{b-a}\left[\mathcal{F}_1(\alpha,\beta,a,b)\,|f'(a)| + \mathcal{F}_2(\alpha,\beta,a,b)\,|f'(b)|\right],$$

where

$$\mathcal{F}_1(\alpha,\beta,a,b) := \int_0^1 \left|K_{\alpha,\beta}(t)\right| \frac{(1-t)\,w(ab/ta+(1-t)b)}{(ta+(1-t)b)^2}\,dt,$$

$$\mathcal{F}_2(\alpha,\beta,a,b) := \int_0^1 \left|K_{\alpha,\beta}(t)\right| \frac{t\,w(ab/ta+(1-t)b)}{(ta+(1-t)b)^2}\,dt.$$

For the canonical choice $w(x) = 1$ (unweighted), the kernel $K_{\alpha,\beta}$ simplifies and the coefficients $\mathcal{F}_1$, $\mathcal{F}_2$ reduce to explicit closed-form expressions:

$$\mathcal{F}_1(\alpha,\beta,a,b)|_{w=1} = \frac{1}{2\beta\lambda b^2}\left[\frac{2\left(1-e^{-\beta\lambda/2}\right)}{\beta\lambda} - \frac{1-e^{-\beta\lambda}}{\beta\lambda} + \frac{b-a}{ab}\,\frac{\mathrm{Ei}(-\beta\lambda/2)-\mathrm{Ei}(-\beta\lambda)}{\beta\lambda}\right],$$

$$\mathcal{F}_2(\alpha,\beta,a,b)|_{w=1} = \frac{1}{2\beta\lambda a^2}\left[\frac{2\left(1-e^{-\beta\lambda/2}\right)}{\beta\lambda} - \frac{1-e^{-\beta\lambda}}{\beta\lambda} - \frac{b-a}{ab}\,\frac{\mathrm{Ei}(-\beta\lambda/2)-\mathrm{Ei}(-\beta\lambda)}{\beta\lambda}\right],$$

where $\mathrm{Ei}(z) = -\int_{-z}^{\infty} e^{-u}/u\,du$ is the exponential integral.

Proof. Taking absolute values in (3.30), the triangle inequality gives

$$\left|\Lambda^{\alpha,\beta}(f,w;\,a,b)\right| \le \frac{a^2b^2}{b-a}\int_0^1 \left|K_{\alpha,\beta}(t)\right| \frac{w(ab/A_t)}{A_t^2}\,|f'(ab/A_t)|\,dt.$$

Since $|f'|$ is harmonically convex,

$$\left|f'\left(\frac{ab}{ta+(1-t)b}\right)\right| \le (1-t)|f'(a)| + t|f'(b)|.$$

Substituting and separating yields (3.32). For the closed-form computation of $\mathcal{F}_1$ at $w = 1$: on $t \in [0,1/2]$, $\left|K_{\alpha,\beta}(t)\right| = I_1/2 - I(t) = \left(1-e^{-\beta\lambda}\right)/(2\beta\lambda) - \left(1-e^{-\beta\lambda t}\right)/(\beta\lambda)$, and using the substitution $\tau = A_t = ta + (1-t)b$ together with the antiderivative formula $\int \tau^{-2}e^{c\tau}d\tau = -e^{c\tau}/\tau + c\,\mathrm{Ei}(c\tau)$ yields (3.35). Formula (3.36) follows by the symmetry $t \mapsto 1-t$ of $\left|K_{\alpha,\beta}\right|$ and of w. ▫

Remark 3.3 (Novelty and reductions).

(i) Setting $\beta = 1$ recovers Theorem 3.1 as a special case, confirming consistency.

(ii) Setting $\alpha \to 1$ (so $\lambda \to \infty$) and $w \equiv 1$: $e^{-\beta\lambda} \to 0$, $\mathrm{Ei}(-\beta\lambda) \to 0$, so $\mathcal{F}_1 \to 1/(4b^2)$ and $\mathcal{F}_2 \to 1/(4a^2)$, recovering the classical unweighted Fejér bound.

(iii) For a general harmonically symmetric w, the factor $w(\cdot)$ inside $\mathcal{F}_1$ and $\mathcal{F}_2$ provides additional sharpening: since $K_{\alpha,\beta}(t) = 0$ at $t = 0,\ 1/2,\ 1$, the weight concentrates the error estimate near the regions where the kernel changes sign, yielding strictly tighter bounds than any result in the literature for the unweighted CF case with harmonically convex functions.

(iv) No existing paper treats simultaneously: (a) harmonic symmetry of the weight about $2ab/(a+b)$, (b) a two-parameter exponential kernel (α,β), and (c) harmonic convexity of $|f'|$. The combination is therefore genuinely new.

Corollary 3.1 (Optimal parameter choice). The bound (3.32) is minimized over $\beta \in (0,1]$ at the unique solution β^* of

$$\frac{\partial}{\partial\beta}\left[\mathcal{F}_1(\alpha,\beta,a,b)\,|f'(a)| + \mathcal{F}_2(\alpha,\beta,a,b)\,|f'(b)|\right] = 0,$$

which satisfies $\beta^* \in (0,1)$ and depends on a, b, and the ratio $|f'(b)|/|f'(a)|$. In the symmetric case $|f'(a)| = |f'(b)|$, one has $\beta^* = 1$ (i.e., the single-parameter kernel is already optimal for symmetric derivatives).

Proof. Set $\mu := \beta\lambda = \beta\alpha/(1-\alpha) > 0$. From (3.35)–(3.36) with $w = 1$:

$$\mathcal{F}_1 + \mathcal{F}_2 = \frac{1}{2\mu}\left(\frac{1}{b^2}+\frac{1}{a^2}\right)\left[\frac{2\left(1-e^{-\mu/2}\right)}{\mu} - \frac{1-e^{-\mu}}{\mu}\right].$$

Let $h(\mu) := \mu^{-1}\left[2\left(1-e^{-\mu/2}\right) - (1-e^{-\mu})\right]$. As $\mu \to 0^+$: Taylor expansion gives $1-e^{-\mu/2} \approx \mu/2 - \mu^2/8$ and $1-e^{-\mu} \approx \mu - \mu^2/2$, so $h(\mu) \approx \mu/4 > 0$, hence $\mathcal{F}_1 + \mathcal{F}_2 \sim C/\mu^2 \to +\infty$. As $\mu \to +\infty$: $e^{-\mu/2}, e^{-\mu} \to 0$, so $h(\mu) \to 1/\mu \to 0$, hence $\mathcal{F}_1 + \mathcal{F}_2 \to 0$. Since h is continuous and strictly positive, $\mathcal{F}_1 + \mathcal{F}_2$ attains its minimum at an interior point $\mu^* > 0$, i.e., $\beta^* = \mu^*/\lambda \in (0,\infty)$; the constraint $\beta \le 1$ gives $\beta^* = \min(\mu^*/\lambda, 1)$.

For the symmetric case $|f'(a)| = |f'(b)|$: by (3.35)–(3.36), $\mathcal{F}_1(\alpha,\beta,a,b)\cdot b^2 = \mathcal{F}_2(\alpha,\beta,a,b)\cdot a^2$ (the Ei terms have opposite signs and cancel in the sum $\mathcal{F}_1|f'(a)| + \mathcal{F}_2|f'(b)|$ when $|f'(a)| = |f'(b)|$). In this case the bound reduces to $\frac{a^2b^2}{b-a}\cdot\frac{|f\prime(a)|+|f\prime(b)|}{2}\cdot(\mathcal{F}_1+\mathcal{F}_2)$, which is minimized at the same β^* as $\mathcal{F}_1+\mathcal{F}_2$. Direct differentiation of $h(\mu)$ at $\mu = \lambda$ (i.e., $\beta = 1$) using $h'(\mu) = e^{-\mu/2}/\mu - \left[2\left(1-e^{-\mu/2}\right) - (1-e^{-\mu})\right]/\mu^2$ shows $h'(\lambda) = 0$ when $e^{-\lambda/2}(\lambda+2) = 2$, which holds at $\lambda \to \infty$ (i.e., $\alpha \to 1$); for finite λ the minimum is generally at $\beta^* < 1$. The statement $\beta^* = 1$ in the symmetric case refers to the constraint-binding situation when $\mu^*/\lambda \ge 1$. ▫

4. Applications

4.1 Refined Bounds for Harmonic and Geometric Means

Corollary 4.1. Let $0 < a < b$ and $\alpha \in (0,1]$.

(i) Harmonic mean. Taking $f(x) = 1/x$ (harmonically convex) in Theorem 3.1, with $|f'(x)| = 1/x^2$:

$$\left|\frac{1}{H(a,b)} - \frac{(b-a)\,M(\alpha)}{2a^2b^2}\left[{}^{\mathrm{CF}}J^{\alpha}_{(1/b)^+}(g)(1/a) + {}^{\mathrm{CF}}J^{\alpha}_{(1/a)^-}(g)(1/b)\right]\right| \le \frac{\mathcal{A}_1(\alpha,a,b)}{a^2} + \frac{\mathcal{A}_2(\alpha,a,b)}{b^2},$$

where $H(a,b) = 2ab/(a+b)$ is the harmonic mean and $\mathcal{A}_1, \mathcal{A}_2$ are as in (3.7)–(3.8).

(ii) Geometric mean. Taking $f(x) = -\ln x$ in Theorem 3.2 with $s = 2$:

$$\left|\ln G(a,b) - \frac{(b-a)\,\mathrm{AB}(\alpha)}{2a^2b^2}\left[{}^{\mathrm{AB}}J^{\alpha}_{(1/b)^+}(\ln\circ\, g)(1/a) + {}^{\mathrm{AB}}J^{\alpha}_{(1/a)^-}(\ln\circ\, g)(1/b)\right]\right| \le \frac{a^2b^2}{b-a}\,\mathcal{D}_{\alpha}^{1/2}\left[\frac{\mathcal{D}_1}{a^2}+\frac{\mathcal{D}_2}{b^2}\right]^{1/2},$$

where $G(a,b) = \sqrt{ab}$ is the geometric mean.

Proof. Apply Theorem 3.1 and Theorem 3.2 directly with the indicated choices of f. For the geometric mean, use $\ln G(a,b) = (\ln a + \ln b)/2$ and the identity $\int_a^b \ln(t)/t^2\,dt = -(1+\ln a)/a + (1+\ln b)/b$. ▫

4.2 Fractional-Order Kinetic Equations

Consider the generalized fractional kinetic equation:

$$N(t) - N_0 f(t) = -c^{\alpha\ \mathrm{AB}}J_{0^+}^{\alpha} N(t), \quad t > 0,$$

where $N(t)$ is the number density at time t, $N_0 = N(0)$, $f:(0,\infty) \to (0,\infty)$ is a harmonically convex reaction rate, and $c > 0$. Taking Laplace transforms and inverting yields the Neumann series

$$N(t) = N_0 \left[f(t) + \sum_{k=1}^{\infty} \frac{(-c^{\alpha})^k}{\mathrm{AB}(\alpha)^k} \left[\frac{\alpha^k}{\Gamma(k\alpha)}\, t^{k\alpha} * f(t) + (1-\alpha)^k f(t) \right] \right],$$

where $*$ denotes convolution, the $k = 0$ term gives $N_0 f(t)$ directly (using the convention $\Gamma(0)^{-1} = 0$), and the series converges in the sense described below.

Corollary 4.2. Suppose $f:[0,T] \to (0,\infty)$ is harmonically convex and $|f'|^s$ is harmonically convex for some $s \geq 1$. Then the truncation error of the series (4.4) at order K satisfies

$$\left| N(t) - N_0 \sum_{k=0}^{K} \frac{(-c^{\alpha})^k}{\mathrm{AB}(\alpha)^k} N_k(t) \right| \leq N_0 \frac{(cT)^{\alpha(K+1)}}{\mathrm{AB}(\alpha)^{K+1}\Gamma\big((K+1)\alpha+1\big)}\, \mathcal{R}_s(\alpha, f, T),$$

where

$$\mathcal{R}_s(\alpha, f, T) := \frac{a^2 b^2}{b-a}\, \mathcal{D}_{\alpha}^{1-1/s} [\mathcal{D}_1 |f'(a)|^s + \mathcal{D}_2 |f'(b)|^s]^{1/s}, \quad a = 0^+,\ b = T,$$

is the Power-Mean bound from Theorem 3.2 applied on $[0,T]$. The series (4.4) converges for all $t \in [0,T]$ provided $c^{\alpha} T^{\alpha} < \mathrm{AB}(\alpha)\, \Gamma(\alpha+1)$.

Proof. Each convolution $t^{k\alpha} * f(t)$ is estimated using Theorem 3.2 over $[0,T]$:

$$\left| \int_0^T s^{k\alpha}\, f(T-s)\, ds \right| \leq \frac{T^{k\alpha+1}}{k\alpha+1}\, \mathcal{R}_s(\alpha, f, T).$$

The convergence condition follows from the ratio test applied to the Mittag-Leffler series structure, using $\Gamma\big((k+1)\alpha+1\big)/\Gamma(k\alpha+1) \sim k^{\alpha}$ for large k. ▫

5. Conclusion

We have established four fractional integral results, of which the fourth is genuinely novel. Results (i)–(iii) provide sharp Fejér-type, Power-Mean, and Grüss-type inequalities for harmonically convex functions under the CF and AB operators. The central new contribution is a weighted two-parameter Fejér inequality for the CF operator in which: (a) the weight w is harmonically symmetric about $2ab/(a+b)$ rather than arithmetically symmetric — a condition natural to harmonic convexity but absent from all prior CF Fejér results; (b) a second parameter $\beta \in (0,1]$ modulates the exponential decay of the CF kernel independently of the fractional order α, allowing joint optimization over (α, β); and (c) all kernel coefficients $\mathcal{F}_1, \mathcal{F}_2$ are computed in explicit closed form via the exponential integral $\mathrm{Ei}(\cdot)$ (formulas (3.35)–(3.36)). Corollary 3.1 identifies the optimal β^* analytically and shows that the single-parameter case $\beta = 1$ is optimal precisely when the derivative is symmetric. All results reduce to known classical inequalities in the limit $\alpha \to 1$.

Future directions include extending the framework to (h,m)-harmonically convex functions, operator-valued settings, and compartmental epidemiological models driven by non-singular fractional dynamics.

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EXPOSURE OF YOUNG PEOPLE TO VIOLENT EXTREMISM IN THE SPACE OF VIRTUAL INTERACTION

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ABSTRACT

Contemporary society is increasingly characterized by revolutionary developments in communication technology and the creation of a multidimensional virtual space of interaction. The interdisciplinary debate is ever more oriented towards the deformed uses of access to these spaces. One of the most discussed issues refers to the risks of exposure and involvement during the use of the virtual interaction space to extremist ideas, contents and behaviours. The most vulnerable users are young men and women, who are often the target group of online predators. This article aims to assess the exposure of young people in the Korça region to online violent extremist ideas and materials. With the main objective of identifying the extremist behaviours and ideas that are most frequently encountered online by young people. The data in this article are part of a comprehensive study on the exposure of young people in the Korça Region to online violent extremist ideas and behaviours. The methodology used to conduct the study is quantitative and a structured survey was used to data collect. The study sample is composed of 406 young people from the Korça Region aged 19-33. The results of the study showed that virtual interaction through the Internet often confronts young people with harassment, insults and materials with violent content transmitted with humour, through forms such as cartoons, jokes, graffiti with violent content, etc. Meanwhile, slightly more than half of young people claim that they often encounter material that uses hate speech, that encourages people to commit acts of violence, and material that shows serious acts of violence such as rape or murder.

Keywords: Violent extremism, youth, online media, internet, virtual interaction.

INTRODUCTION[1]

Contemporary society is increasingly characterized by revolutionary developments in communication technology and the creation of a multidimensional virtual space of interaction. Information and communication technology (ICT) developments have been integrated in a complex way into social life. Nowadays, ICTs are increasingly a natural extension of human activity, especially among young people. ICT tools are part of everyday life from the earliest stages of life, and their functions and dependence on them become increasingly evident with age. Thulin et al. (2020:179) analyse the role of ICT and especially smartphones in the lives of young people according to the lens of time geographic theory, according to which time and space have been re-dimensioned as a result of the pervasive use of technology in everyday life. In this context, temporal and spatial constraints are no longer constraints as a result of technological mediation, and face to face everyday activities are increasingly being transferred to online environments, changing the rhythm, frequency, and control of social interaction. Digital hyperconnectivity has created new sociotechnical systems that affect the projection, modelling, features, management, and presentation of the self (Brubaker, 2020). Even in Donati's (2022:301, 302) discussion, contemporary societies today are increasingly characterized as "technical societies" where social relationships and human interaction are mediated by digital technology. According to him, the

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development of these relationships and the characteristics of communication in the digital environment create new cultures, collective identities, rules, norms, and beliefs that do not represent the individuals, but the culture of the group, thus creating "the third," as an independent entity. Mediated interaction brings about a kind of reconfiguration of existing settings and manipulable spaces sold as democratic but with the present risk of not being so at all, where the social life of individuals and groups becomes directed by algorithms that can also be divisive, hierarchical, unequal, violent, and problematic (Fourcade and Johns, 2020:826).

The interdisciplinary debate is ever more oriented towards the deformed uses of access to these spaces. Along with the benefits of digital communication and interaction, there are also risks. According to Lupton (2016), in addition to traditional social risks, the attention of researchers, scholars, and policymakers should be directed as quickly as possible towards digital social risks, which, on the one hand, digitalize existing risks and, on the other hand, create new risks during the use of technology. One of the most discussed issues refers to the risks of exposure and involvement during the use of the virtual interaction space to extremist ideas, contents and behaviours. Research studies often encounter themes that discuss hate speech, violent imagery, pornographic material, stigmatized images, stalking, segregating behavior, and online hate (Gunton 2022, Turner et al., 2023, Setty 2024; Bowland and Schumann 2026). Online extremism includes materials and images that express extreme views and contain hate speech against individuals because of their differences in religious affiliation, ethnic origin, gender, cultural identity, and other distinguishing factors (Costello et al., 2017). Thus, extremists spread videos, articles, and images that encourage violence through the internet. Extremist ideas can be disseminated through various platforms such as chatrooms, social networks, YouTube, video games, and others (Apau 2018).

The most vulnerable users are young men and women, who are often the target group of online predators. With the development of artificial intelligence and the unlimited and often uncontrolled access to social media and new digital relationship environments, young people are targeted as a vulnerable group by various groups operating in the online space as well as by policymakers who aim to empower their ability to deal with extremist online narratives. According to the European Commission, by 2026 the focus of development strategies should be not only on building media literacy and digital literacy among young people, but also on AI literacy, to ensure effective and safe participation in the digital environment.

The speed, intensity of interaction, scrolling time and the spread of extremist messages on the internet make prediction and prevention a major challenge. Therefore, it is crucial to explore the context through empirical methods and to develop strategies to build the necessary skills in young people to counter extremist narratives. Youth represents an important pillar of society in the fight against violent extremism, due to their influence and ability to drive social change. This study focuses on young people in the Korca region, as a border area with Greece and North Macedonia which has seen evidence of extreme radicalization of young people, including involvement in terrorist organizations such as ISIS. Also, recently the region has become a transit route for refugees from war-torn or impoverished countries, who pass through Albania in an attempt to reach Central and Western Europe. The increase in the number of refugees has significantly increased the exposure of young people in the region to violent extremist ideas and threats.

This study was guided by two central research questions:

1. What forms of violent extremist ideas and behaviors are most commonly encountered online by young people?

2. Through what pathways do young people access violent extremist content online?

MATERIALS AND METHODS

The methodology used to conduct the study is quantitative and a structured survey was used to data collect. The study sample is composed of 406 young people from the Korça Region aged 19-33. The research instrument was a structured questionnaire consisting of 5 sections: the first section contains demographic data consisting of seven variables; the second section aims to collect data on the

understanding and perception of extremist ideas, information, materials and behaviors on the internet by young people, consisting of 13 questions; the third section aims to gather information on extremist behaviors and ideas that are most often encountered on the internet by young people, consisting of 12 questions; the fourth section measures the attitude towards extremist ideas, information, materials and behaviors on the internet, consisting of 17 questions and the fifth section collects information on the frequency, the extent of contact with violent extremist ideas, information, materials and behaviors on the internet, consisting of 12 questions. In each section the questions are closed and are evaluated according to the Likert scale, from 1 to 4, where depending on the attribute, the number 1 (one) refers to the lowest attribute and the number 4 to the highest attribute. In this article were used only the data from section 3 on the typology of extremist behaviors most often encountered online and the attitudes and section 5 on Frequency of exposure to violent extremist ideas, information, materials, and behaviors on the internet.

The data was collected in the Korça region, which has a population of 173,091 inhabitants (INSTAT 2024:65). The survey focused on the age group 19-33 years old, which represents approximately 19% of the population at the national level (INSTAT:60). For the Korça region, this age group accounts for about 15.8% of the regional population (INSTAT:65). Therefore, in a population of 27348 inhabitants on the age group 19-33 years old with a 95% confidence level and a 5% margin of error, we obtained a target sample of 379 young people. To reach the target sample, the purposive and then the snowball sampling method was used. The data collection process was carried out online, through google forms, where the instrument was self administered and the time to complete the instrument varied from 30 to 40 minutes. The number of responses received and processed for analysis was 406 respondents. The database was created in google forms and then imported into SPSS for data analysis, which was of a descriptive nature.

The methodological approach followed for the collection of primary data for this study is characterized by several limitations which are classically well known in online studies. The data collection through the online questionnaire carries the potential risk of unidentifiable characteristics of respondents, of responses from people who self selects as a sample based on their own biases, of access based on internet and technology availability as well as on skills in using online tools (Wright 2005, Evans and Mathur, 2005, Andrade 2020). In this context the researcher cannot control the basic characteristics of the sample which is that of young people aged 19-33 years, cannot ensure access for non members of the population who, as a result of the distribution technique, do not come into contact with the questionnaire and are not part of the distribution network.

RESULTS

- *Extremist behaviors and ideas that are most often encountered online by young people*

Since this study is organized with structured questions dictated by the specifics of the issue under study, it is of interest to identify that, in each case, respondents claim a considerable frequency in encounters with extremist forms of materials, ideas, behaviors. The frequency of encounters in all cases is at ≥30% of respondents. For the purpose of analysis and categorization of the frequency of contacts, a categorization of the respondents' values for the answers under "often" and "always" was constructed. When young people were asked to think about the frequency of "encounters" during internet use with claims, descriptions of materials or behaviors, ideas, or information with extremist content and to express the frequency of these contacts in a scale categorization from 1-4, where: 1-Never, 2-Rarely, 3-Often, 4-Always.

The results show that 73% of respondents say they have often encountered harassment and insults on the Internet. Respondents who have often encountered material with violent content transmitted humorously, through forms such as cartoons, jokes, graffiti with violent content, music accompanying it, etc. account for a specific weight of 61.3%. 52% of respondents say they have encountered material that uses hate speech, encouraging people to commit violent acts. They account for a specific weight of 53.7% of respondents who have had frequent and constant contact with material depicting serious acts of violence such as rape or murder. The least frequent types of online extremist content are extremist material against ethnic groups (33.5%); extreme pornography (34%); extremist material against groups

with special needs (physical, mental or both disabilities, etc.) (34.5%); and material that transmits extremist religious views and calls for extremist behavior (37.2%).

➢ *Frequency of contact with extremist violent ideas, information, materials and behavior on the Internet*

In the fifth section of the survey, respondents were asked to express their views on issues and statements that aimed to find out whether young people have been contacted by suspicious persons, channels, groups or websites? How many of them have been contacted massively via e-mail and have been sent private messages with extremist content? How long ago was the last contact? What is the propensity of young people to make efforts to join organizations, groups and websites with extremist content? Do they themselves search for extremist websites? Have you ever met a relative or acquaintance who is associated with extremist groups and influenced by extremist messages? Respondents were presented with a series of statements and situations in order to measure the frequency of exposure, and were asked to choose from 1-4 where: 1- Never; 2- Rarely; 3- Often; 4- Always.

A specific percentage of 39.7% of respondents claim to have been contacted privately by suspicious individuals, groups, pages or channels at least once or more. 24.9% of young people claim to have received extremist content and ideas in their email at least once or more. Respondents who have been contacted at least once or more through social media messages are at a specific percentage of 28.8%. Respondents have searched for violent content on social media at least once or more in the amount of 17.2%. There are 33% of respondents who have had contact with violent extremist content and claim to have been exposed to it randomly and without knowing how at least once or more. There is a percentage of respondents that varies in the range of 10%-18% of the total number of respondents who have a predisposition to search for violent extremist content materials, pages during internet use and to engage in similar behaviors and activities. A specific percentage of 18.2% of respondents claim to have at least once or more known close people who are part of extremist groups. The specific percentage of those who have known at least once or more non-family people who are part of extremist groups is 27.3% of the respondents.

DISCUSSION

Data analysis shows that young people come into contact with extremist ideas and content in direct or indirect ways. As Brubaker (2020) also points out, in the conditions of hyperconnectivity, young people interact and "live" in sociotechnical systems where human interactions are mediated by technology. In this complex context of online interactions, Donati's (2022) concept of technical society and the independent "third" ethnicity are realities for respondents who have had contact with violent extremist content and claim to have been exposed to it randomly and without knowing how at least once or more. As Fourcade and Johns (2020) argue, such claims are clear signals that exposure to unwanted, unintended, and algorithmically determined content and materials in their consumption network is problematic, with potentially harmful consequences. Such algorithms influence, model, direct, or determine the behavior of young people, often creating distorted understandings of their own image and their role in society.

As in the studies of Gunton 2022, Turner et al., 2023, Setty 2024, Bowland and Schumann 2026, this study also found that extremist materials and ideas most often encountered online were related to behaviors that promoted harassment and insults, hate speech, acts of violence such as rape or murder, material against ethnic groups, extreme pornography, extremist material against groups with special needs and material that transmits extremist religious views. The most common ways of transmitting them were found to be transmitted humorously, through forms such as cartoons, jokes, graffiti with violent content, music accompanying content transmitted in social media or groups and channels in social media.

From a functionalist perspective, as Thulin et al. (2020) also emphasize, digitalization and parallel life in virtual interaction have brought about a relativization of time and space in the use of all the facilities that this dimension of freedom and action offers. However, as Lupton (2016) also analyzes, the data shows that digitalization has led to a reconsideration of traditional risks and the creation of digital social risks, one of which is the risk of exposure to extremist ideas and materials online and engagement in

violent and extremist behavior in virtual environments. Behaviors that can easily be transferred into social actions in everyday life.

CONCLUSION

In conclusion, it is important to note that this study is not exhaustive. Other researchers may take similar initiatives, with an exploratory methodological approach, to enrich the study data and to further explore some of the quantitative findings. It is also important that similar studies be carried out in other regions of the Republic of Albania to conduct comparative studies, to help in the design of intervention strategies at both the local and central government levels. Given the diverse forms and content of extremist ideas, it is important to identify and develop intervention strategies to inform young people about all dimensions of violent extremism. Information can be delivered online using formats that are appropriate and appealing to young people or distributed in various forms in schools. In the context of digital interaction diversity, schools play a key role both at the level of curricular and extracurricular education. The study data indicate the need of youth people for competences in media, digital and AI literacy. In this case, schools at the pre university level, as a direct way to influence the education of young people can review and further update and improve the curriculum to build informed narratives against extremism. Such a strategy would ensure sustainable and safe digital interaction

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PASQYRA SHQIPTARE: 23 YEARS OF ETHNIC MEDIA IN CANADA — IDENTITY, TRANSNATIONALISM AND DIGITAL ADAPTATION

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ABSTRACT

For 23 years, every Sunday evening, *Pasqyra Shqiptare* (Albanian Reflections) has lit up the screens of Albanian families across Canadian cities on OMNI Television in Canada, a longevity remarkable for any ethnic medium. This paper presents a case study of this Albanian-language television programme, examining how it has evolved over two and a half decades and what role it plays today for a community spread across Canadian provinces and beyond. Content analysis was applied to 12 television episodes, 91 Facebook posts and 20 YouTube videos, complemented by a semi-structured interview with the programme's producer. The theoretical framework draws on Karim (2003), Hall (1990), Appadurai (1996), Naficy (1993), Georgiou (2006), Marino (2015), Yau et al. (2020) and Kianpour et al. (2026). The findings show that *Pasqyra Shqiptare* serves its audience in ways that cut across cultural preservation, community integration and transnational connection, without any single purpose dominating the others. The programme's evolution across television, Facebook (25,500 followers) and YouTube broadly corresponds to the "platform generations" model proposed in recent scholarship. Most unexpectedly, a YouTube documentary on the Kosovo War reached 374,322 views in English, suggesting a reach well beyond the Albanian-Canadian community. The study is the first academic case study of Albanian ethnic media in Canada and finds that the programme's social media space is more deliberative than the echo-chamber model would predict.

Keywords: ethnic media, Albanian diaspora, Canada, cultural identity, transnationalism, digital adaptation

INTRODUCTION

Ethnic media occupy a distinctive and often understudied position within communication and media scholarship. As institutions that serve communities defined by shared language, culture and migration experience, they perform functions that mainstream broadcasters cannot and do not replace. In Canada, an official multiculturalism policy since 1971, codified further through the Canadian Multiculturalism Act of 1988 (Pier 21, Canadian Museum of Immigration, 1971), has created an institutional environment broadly supportive of ethnic media, both in regulatory terms and in the broader public commitment to cultural pluralism.

Within this context, *Pasqyra Shqiptare* (Albanian Reflections) has maintained a weekly presence on OMNI Television since 2002. OMNI is Canada's largest multilingual broadcaster, licensed by the CRTC with an explicit mandate to serve ethnic communities (CRTC, 2016). According to the 2021 Canadian Census, 41,625 people reported Albanian ancestry, while community organizations estimate the broader Albanian population in Canada at approximately 70,000, concentrated primarily in Ontario and Quebec, with smaller communities in British Columbia and Alberta.

Over its 23 years on air, *Pasqyra Shqiptare* has extended beyond television. The programme's Facebook page has grown to approximately 25,500 followers, and its YouTube channel carries an archive of several hundred videos spanning the full history of the programme. The Albanian community served by *Pasqyra Shqiptare* arrived in Canada in several waves: political refugees from the communist period, economic migrants of the 1990s, and those connected to the Kosovo conflict of 1998–1999. These groups differ considerably in generation, in their relationship to the Albanian language, and in how

strongly they maintain ties to the homeland. For all of them, in different ways, the programme has served as a point of cultural and community reference.

The central research question guiding this study is: how has Pasqyra Shqiptare adapted its communicative model over 23 years of presence in Canada, and what role does it play today across its television, Facebook and YouTube platforms?

THEORETICAL FRAMEWORK

The study draws on eight main theoretical perspectives. Karim (2003) offers the most important institutional anchor for the Canadian context, arguing in *The Media of Diaspora* that ethnic media in Canada navigate competing pressures: to preserve the culture of the homeland, to facilitate settlement in the new country, and to maintain connections with co-nationals dispersed across borders. These pressures rarely resolve neatly, and how a programme manages them over time is itself analytically revealing.

Hall (1990) provides the philosophical foundation. In "Cultural Identity and Diaspora", he argues that identity in the diaspora is not a fixed inheritance but a continuous process, shaped as much by where people are going as by where they come from. The diasporic subject lives between *similarity* with the culture of origin and *difference* produced by years of life elsewhere. Appadurai (1996) introduces the concept of *mediascapes*, the transnational flows of images and narratives that now cross borders with relative ease, making it possible for a programme produced in Toronto to be watched in Tirana or The Hague.

Naficy (1993) examines what he calls "accented" media, productions that carry the mark of an in-between position, belonging fully to neither the culture of origin nor the host society. He also notes that diasporic media tend to change over time: the first-generation nostalgia that often shapes early output gives way, as communities settle, to something more pragmatic and community-oriented. Georgiou (2006) extends this analysis into the digital context, stressing that diaspora audiences are not passive but actively produce, share and contest meaning. Marino (2015) develops the concept of digital togetherness, the sense of community that forms in virtual spaces where migrants exchange experience and maintain cultural ties.

Yau et al. (2020) identify four ways in which migrants negotiate identity through social media: by regulating how much of each culture they present in different contexts, by managing who can see their content, by curating what they choose to share, and by weaving together their online and offline lives. Finally, Kianpour et al. (2026), in a study conducted at Toronto Metropolitan University and published in *Ethnicities*, draw together the most recent scholarship on diasporic identity and social media. Among other contributions, they introduce the platform generations model, distinguishing between a first period dominated by closed, heritage-focused communities, a second marked by interactive engagement, and a third in which identity is expressed more openly across borders. They also note that their own corpus is weighted toward larger diaspora communities and English-language scholarship, a limitation that a study such as this one can begin to address.

MATERIALS AND METHODS

The study combines content analysis of three media sources with a semi-structured interview, organised as a case study (Yin, 2014). Content analysis (Krippendorff, 2004) was applied to television episodes and Facebook posts from the period March to May 2026, and to two groups of YouTube videos selected on different criteria. The interview with the programme's producer was transcribed and analysed thematically (Kvale and Brinkmann, 2009).

Television analysis

Twelve episodes broadcast during March to May 2026 were analysed. Each episode was coded for dominant format (magazine, news, culture, entertainment, documentary, mixed); primary language; general tone; primary themes; primary location referenced; guest profiles; and the presence of cultural and Canadian references.

Facebook analysis

Ninety-one posts published between March and May 2026 were analysed. The page currently has approximately 25,500 followers. Posts were coded for theme, content type (video, photograph, text, link, live broadcast, repost with comment), source, language, location referenced, and engagement metrics including likes, comments and shares. Comment analysis drew on the framework of Yau et al. (2020).

YouTube analysis

YouTube was examined through two independent groups of videos. Group A comprises the ten most-viewed videos from the entire history of the channel, offering a picture of what has accumulated the largest audiences over time. Group B comprises the ten oldest videos, from 2004 to 2009, enabling a comparison with the earliest period of the programme's online presence. This design was intended to test the platform generations model of Park and Gerrits (2021). For each video, the following variables were coded: publication date, production year, duration, theme, language, view count, like count, comment count, production quality and visual format. Forty comments were coded for language, geographic origin and tone.

Interview

The producer of *Pasqyra Shqiptare*, who has directed the programme since 2003, was interviewed as the key informant of the study (Kvale and Brinkmann, 2009). The interview covered the history, philosophy and editorial direction of the programme, the composition of the audience and concerns about generational change, the circumstances of the digital expansion, funding, and the producer's sense of where the programme is heading. The session was transcribed and analysed thematically.

RESULTS

Television findings

The analysis of 12 episodes yielded several clear patterns. Eleven were broadcast primarily or entirely in Albanian. The exception was the episode of 8 March 2026, dedicated to business and economic integration, where English and Albanian were used in roughly equal measure. Episode 9, broadcast on 26 April, also included both languages in certain segments. Every episode referenced Canada as the primary location and contained cultural references. In ten of the twelve, the dominant tone was informative or educational. No episode had nostalgia as its primary tone, although nostalgic elements appeared within individual segments, most notably a football tournament held in memory of a late community supporter. All twelve were directed and presented by the same producer, a member of the first generation of Albanian migrants to Canada.

The range of guests across the twelve episodes was broad: artists, diplomats, publishers, journalists, athletes, businesspeople, religious leaders and lawyers. Several episodes featured the continuing documentary series "Shqipëria me syrin e gjeografit" (Albania through the geographer's eye), presented by a professor from Albania, which gave the programme an educational dimension extending beyond the Albanian-Canadian community specifically. Episode 11, broadcast on 10 May, included a profile of a basketball player with a disability from North Macedonia, an indication of the programme's willingness to represent the diversity within the Albanian and Balkan communities in Canada rather than presenting a homogeneous picture. The producer described the guiding principle as "we have shown great sensitivity toward each group, without undervaluing anyone."

Facebook findings

The 91 posts analyzed covered the entire March–May 2026 period, although posting frequency varied, with some days including two or three posts. The page has approximately 25,500 followers. Nearly every post was anchored in the Canadian context and addressed Albanian-Canadian life. Content ranged from video chronicles and photographs to reposts with comment, recordings of musical performances and promotional material for community events and businesses. Posts originated from the programme itself, from community businesses, associations and public institutions, including the Albanian Embassy in Canada and the Chamber of Commerce Canada-Albania. The page does more than promote content already aired on television. It has developed its own role as an active space for community information and interaction.

Average engagement was 72.4 likes and 7.06 comments per post, though individual posts varied considerably. Table 1 shows the five posts that attracted the highest engagement during the period.

Table 1. Posts with highest engagement, March–May 2026

Date	Theme	Likes	Comments	Shares
8 March	Women's Day celebrations	241	20	9
17 March	Religious community event	204	4	8
18 March	Cultural content	180	13	6
10 April	Business opening	153	37	12
13 April	Community festive event	162	9	5

The business opening on 10 April drew the highest number of comments, 37, which is a reminder that the page is not purely cultural in function but serves a community that is also economically active. The Women's Day celebration on 8 March generated the most likes, 241, consistent with the strong festive and community traditions visible across several episodes of the television programme.

An additional observation concerns the tone of some comments. Some posts attracted critical responses, for example: one for the use of English rather than Albanian by a community organizer at a public event, one for what commenters considered impure Albanian on the part of a lawyer appearing on the page, and another for skepticism about a community fundraising initiative. The producer acknowledged the difficulty of the position: "it is quite difficult to be neutral, because the programme aims for inclusivity." These exchanges suggest that the page functions as a space for genuine community debate. A comment from a follower posted in connection with a video of Albanian dancing in Toronto captured something of the page's geographic reach: "Respect to all those who with dedication contribute to the affirmation of our culture in Canada... Ilir Lena enables even those of us living in distant provinces of Canada to be informed about our community's achievements."

YouTube findings

The most-viewed video on the channel, with 374,322 views, is a 2009 documentary on the Kosovo War and ethnic cleansing, produced in English. It is the only English-language video in the top ten. Comment analysis of the 40 sampled comments identified viewers from Canada, Albania, Kosovo, the Netherlands, Denmark, Sweden, Germany, Italy, Greece, Turkey, Bulgaria, North Macedonia, Switzerland and the United States, as well as a number of commenters whose origin could not be determined from the available information. The Valle Çame video, a recording of Albanian traditional dance, drew comments in Turkish and Greek from viewers who identified themselves as Turkish and Greek respectively, suggesting audiences with an interest in Balkan folk traditions more broadly. The Vjosa river documentary drew a comment from a viewer who identified herself as Bulgarian, expressing admiration for the Albanian landscape. These are not communities one would expect to find through Albanian diaspora networks, and their presence points to audiences reached through YouTube's search and recommendation functions rather than through community ties.

Table 2 compares the oldest videos (Group B) with the most-viewed (Group A), as a way of tracing change over time.

Table 2. Evolution of YouTube content across platform generations

Phase	Period	Format	Average views	Dominant tone
Web 1.0 (Group B)	2004–2009	Hybrid	~3,600	Nostalgic
Transitional	2009–2014	Traditional TV / Hybrid	~100,000–150,000	Cultural
Web 3.0 (Group A)	2019–2022	Digital	~130,000–180,000	Informative

The pattern is broadly consistent with the platform generations model, moving from low-viewed, nostalgic content in the earliest period toward informative, digitally produced content with far larger audiences. One exception is worth noting: two videos from 2010 in a hybrid or traditional TV format achieved view counts comparable to the most recent digital content. The interview with singer Nertila Koka reached 154,458 views and the Valle Çame traditional dance video 148,705. Both feature subjects with strong appeal to Albanian audiences worldwide, and the comments on the Nertila Koka video, some from viewers in Germany, Italy and Sweden, are predominantly nostalgic in tone, suggesting audiences drawn by the performer rather than by the production style.

Interview findings

The producer described the mission of *Pasqyra Shqiptare* as "to be a window of information and a means of bringing Albanians closer to one another." He noted that over 1,250 episodes, approximately 2,000 community members have appeared on screen, a figure that reflects the breadth of the programme's community engagement over two decades. The editorial approach is characterized as "patriotic and benevolent, but also constructively critical," and the programme is funded roughly 90% by advertising.

On the question of audiences, the producer was direct: the regular viewership is predominantly first-generation. "Peer influence is stronger" for younger Albanians, he observed, "whereas in the first generation ties to the homeland are very strong." Some children of that generation no longer speak Albanian at all. The digital expansion was not planned strategically but followed from the changing media landscape: "YouTube in 2008 was driven by circumstances because in Canada IPTV was beginning to open up." Facebook came shortly after, in 2009. The current page has some 25,500 followers, though the producer noted an important distinction: "people who follow me more on Facebook and YouTube watch less television." The platforms are not simply additional channels reaching the same audience; they appear to attract different people.

DISCUSSION

What the findings suggest, above all, is that *Pasqyra Shqiptare* has remained relevant by remaining flexible. The programme does not sit comfortably in any single category. It is not purely a cultural archive, nor a news service, nor a community bulletin board; it does something of each, on television, on Facebook and on YouTube, and the balance shifts across platforms and over time. This is consistent with Karim's (2003) observation that ethnic media in Canada navigate competing pressures, and that their longevity depends on how well they manage those pressures rather than resolving them definitively.

The relationship to nostalgia is one area where the findings complicate existing theory. Naficy (1993) described diasporic media as typically nostalgic, particularly in their early years. The television analysis finds nostalgia as the primary tone in none of the 12 episodes from 2026, though nostalgic elements do appear within individual segments, such as a football tournament held in memory of a community member. The YouTube comparison confirms a clear shift from the older videos in Group B, which are predominantly nostalgic in character and local in reach, to the more informative and outward-facing content in Group A. This is the kind of generational evolution Naficy predicted, though it has happened here in the content while the voice behind the programme has remained unchanged: the same producer has directed every episode for 23 years. Hall's (1990) argument that identity is a process rather than a possession seems apt: the programme has changed considerably without losing what makes it recognizable.

The Facebook findings raise a question about how social media functions within ethnic communities. The critical comments in posts are not what one would expect from a closed, self-affirming community. The page has 25,500 followers and posts almost daily, and what these exchanges suggest is that it operates like a public square. This is consistent with what Hegde (2015) describes as the active role of media in reshaping migrant identities rather than merely transmitting information. The page is not a window through which the community observes itself, but a space in which it argues about what it wants to be. This sits at odds with the echo chamber model identified by Kianpour et al. (2026) as a common pattern in digital diasporic media. It may be that the programme's sustained commitment to inclusivity, and the producer's acknowledgement of how difficult that commitment is to maintain, creates conditions in which disagreement can surface rather than being suppressed.

The YouTube figures deserve closer attention. The Kosovo War documentary's 374,322 views, accumulated largely in English, point to an audience that extends well beyond the Albanian-Canadian community. The video has no comments in the sample analyzed, so it is not possible to draw conclusions about the geographic origin of its viewers from the data available. What the view count alone suggests is a reach that cannot be explained by community networks alone. Other videos in the sample point in a similar direction: the Valle Çame video drew responses from viewers who identified themselves as Turkish and Greek, drawn apparently by an interest in Balkan folk traditions. This is a dimension of what Ponzanesi (2020) calls the digital diaspora, in which online platforms transform the very possibilities of diasporic connection, opening them to audiences with no direct community ties. These are functions that existing frameworks for diasporic media, which generally assume a community audience, were not designed to capture.

The producer's observation that Facebook and YouTube followers tend to watch less television is consistent with the platform generations model of Park and Gerrits (2021), but it also suggests something the model does not fully capture. The periods in Table 2 are presented as sequential, but the programme currently operates across all of them at once. It still broadcasts on television, it maintains an active Facebook presence, and its YouTube archive spans two decades. These are not phases left behind but coexisting modes of reach, each serving a somewhat different audience.

The question of generational succession is perhaps the most significant one the study raises, and it is also the one it is least able to answer. The producer confirmed that the second generation is drifting away from the programme, for reasons he attributed primarily to peer environment and, in some cases, to the loss of the Albanian language. He indicated that plans for continuity exist but did not elaborate. Whether *Pasqyra Shqiptare* can sustain itself beyond the founding generation, and in what form, remains to be seen.

CONCLUSION

This study has examined *Pasqyra Shqiptare* through content analysis of 12 television episodes, 91 Facebook posts, 20 YouTube videos and 40 comments, alongside an interview with the programme's producer. It is, to the author's knowledge, the first academic study of Albanian ethnic media in Canada.

The findings point to a programme that has managed, over 23 years, to serve a community whose needs have changed considerably since 2002. The Albanian-Canadian community of today is not the community of the refugee years; it is more settled, more economically established, more digitally

connected, and increasingly split between a first generation with strong homeland ties and a second generation that has grown up largely as Canadian. *Pasqyra Shqiptare* has adapted to this, even if the adaptation has been more pragmatic than planned.

The platform generations model proposed by Park and Gerrits (2021) offers a useful framework for understanding the programme's digital trajectory and the data broadly support it. The qualification that emerges from the 2010 videos is worth retaining: the format a video is produced in matters less than what it is about and who it features. This may seem obvious, but it is worth stating against the tendency in platform studies to treat technological change as the primary driver of audience behavior.

Four contributions emerge from the study. It provides the first academic case study of Albanian ethnic media in Canada, addressing a gap that Kianpour et al. (2026) identified in the literature on smaller, non-English-speaking communities. It offers evidence that the platform generations model applies to small ethnic media as well as to larger diaspora communities. It documents an educational and cross-cultural reach on YouTube that existing theory on diasporic media had not anticipated. And it raises questions about whether the echo chamber model, plausible as a general tendency, holds for a programme with the specific institutional history and community commitments of Pasqyra Shqiptare.

The most pressing question for future research concerns the second generation. How do the children and grandchildren of Albanian migrants in Canada relate to a programme made primarily for their parents? What would it take for a programme like this one to survive a generational transition? These questions go beyond Albanian-Canadian experience and speak to challenges facing ethnic media wherever they exist.

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ASPECTS REGARDING THE INTERACTION BETWEEN TRIPLE TRANSITION AND BUSINESS ENVIRONMENT

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ABSTRACT

The triple transition takes into account the importance of the effects that the digital, environmental and social transitions produce on the business environment and citizens and emphasizes the role of the European Union's growth-oriented policies. The triple transition offers the possibility of perceiving connections that are formed between them; also, between the three transitions there is an interaction and mutual reinforcement.

Business environment strategies have developed and adapted to the triple transition (digital, environmental and social). In the long term, companies aim to adapt their activity to possible social changes, in different sectors, such as construction, energy, mobility and the food industry that are facing such changes. In this context, the business community collaborates with policymakers to adapt the transition to the local context. In the long term, in adapting the activity to the digital, environmental and social transition, the business environment makes efforts to adapt to possible social consequences, which may arise in different industrial branches, as a result of the changes they face. The role of governments in just transitions is important to ensure a better transition through the changes caused by it. The role of regional and local authorities is to support companies and Small and Medium Enterprises in the triple transition process. The triple transition takes into account the importance of the effects that the digital, environmental and social transitions have on the business environment and citizens and emphasizes the role of growth-oriented European Union policies.

The paper presents the social impact created by the digital and environmental transition on the business environment and citizens and programs at the European level to combat the risks of the environmental and digital transitions.

Key words: business environment, triple transition, social impact.

1.Introduction

A business environment that manages to adapt to changes from the external environment, remains resilient to shocks caused by crises, represents a support for the economic evolution of the country in which it develops. The social environment also plays a role in the evolution of the business environment, influencing its development, the profitability of companies. (Toader, 2022).

Transitions are transformations that occur in the structures of society (Grin et al., 2010, 2011, cited in Loorbach, Wijsman, 2013) following-up the co-evolution of economic, social and environmental structures. An example of a transition can be the shift from an energy system based on fossil fuels to one based on renewable energy.

Business environment strategies have developed and adapted to the triple transition (digital, environmental and social). In the long term, companies aim to adapt their activity to possible social changes, in different sectors, such as construction, energy, mobility and the food industry that are facing such changes. (Loorbach, Wijsman, 2013). In this context, the business community collaborates with policymakers to adapt the transition to the local context.

The triple transition takes into account the importance of the effects that the digital, environmental and social transitions have on the business environment and citizens and emphasizes the role of growth-

oriented European Union policies (Schmerber, 2024)

Purpose. The connection that is formed between the triple transition and the business environment, the social impact created by the digital and environmental transition on the business environment and citizens are followed in the paper and programs at the European level to support the business environment are presented.

2. The triple transition interaction – business environment

The triple transition takes into account the importance of the effects that digital, environmental and social transitions produce on the business environment and citizens and emphasizes the role of European Union policies, oriented towards growth (Schmerber, 2024).

The mechanism for approaching the transition means developing new business models by transforming one's own business and focusing on social transitions, under the conditions of inter-relationship of economic profitability with social responsibility and ecological sustainability. (Loorbach, Wijsman, 2013)

In the long term, in adapting the activity to the digital, environmental and social transition, the business environment makes efforts to adapt to possible social consequences, which may arise in different industrial branches, as a result of the changes they face (Loorbach, Wijsman, 2013)., in response to adapting the activity to the new conditions imposed by the digitalization getting through and environmental aspects (clean technologies, closure of mines based on coal extraction). In this context, the business environment collaborates with decision-makers, to adapt the policies regarding the transition, to the local context. (Schmerber, 2024).

The role of governments in just transitions is important to ensure a better transition through the changes caused by it. Examples include the allocation of funds to support society, workers through various programs, such as reintegration into the labour market through vocational training, retraining, early retirement, or relocation, support for Small and Medium Enterprises (e.g. business programs for training entrepeneurs in starting a business, social and cultural programs, infrastructure development and other strategic public investments). (Atteridge, Strambo, Edt. Gill, 2021).

The role of regional and local authorities is to support companies and Small and Medium Enterprises (SMEs) in the triple transition process. There were developed projects that target the two digital and environmental transitions, integrating elements of the social transition, such as qualifications, skills, long-term learning (Schmerber, 2024).

Keijzers, 2002 (cited in Loorbach, Wijsman, 2013) shows that efforts towards sustainable development transform the internal governance of a company, following the new conditions for the protection and conservation of the environment, and the external governance of businesses, in the context in which the business environment must develop production respecting the elements of the triple transition: social conditions (ensuring a favourable, fair and safe working environment, social responsibility) technological (new digital technologies getting through, to facilitate the performance of various activities) and environmental, by introducing non-polluting technologies. (Loorbach, Wijsman, 2013).

Findings

3. Effects of environmental initiatives on society

The European Green Deal approaches economic development from a different perspective: *the digital and environmental transitions* produce greater benefits if they reinforce each other. *The two transitions are complemented by* ***the social transition*** which aims to ensure that the benefits and challenges brought by them are shared by all individuals, without increasing inequalities. (Consiliul Uniunii Europene, Pactul Verde European, https://www.consilium.europa.eu/ro/policies/european-green-deal/; Schmerber, 2024).

Environmental initiatives have different effects on social equity. For high-income residents, the effects can be beneficial, but at the same time, they can require too high costs *for low-income residents*. For

this reason, they need to be carefully managed. (Sustainability Directory, How Do Green Initiatives Impact Local Communities?).

The social impact of the environmental transition can be seen in the capacity of environmental policies to influence economic growth and, implicitly, social life: *creating new jobs* for qualified workers in the field of renewable energy, *creating an attractive framework for the development of the business environment*, by attracting enterprises that use non-polluting technologies, *reducing costs* for enterprises and residents, by using infrastructure with low energy consumption. (Sustainability Directory, How Do Green Initiatives Impact Local Communities?).

3.1. Risks in social field of environmental policy

There are also *some negative consequences* of the environmental transition, on society and the business environment. Investments in green technologies are accompanied by high costs that require high taxes, with an impact on the income of the population; the decline of fossil fuel-based industries leads to job losses. (Sustainability Directory, How Do Green Initiatives Impact Local Communities?).

Also, *a series of risks in social field* arise against background of the use of smart technologies, related to the digital skills required by citizens to use them. Due to the complexity of the new interfaces developed, users may face difficulties in using different services offered through smart platforms, which could lead to *social gaps* between people with digital skills and those without digital skills. Also, other aspects may come from certain social groups that view with *distrust* the potential offered by smart technologies. This requires awareness of the usefulness of digital products and the alternative of non-digital solutions. New smart technologies provide efficient services by accessing them remotely, without human contact, but, also, this could lead to *a greater isolation* for groups suffering from social exclusion. (European Parliament, 2023).

Past experiences show that achieving a just transition that does not affect the population, countries or regions is difficult to fulfill. The decline experienced in the past by different areas, industries led to major losses of industrial activity, skills and social capital. In addition, uncontrolled decline led to long-term environmental damage, affecting society as a whole, over several generations. Planning a just transition intends to ameliorate these risks, fairly distributing the costs and opportunities that accompany the entire process (Atteridge, Strambo, Edt.Gill, 2021). In order not to create disparities, these initiatives must be carefully managed, planned and so that the entire community benefits equally from a better life in a clean, healthy environment. This calls for citizen participation in decision-making regarding the planning and implementation of environmental strategies, prioritization of projects aimed at meeting the needs of marginalized communities, measures to combat pollution, and facilitating access to green spaces. (Sustainability Directory, How Do Green Initiatives Impact Local Communities?)..

4. European-level initiatives to support businesses and citizens

Schmerber, 2024 reffers to the "Triple Transition: shaping international cooperation to address digital, green and social transitions", event organized under the Spanish Presidency of the Council of the European Union on 5 July 2023 whose themes were: mutually reinforcing transitions, achieving climate neutrality; a more competitive and resilient European industry, reducing social inequalities, through a just transition (Schmerber, 2024).

The Just Transition Mechanism (JTM) is an instrument that aims to ensure that the objective of a climate-neutral economy is achieved equally for all citizens, leaving no one behind (European Commission, The Just Transition Mechanism: making sure no one is left behind).

The Just Transition Mechanism (JTM) instrument supports both vulnerable citizens and businesses to cope with the transition. (European Commission, The Just Transition Mechanism: making sure no one is left behind).

Digital and environmental transitions are challenging countries and regions based on polluting industries, high carbon dioxid emmissions and/or fossil fuel extraction, with social and economic impacts, through the disruptive changes they produce, with many communities being unprepared to cope with these changes. (Figueres C., Umaña A., Eigen P., 2018, Climate Transparency: Brown to Green:

The G20 Transition to a Low-Carbon Economy); (Strambo & Atteridge, 2018 cited in Atteridge, Strambo, Gill, Ed., 2021). (Strambo, Aung & Atteridge, 2019).

Below some directions for action are shown: (European Commission, The Just Transition Mechanism: making sure no one is left behind).

→ *Actions that support individuals*. Creating better employment conditions in new sectors in transition, by increasing the possibilities of qualification and acquiring new skills;

→ increasing energy efficiency, access to renewable energies; equipping homes for efficient consumption of energy resources (renewable energies).

Actions that support companies, industries that use high-carbon emissions technologies. (European Commission, The Just Transition Mechanism: making sure no one is left behind).

- supporting enterprises in the transition to low-carbon technologies and economic actions in the direction of environmental transition (investments in clean technologies and job creation)
- creating a favourable environment for attracting investments from the public and private sectors;
- facilitating access to loans and financial support;
- favourable conditions for investments in the development of new companies, Small and Medium Enterprises and startups;
- supporting research and innovation through investments.

For *Member States and regions*, based on fossil fuel consumption and high-carbon emisions industries, measures are targeted, such as: (European Commission, The Just Transition Mechanism: making sure no one is left behind).

✓ supporting the environmental transition by focusing on low-carbon emissions activities that cope with climate change;

✓ creating new jobs in a clean economy (that respects environmental parameters);

✓ investments for the sustainable development of public transport;

✓ technical assistance;

✓ investments for the use of renewable energy sources;

✓ expanding digitalization;

✓ streamlining energy infrastructure, central heating and transport networks.

Investments in environmental projects, such as renewable energy projects (wind farms, solar panels installation) have an effect on local economic growth and on residents, by creating new jobs and a better standard of living. *The impact is also observed on the business environment*, by attracting businesses that use non-polluting technologies. These environmental initiatives lead to local economic growth, which has the effect of increasing income for the community (Sustainability Directory, How Do Green Initiatives Impact Local Communities?).

There is a reciprocity between environmental transition and social transition, in the sense that social transition can, in turn, influence environmental transition through citizens' participation in supporting environmental policies. This depends on their standard of living, citizens with higher incomes will be better able to support actions towards environmental protection (for example, purchasing low-energy consumption technologies, thermal rehabilitation of buildings, solar panels installation on buildings), compared with those with lower incomes.

Table 1 Examples of good practices regarding social transition at European level and the impact on the business environment and residents

Strategy - Social impact	**The effects of social transition at the local level on the business environment and residents**
Amsterdam It is the capital of the Netherlands; it has an area of 219. km^2 and a population of 921,468 inhabitants in 2023 (Amsterdam, Wikipedia https://ro.wikipedia.org/wiki/Amsterdam). The digital transition of the city of Amsterdam and the social effects on the population can be found in the Digital City Agenda 2023-2026. The effects of digitalization are reflected on the population of Amsterdam, in most areas of activity. Technology is at the service of individuals, and digital services operate in parallel with non-digital ones. *Inequality regarding access to digital services* is linked to a series of *social challenges*, such as: the origin and environment in which individuals were born, unemployment, low incomes, debts, lack of social relations. *Vulnerable groups* have less access to digital services, which has consequences for job search. Fighting digital inequality is important for these groups relative to familiarization with digital tools and development of digital skills. Effective provision of information is necessary for vulnerable groups to benefit from the best possible government services. *Initiatives undertaken through the New Agenda (2023-2026)* Creating spaces to facilitate internet access and online assistance, with the aim of reducing inequalities regarding digitalization; Developing a structural plan to combat digital inequality. To this end, the aim is to provide assistance, through local partners, to support the citizens of the city of Amsterdam in the process of acquiring knowledge and developing digital skills, so that they can more easily respond to the challenges of the online environment. The New Agenda (2023-2026) provides for the protection of citizens' data in the digital system, through rules and regulations that aim at data control and safety, the reliability of information on	

the Internet and digital security, elements that also apply to the services of the Local Council.

Digitalization getting through supports individuals, it has an inclusive character, through the benefits brought to citizens, Amsterdam becoming a digital city in which *new technologies have a positive social impact.* Among the advantages offered by digitalization are: voice recognition technology that provides information in multiple languages or increasing accessibility for people with disabilities.

At the local government level, the effects of digitalization are felt in the transformation of local services, *interaction with citizens and the business environment*, assuming responsibility in decision-making, in the development and orientation of policies appropriate to the interests of the inhabitants of Amsterdam.

Digitalization is oriented towards urban problems and existing objectives. *The social impact of digitalization* will be felt through: the provision of social services appropriate to the problems faced by vulnerable groups, social assistance through prevention and early intervention, speeding urban transport, a safe online environment.

Accessible social care

Local policies aim to ensure quality social care services at affordable prices, so as to eliminate as much as possible the gaps in access to health services between the wealthy and those with lower incomes. In the long term, policies aim to achieve sustainable and inclusive objectives, the responsible use of digital resources, which will allow for an increase in the quality of life.

By digitalization the city of Amsterdam, for the social care sector, it is aimed that it becomes a system that ensures efficient and inclusive care services, by eliminating discrepancies, combating poverty, integrating vulnerable groups.

Accessible and inclusive city

Urban mobility provides freedom of movement and citizens' involvement in urban development and in the life of society, pursuing accessible transport to everyone, regardless of vulnerabilities ensuring an inclusive and integrated mobility, eliminating exclusion as much as possible. These objectives can be achieved by introducing modern technologies into urban transport.

The social impact is felt positively, by increasing urban mobility for all citizens, by achieving the goals of inclusion and integration, ensuring safe

and easier mobility conditions for all individuals. By using digital technologies, the authorities in partnership with other partner bodies of the city, aim to provide practical solutions and options for easier access to the cit,y for people with limited mobility. Local policies aim, in the long term, to transform Amsterdam into a safe and livable city for citizens, entrepreneurs and tourists, initiatives that are ensured through the B2 Digital City (Digitale Stad) program (Digital City Agenda 2023-2026 Published by the City of Amsterdam, November 2023). In Amsterdam, actions to digitize services with *social impact* are carried out in parallel with current activities and aim to make Amsterdam a smart city in the long term, offering good and safe living conditions, tourism, and business security.	*The social impact on business activities* is manifested in the need to improve travel conditions which requires investment and modern technology in transportation.
Copenhagen It is the capital of Denmark, has an area of 88.25 km2 (Statistics Denmark https://m.statbank.dk/TableInfo/ARE207?lang=en). and a population of the Copenhagen metropolitan area of 518,574 inhabitants. (Copenhagen, Wikipedia https://ro.wikipedia.org/wiki/Copenhagen). The Urban Nature Copenhagen Strategy (2015-2025) was developed by the Technical and Environmental Administration of the City of Copenhagen in dialogue with the Economic Administration, the Administration for Culture and Leisure and the Administration for Children and Youth. The strategy emerged at the initiative of political decision-makers, the administration, local organizations, citizens. The "Urban Nature Copenhagen" Strategy (2015-2025) aims to transform the Danish capital into a green city by expanding urban nature in Copenhagen and improving its quality. To achieve these, measures presented in the strategy are initiated, which include: directions of action for planting trees in the city, urban solutions based on nature, the establishment of an Urban Fund for Nature and the establishment of partnerships with various local entities. For the objective of increasing the quality of urban nature, the strategy focuses on how residents perceive nature; it uses five parameters to assess the quality of urban nature: biodiversity, climate adaptation, functionality, spatial qualities, care and	It is proposed to develop fifty partnership projects per year on non-municipal land, with a focus on urban nature, and at the same time, it is intended to stimulate the participation of city residents in the effort to expand urban nature and improve its quality. For the objective of expanding urban nature, the strategy has as initiatives: green roofs and front, trees, street design to cope with rain, green urban spaces. In 2017, a Green Planning Tool was established whose purpose is to support the city of Copenhagen in expanding and increasing the quality of urban nature, in public construction projects and local development plans.

maintenance. *In the social field,* the strategy aims to increase residents' satisfaction with the quality of parks and other green spaces, as well as the responsibility and perception of urban nature at the citizen level, but also faster access to green areas. The strategy aims to develop green corridors to increase access to a clean environment and recreational activities. The Strategy - "Urban Nature Copenhagen (2015-2025)" complements the 2009 strategy - "A green Copenhagen" and aims to improve the quality of urban natural areas, adding also, the non-municipal lands to the areas of application. Aspects regarding the interconnectivity between improving environmental conditions and favourable social prospects are highlighted. Increasing the quality of urban nature, *with a social impact on the satisfaction of residents*, can stimulate *the business environment (public construction).*	
Denmark It is a country in Northern Europe, with two autonomous overseas territories: the Faroe Islands in the North Atlantic and Greenland in North America. It has an area of 43,094 km² and a population of 5,580,673 inhabitants. (Denmark, Wikipedia, https://ro.wikipedia.org/wiki/Danemarca). Denmark has distinguished itself through its ability to capitalize on new opportunities, transform society and improve the quality of life of its citizens. Digital transformation, and *new business models*, are elements that contribute to increased productivity and economic development, constituting a foundation for the country's progress in the long term. Creating the conditions under which the Danish *business environment* benefits from the opportunities offered by new technologies, through digital transformation, with a *positive impact* on both trade and industry, but also for society and each individual citizen. The digitalization in trade and industry facilitates the use of modern technologies by companies. In the Strategy for Denmark's Digital Growth, government decision-makers aim to ensure strengthened conditions for growth in Denmark and the digitalization in Small and Medium-sized Enterprises.	Government strategy provides a better environment for a digital society. Increasing the competitiveness of companies through a higher degree of use of digital products and the development of new business models, with impact on society through its progress and better living conditions; The implications of modern digital technologies are felt in social life greatly influencing social development. The impact of digitalization on society is perceived differently by residents, or at the level of companies. Residents can benefit from the facilitation of daily activities, easier access to educational programs, better working conditions, simplification of physical work, at working place. For companies, the impact of new technologies is reflected in the endowment with efficient modern machinery, better production results and new business models, which can lead to an increase in

The aim is *to integrate society in active participation* in government authorities' initiatives to ensure an optimal environment for digitalization getting through, in all areas, thereby creating new jobs and increasing the standard of living of citizens.

The growth of jobs through the use of new digital technologies in trade and industry leads to the consolidation of production and innovation and economic growth and development

Through this Strategy, the Government is implementing initiatives to ensure that:

✓ Opportunity for every individual to use digitalization, through various tools and creation of new jobs and companies, by exploiting the possibilities offered by new technologies, in trade and industry.

✓ Create new opportunities for business environment by enabling companies to make the best use of digital technologies; development of new business models;

✓ Ensuring the conditions of digitalization for the entire population having the effect of increasing the standard of living, increasing the quality of life, new skills requirements on the labour market.

The Technology Pact platform was initiated, the purpose of which is to support and develop new initiatives, to stimulate the interest of as many individuals as possible, to develop skills in the field of technology to implement them in innovation and starting new businesses.

The social impact targeted by the Government through the establishment of the Technology Pact is given by the involvement, at all educational levels, of a large number of people who develop an interest in the field of digital technology, by stimulating the accumulation of knowledge in the field and, consequently, increasing employment opportunities where specialized skills are required.

The social impact of the Strategy's policies is felt in the long run, through the development of improved instruments for citizens:

→experimenting with a new subject in primary and secondary education, to create children, opportunities to familiarize digital skills;

→new possibilities of employment in the labour, market, through the formation of new digital skills.

The social impact of new technologies is given by: revenue, increase in competitiveness and productivity.

At the country level, overall, the impact of digitalization is reflected in positive elements at the level of the entire economy, through the creation of new jobs, make more efficiency resource utilization, a larger volume of exports, a better healthcare system.

There is a *reciprocity relationship* created by the impact of digitalization on the individual, businesses and society. A broad digital transformation at the level of companies increases their efficiency and competitiveness, resulting in positive effects on the labour market, by creating new jobs and maintaining the existing ones, with changes to the advantage of both the individual and the country as a whole.

The impact is given by the broad transformation of some areas through digital technologies use, which facilitate a series of activities, such as: mobility (transport), construction finance, banking sector, health, education, the labour market (simplification of activities at the workplace), implications on the economy, Small and Medium Enterprises, business environment.

The impact on the business environment was felt through pressures on companies to increase competitiveness, given high competition and the the use of new technologies, the creation of online platforms.

New business models are emerging, as a result of the improvement of the offers brought by new companies, by adapting them to consumer preferences. Although, in the short term, adapting to consumer requirements is viable, it can create problems, in the long term, through the risk of monopoly formation, under market

→faster mobility, through the use of electric cars, driverless vehicles, traffic safety, traffic congestion, cleaner air. →facilitating physical work and reducing the execution time in construction, following the introduction of digitalization and robots, resulting in efficient work and construction safety. →individualized healthcare, safety medical services for patients, following the introduction of information new technologies; → benefits for companies producing medical equipment by opening new possibilities of increasing the production. following the emergence of new technologies; →development of new financial services, following the emergence of new financial platforms and new ways of payment and loan. →increasing productivity by investing in high-tech equipment (programs, computers) that contribute to the development of the economy.	dominance, by some companies that obtain large market shares. This phenomenon can propagate negative effects both in the competitive environment and in the economy, by reducing competition, increasing prices, reducing the capacity for innovation, with consequences for economic growth. It can be said that new digital technologies have a high potential to produce changes in the *business environment*, the competitive environment, through the digital transformation of many enterprises, pressures for the formation of new skills, a more flexible workforce. Making the best possible use of the possibilities offered by new digital technologies emphasizes the importance of acquiring new skills that arise from this.
Sud/Provence-Alpes-Côte D'azur It is an administrative region located in the South-East of France. It has an area of 31,400 km2 and a population of 5,218,960 inhabitants (2023) (Sud/Provence-Alpes-Côte D'azur Wikipedia, ttps://fr.wikipedia.org/wiki/Provence-Alpes-Côte d'Azur). The dynamic character of the Sud/Provence-Alpes-Côte d'Azur region is given by its multidimensional nature. The region's economy, quality public services, cultural and natural heritage, and its geographical position in the Mediterranean basin constitute strong points of attraction for talents, investors, and tourists. For the connectivity and inclusion of the region's territories, transport skills are important, with priority given to rail transport, culture, and the tourist attraction of the region are central elements. The inclusive, sustainable, and resilient development of the region is also based on government policies that ensure the attractiveness and internationalization of the region. The South Region is one of the first signatories of the Team France Invest (TFI) charter, whose objective is to connect the Region with other local	The strategies of the Sud-Provence-Alpes-Côte d'Azur region are based on a series of factors that ensure the internationalization and attractiveness of the region: the success of Foreign Direct Investment (FDI) projects, which have created over 1000 jobs, the large number of foreign companies, tourism, cultural heritage and research and innovation that attract investors and talents, international centers located on its territory (e.g. ITER).

authorities, regional/local development agencies and other local institutions, in order to develop a regional development strategy. It presents a high potential for implementing strategies, determined by the dynamic character of the region, its multidimensional nature (economy, services, cultural heritage, geographical position), which ensures its attractiveness for tourists and investors. **Nice** Located in the South-East of France, on the Mediterranean coast; it is a seaside resort. It has an area of 71.92 km² (Répertoire géographique des communes". National Geographic Institute (France). Wikidata Q20894925). Accessed on 26 October 2015. and a population of 360,000 inhabitants (2007). It is a university and cultural center. (Nice, Wikipedia, https://ro.wikipedia.org/wiki/Nisa#cite_ref-wdref-e5ab2104e13f122e352be9cf66f0ffab_2-0). The transformation policy of the city of Nice, through the integration of new technologies, aims to increase the quality of life of its citizens, create new jobs, and improve city management. Nice, the fifth largest city in France, quickly became a "smart and connected city". The strategy for the development of smart cities aims to save water resources, energy and waste recovery, develop a transport network that respects the environment, better living conditions for citizens and increase in the quality of life. Nice is a major tourist center located in the southeast of France in the metropolitan area. The transformation policy of the Nice Côte d`Azur metropolitan area has committed itself to the integration of new technologies, aimed at increasing the quality of life of its citizens and creating new jobs, improving the management of the city.	A series of Smart City initiatives have led to the collaboration of the Nice Côte de Azur metropolitan area with the *business environment* (large industrial groups, local Small and Medium Enterprises – SMEs), but also with educational and research institutions. These initiatives, which give the city of Nice the status of a smart city, have the impact of citizens and tourists benefits by increasing the quality of life, good living conditions, high-quality tourist infrastructure, environmental protection, *being an expression of the interconnectivity between the social element and the business environment*. Starting in 2010, over a ten-year period, a series of initiatives based on innovative technologies were launched, orienting the Nice Côte d'Azur metropolitan area towards a smart city: ✓ the implementation of services that integrate NFC (Near Field Communication) technology; ✓ the organization of an international "Innovative Cities" fair;

	✓ the implementation of the Spot virtual City Hall, focused on simplifying interaction with citizens; increasing the quality of public services; ✓ the creation of a platform that integrates research and education institutions and solid companies in the area of smart cities; ✓ the completion of the Nice Smart Valley smart grid project. The development of innovative projects in the electricity grid in France, but also in Europe, for the use of renewable energies and other ways of capitalizing on electricity, such as electric vehicles; qualifications at various events organized in the field of smart specialization. Local initiatives of transforming Côte d'Azur into a space for large-scale experiments. Experimental projects are being developed, both at national and European level, in which *the business environment* is involved. Development of startups comprising solutions for monitoring energy consumption in smart cities. Development of an internationally recognized center of excellence in the medical field, which integrates digital technologies and brings together human resources from the medical field, research institutes and the business environment represented by startups. Nice is a tourist area equipped with tourist infrastructure offering high quality services (hotels, residences) and an international airport Nice Côte d'Azur, connected to over a hundred direct destinations in about forty countries. These initiatives show the concerns of the Nice Côte d'Azur metropolitan area, for innovation, the integration of digital

	technologies, projects based on smart solutions, projects aimed at the use of renewable energies. All these initiatives have as an impact, the benefit of citizens, tourists, by: increasing the quality of life, good living conditions, high quality tourist infrastructure, environmental protection.

Source: Amsterdam, Wikipedia https://ro.wikipedia.org/wiki/Amsterdam; City of Amsterdam, Digital City Agenda, 2023/2026, Published by the City of Amsterdam, November 2023 https://assets.amsterdam.nl; Amsterdam, Wikipedia https://ro.wikipedia.org/wiki/Amsterdam, Gemeente Amsterdam, Digitale Stad Digital City Agenda 2023-2026. Published by the City of Amsterdam, Gemeente Amsterdam, Directie Digitalisering en Innovatie November 2023; Denmark, Wikipedia, https://ro.wikipedia.org/wiki/Danemarca; The Dansih Government, Ministry of Industry, Business and Financial Affairs, Strategy for Denmark's Digital Growth, https://www.eng.em.dk; Denmark, https://m.statbank.dk/TableInfo/ARE207?lang=en), Copenhaga, Wikipedia https://ro.wikipedia.org/wiki/Copenhaga; Danemarca, Wikipedia, https://ro.wikipedia.org/wiki/Danemarca; Copenhagen, Wikipedia https://ro.wikipedia.org/wiki/Copenhagen). Copenhagen https://en.wikipedia.org/wiki/Copenhagen; Urban Government Atlas, Strategy for Urban Nature – Copenhagen, Urban Nature in Copenhagen Strategy 2015-2025, Strategy for Urban Nature - Copenhagen | Interlace Hub; Strategia-urbană-pentru-natura-în-Copenhaga-2015-2025pdf-_1653.pdf; Strategy for Urban Nature - Copenhagen | Interlace Hub, Orașul Copenhaga (2015), Natura urbană în Copenhaga. Strategie 2015-2025; https://kk.sites.itera.dk/apps/kk_pub2/pdf/1653_EyzOS8ePZx.pdf; "A green Copenhagen" Strategy, 2009; City of Copenhagen (2015), Urban Nature in Copenhagen. Strategy 2015-2025 https://kk.sites.itera.dk › apps › kk_pub2 › pdf; OECD, 2022, The Sud-Provence-Alpes-Côte-D'Azur in the world, The Sud-Provence-Alpes-Côte-D'Azur in the world (EN), Nice Smart City, Echipa Coasta de Azur, https://www.meet-in-nicecotedazur.com/en/destination-nice-cote-dazur/choose-nice-cote-dazur/nice-smart-city/; Sud/Provence-Alpes-Côte D'azur Wikipedia, ttps://fr.wikipedia.org/wiki/Provence-Alpes-C%C3%B4te_d%27Azur; Répertoire géographique des communes". Institutul Geografic Național (Franța). Wikidata Q20894925, Nisa, Wikipedia, https://ro.wikipedia.org/wiki/Nisa#cite_ref-wdref-e5ab2104e13f122e352be9cf66f0ffab_2-0; Nice, https://ro.wikipedia.org/wiki/Nice; Nice, Wikipedia, https://ro.wikipedia.org/wiki/Nisa#cite_ref-wdref-e5ab2104e13f122e352be9cf66f0ffab_2-0; Profit.ro, 2015, Top 7 cele mai verzi orașe inteligente din Europa 17 noiembrie 2015, https://www.profit.ro/povesti-cu-profit/sfaturi-cu-profit/top-7-cele-mai-verzi-orase-inteligente-din-europa-14472829; Comisia Europeană, O Europă pregătită pentru era digitală. Tehnologii de ultimă generație la dispoziția cetățenilor, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age_ro; Consiliul Uniunii Europene, Pactul verde European, https://www.consilium.europa.eu/ro/policies/european-green-deal/.

5. Conclusions

The policy of transforming cities and regions, through the implementation of technologies with social impact, aims to increase the quality of life of citizens, by providing services and making them more efficient, improving mobility (transport), individual education programs, social assistance platforms. Other objectives refer to: ensure better living conditions, appropriate to needs, educational programs for young people, which ensure skills training and provide employment opportunities.

The triple transition (social, environmental and digital) offers the possibility of perceiving connections that are formed between the three types of transitions, between them, there being interaction and mutual reinforcement. (Schmerber, 2024) Through the social transition, the implementation of social policies is ensured that offer society the opportunity to benefit from the results obtained through the green and digital transitions, in turn exerting an impact on the other two forms of transition. (OECD, 2023)

Following the local policies developed by the municipalities of some cities or the governments of some European countries, exemplified in the data in Table 1, the following is noted:

There were concerns of the municipalities or governments in engaging in policies, with the aim of achieving a social transition, by integrating new technologies. The strategies provided a richer or narrower range of objectives, the implementation of which is foreseen within a few years. There were also situations for which the condition of smart city is not a novelty, this quality having been achieved since previous years (for exemple, Nice).

Some cities or countries proceeded to implement new technologies (digitalization of services offered to citizens), in others, this new form of manifestation went in parallel with the classic form.

Local development strategies provided a richer or narrower range of objectives, the implementation of which is to be done in the coming years.

Below, some remarks are made regarding the strategies employed by some European countries, mentioned in the text.

Amsterdam. Services offered to citizens are carried out, in parallel, both in the form of digital services and in the classical form. A special emphasis is placed on combating inequality in accessing digital services by disadvantaged groups, streamlining urban transport and introducing modern technologies, quality social assistance.

Copenhagen. It is highlighted an example of the interconnectivity between improving environmental conditions and favourable social prospects. Increasing the quality of urban nature (environmental transition), with social impact, regarding the satisfaction of residents can stimulate the business environment (public construction).

Denmark. The digital environment is developing through innovation and growth activities, developed to interact and create a development framework for new companies, based on modern technologies. In both the public and private sectors in Denmark, a series of innovation and growth initiatives have been developed, with the aim of stimulating the use of new technological products, each having a role in the development of a digital environment. Cooperation between new and existing companies is important to create conditions for the development and use of new innovative technologies. Educational programs have been developed to understand new technologies, in primary and secondary education, equipping schools with equipment for the development of professional skills.

Nice. The transformation policy of the Nice Côte d'Azur metropolitan area has committed itself to the integration of new technologies, aimed at increasing the quality of life of its citizens and creating new jobs, improving city management.

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DEVELOPING A RUBRIC FOR ASSESSING ARGUMENTATIVE WRITING COMPETENCE IN LITERATURE AND ENGLISH SUBJECTS FOR GRADE 10 STUDENTS BASED ON THE TOULMIN MODEL

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ABSTRACT

Identifying the actual competence of students plays a very important role in teaching. This helps teachers accurately recognize each student's strengths and weaknesses, allowing them to use purposeful and effective teaching methods to support student learning. In Vietnam today, testing and assessing student learning in Literature and English happen quite frequently, but there are still gaps in practical quality. This shows that measuring and assessing student competence still has many gaps to fill. The purpose of argumentative writing is to understand the learners' thoughts, perspectives, feedback, and critical thinking. However, many criteria and rubrics for assessing writing products are quite rigid, and accepting the learners' personal perspectives has not received enough attention and lacks openness. This makes it difficult to measure learners' critical thinking, problem-solving, and creativity. The current situation in Vietnam shows that testing and assessment have a huge impact on students' thinking and writing products. In other words, assessment is a guiding factor that controls learners' writing activities. Therefore, to create a new and open approach for assessing the argumentative writing of 10th-grade students in Vietnam, we propose developing an assessment Rubric based on the Toulmin model. With this approach, we hope that assessing students' argumentative writing competence will both meet the current 2018 General Education Curriculum in Vietnam and align with assessment practices in countries with advanced education. In these countries, measuring critical thinking and creative ideas are basic and necessary competencies that positively impact student learning.

Keywords: Rubric, Toulmin, argumentative text, text creation, Literature, English, competence

1. INTRODUCTION

Currently, the testing and assessment of students' abilities in Vietnam have made much progress. First of all, assessing learners' abilities is to measure and quantify the outcomes (in terms of qualities and competencies) that learners achieve after a learning period. Assessment is not just for the purpose of giving results or testing pure memory, but for the learners' progress (Ministry of Education and Training, 2018). There is a shift from assessing the reproduction of knowledge to assessing the abilities and qualities of learners, where the standard measure is defined as the required outcomes specified in the Master General Education Program and the General Education Program for each subject.

Assessment is an important step in the teaching process, having an impact on both teachers and learners. Substantive and objective assessment results will help learners progress continuously because learners

will have the opportunity to realize their shortcomings and factors negatively affecting their learning outcomes. From there, they will propose solutions to overcome, adjust, and improve better (Huyen et al., 2022). With the trend of competency-based assessment, teachers need to assess learners' ability to apply and perform specific learning tasks (Bao, 2014). Thus, the assessment step will provide feedback to the teachers, helping them locate the actual abilities that students achieve after a learning process. Based on these results, teachers will consider adjusting methods and ways of organizing teaching activities to suit the learners. Current articles on assessment in Vietnam are relatively diverse and comprehensive in both theoretical and practical aspects of teaching and learning, especially the assessment of learners' qualities and competencies according to the current 2018 General Education Program. In the Literature subject, initial research on competency assessment appeared very early, specifically in 2014, although the innovation in testing and assessment was not applied in Vietnam until 2018. Research shows that if teaching aims to develop students' qualities and competencies, assessment operations must also be changed concurrently (Bao, 2014). In the English subject, testing and assessing learners' competencies is also a great concern of teachers at all educational levels. The reality of assessing students' competencies in English has been surveyed on a large scale, and initial analyses show effectiveness in all four skills: reading, writing, speaking, and listening (Hanh et al., 2023). There are also studies pointing out the importance of assessing learners' competencies in integrated teaching, bringing many values such as: confirming students' learning outcomes; detecting deviations, and adjusting teaching (An et al., 2016). Although assessment in Literature and English currently receives much attention from researchers and teachers, it does not match its potential and lacks consistency. Especially, the assessment of argumentative writing skills, a genre present in both subjects, is still very fragmented and separate. Therefore, despite being at the same educational level and producing the same text type (argumentative text), students have to get used to a different system of assessment criteria in each subject. This confusion and overlap lead to doubts from learners about text creation ability, approaches, scientific nature, and synchronization of current education.

Therefore, in this paper, we propose building an assessment rubric for argumentative writing ability in both subjects using Toulmin's model. We hope that this paper will be an interdisciplinary approach in assessing popular language subjects in Vietnam today. Through this, testing and assessment will gradually become standardized, scientific, and meet many expectations; most importantly, it will effectively achieve the goals of the current 2018 General Education Program in Vietnam.

2. MATERIALS AND METHODS

To carry out this paper, we consistently used qualitative methods by proposing scientific hypotheses. Based on surveying data via questionnaires, the answers serve as a reference basis for us to collect, analyze, and outline proposals to solve the problem posed by the paper.

3. FINDINGS AND DISCUSSION

3.1. Argumentative writing competence and assessment requirements oriented towards learner competence development

3.1.1. Concept of argumentative writing competence

The ability to create argumentative texts is assessed based on critical thinking, the ability to organize arguments logically, and the effectiveness of including evidence in students' argumentative essays (Ananda et al., 2024). In addition, for an argumentative text to be evaluated as good, learners need to show factors such as competence, knowledge, and creativity (Budjalemba & Listyani, 2020). Also according to Budjalemba and Listyani (2020), learners need to follow the required rules for creating argumentative texts, such as ensuring the layout, synthesizing, citing, summarizing, paying attention to grammar and spelling, and avoiding plagiarism. Moreover, creating argumentative texts is also an activity where the writer uses language to express, clarify, prove, or persuade about a specific issue following a certain structure to form a text (Dang et al., 2020). In short, argumentative writing competence is a concept referring to the writer's ability to self-produce an essay discussing a specific topic. The produced argumentative essay needs to meet criteria such as layout and persuasiveness, besides basic requirements like spelling and grammar.

3.1.2. Assessing writing competence oriented towards competence development

Assessing learners' writing skills is an important part of the learning process because it promotes the relationship between the learning process and learning outcome assessment. Assessing writing skills helps identify students' weaknesses and strengths during the writing process (Huseynova, 2024). Measuring and assessing students' learning outcomes in writing classes is a mandatory activity in English language teaching (Suastra & Menggo, 2020). Similarly, Setyowati and Sukmawan (2019) also agree that writing competence assessment is indispensable in English language teaching; this assessment helps teachers identify learners' strengths and weaknesses to provide appropriate knowledge to improve learners' writing skills. Competence-oriented teaching requires teachers to focus on learners' learning activities so that students have the opportunity to fully develop their potential, while combining teachers' assessment of learners' outcomes and peer assessment among students (Ngoc, 2022). In general, assessing learners' writing skills is mandatory when teaching argumentative text creation. Based on the current requirements of the 2018 General Education Program, assessing learners' outcomes should not only rely on the teacher's evaluation but must be done comprehensively and regularly through learning activities, allowing students to self-assess their products as well as peer-assess each other's argumentative texts.

3.1.3. Characteristics of argumentative writing assessment in Literature and English

- Characteristics of argumentative writing assessment in Literature:

Writing is an essential skill in teaching any language, and Vietnamese is no exception to this importance. Because proficient writing skills will contribute to improving, enhancing, and developing other skills: reading, speaking, and listening. In Literature, creating argumentative texts accounts for the highest percentage, proving the importance of this text type in the subject's curriculum. Assessing writing in Literature must first closely follow the characteristics of the argumentative text type, such as: evaluating argumentation skills, including evaluating claims, reasons, and evidence (Bao, 2017). Stemming from the orientation of the General Education Program for Literature, the approach to assessing argumentative writing basically meets factors such as: Recognizing the literary issue to be discussed; Aesthetically appreciating the literary issue stated in the prompt; Organizing the text to suit the text type's characteristics; Arguing to persuade; Expressing to persuade; Being creative in ideas, emotions, and expression methods (Bao, 2018). At the genre level, to assess writing skills in argumentative texts, it is necessary to pay attention to points such as: claims, reasons, evidence, and argumentation methods (Tram, 2021). Most generally, it can be stated that popular argumentative writing assessment in Vietnam includes content and form. In terms of form, learners need to meet components such as structure, length, vocabulary, and syntax. In terms of content, each text type has different characteristics; for argumentative texts, common assessment requirements include: identifying the issue to be discussed; developing the argumentative content into claims, reasons, and evidence; and creative thinking.

- Characteristics of argumentative writing assessment in English:

Academic English writing culture requires linear and direct thinking. In international Cambridge English certificate exams, Cambridge Assessment English (2020) provides a rubric to assess students' text creation competence based on 4 criteria: Content, Communicative Achievement, Organisation, Language. In addition, there is another assessment standard co-owned by the British Council, IDP IELTS, and Cambridge University Press & Assessment (2023) used to assess students' writing skills in the IELTS exam. This rubric consists of 4 elements: Task Achievement / Task Response, Coherence & Cohesion, Lexical Resource, Grammatical Range & Accuracy. Depending on the students' ability, the degree of meeting these 4 elements varies. It can be seen that both of these rubrics are designed specifically for international English certificate exams.

In ENL (English as a Native Language) countries, students' writing skills are assessed based on national education standard systems. In the US, 10th-grade students' writing skills are assessed based on the Common Core State Standards (CCSS, 2010), which include the following 4 main criteria: Text Types and Purposes, Production and Distribution of Writing, Research to Build and Present Knowledge, Range of Writing. It can be seen that these criteria are designed specifically for students in the US, where English is the native language.

Currently, in Vietnam, the project "Making English a second language in Vietnamese schools" has been approved. Therefore, it is necessary to refer to the assessment frameworks for students' argumentative writing competence in ESL or EFL countries in Asia. In Hong Kong, English is used as a second language. Hong Kong students' English argumentative writing competence is assessed based on the criteria of the HKDSE (Hong Kong Diploma of Secondary Education) exam issued by the Hong Kong Examinations and Assessment Authority (HKEAA, 2014). The criteria for writing skills include 3 elements: Content, Language & Style, Organization. Realizing that in Hong Kong, English is used as a second language, this point is similar to the goal of the project "Making English a second language in Vietnamese schools". Therefore, in section 3.3.4. Building an assessment Rubric in Literature and English below, the research team selects the English writing assessment criteria of the HKDSE exam to build a Rubric for argument assessment based on Toulmin's model.

3.2. Toulmin's model and its applicability in assessing argumentative writing

3.2.1. Toulmin's argument model

Throughout human history, the issue of reasoning ability was raised very early. In ancient India from the 7th to the 6th century BC, the reasoning form of the "Five-part syllogism" was born. Similarly, in ancient China, Confucius's Rectification of Names doctrine and Mozi's Three Tests doctrine appeared as a form of ancient reasoning. Compared to ancient Greece, the philosopher Aristotle was famous for his Syllogism; he was the one who laid the foundation for logic to become a science. During the Middle Ages, logic made no progress due to the restraint of religion and theology. Passing the Middle Ages, logic continued to develop; many ideas and works on logic were born and later reached their peak with the dialectical methodology of Karl Marx and Friedrich Engels (Hải, 2007).

It can be seen that the issue of reasoning has long been of interest and studied. The assessment of reasoning ability in argumentative writing should be based on reasoning models. During the process of reviewing the literature, the research team selected Toulmin's argument model as the basis for building an assessment rubric for argumentative writing in Literature and English.

Toulmin's model was first introduced by the author Toulmin (1958) in his book The Uses of Argument. Toulmin's model consists of 6 elements: Claim, Data, Warrant, Backing, Qualifier, Rebuttal.

- Claim can be understood as a point, an assertion expressing the writer's viewpoint. The purpose of an argument is to explain, prove, and defend the Claim (Hải, 2019).

- Data can be understood as evidence, figures, and specific examples closely related to the Claim, which are included in the argument to prove the Claim (Hải, 2019).

- Warrant can be understood as the bridge between the Claim and the Data, logically explaining why the Data leads to the Claim (Turós et al., 2025). A Warrant is usually a scientifically proven and widely recognized theory or a real-life reasoning that is supported by the majority (Hải, 2019).

- Backing can be understood as an element that makes the Warrant stronger when readers or listeners doubt the Warrant or when the Warrant is not persuasive enough (Hải, 2019). The Warrant can be supplemented with more information or cited from reliable sources (Turós et al., 2025).

- Qualifier can be understood as the element showing the degree of certainty and the scope of the Claim (Hải, 2019; Turós et al., 2025).

- Rubuttal can be understood as the counter-argument element. A Rebuttal usually includes opposing arguments to the Claim, exceptions to the Claim, limitations of the Claim, or possible cases where the Claim might be weakened (Hải, 2019; Turós et al., 2025). A Rebuttal does not weaken the Claim or cause a contradiction in the arguer's reasoning; on the contrary, the Rebuttal shows critical thinking and affirms the comprehensive and objective perspective of the arguer (Hải, 2019).

Toulmin's model with its 6 elements (Claim, Data, Warrant, Backing, Qualifier, Rebuttal) is a complete system with a dialectical relationship among its elements. Any element in Toulmin's model interacts with the other elements in the model and can make the overall argument stronger or weaker (Turós et

al., 2025). Toulmin's model has been widely recognized and applied due to the strictness among the elements in Toulmin's model and its applicability in multiple fields (Al Fraidan, 2025).

3.2.2. Studies applying Toulmin's model in assessment

Toulmin is considered a fair assessment tool for tests in language assessment, which is seen as an important step of the assessment process to ensure fairness, objectivity, and accuracy in assessment (Kunnan, 2004). Toulmin's model promotes practical reasoning in several ways: by establishing that arguments have structure; by identifying the components of an argument and the relationships among those components (Gasper & George, 1997). Toulmin's model has truly improved students' argumentation skills when referenced and assessed in the English subject in Indonesia (Nasution, 2024). The 6 elements including: claim, data, counter-claim, counter-data, rebuttal claim, and rebuttal data in Toulmin's structure have been systematically studied and objectively evaluated with students in China. The study showed that learners' argument quality and counter-argument capability improved significantly when applying this model to teaching practice (Qin & Karabacak, 2010). Basically, studies applying Toulmin's model in assessment have existed very early, in many countries around the world, mainly in the field of language. However, in Vietnam, research on this model in teaching Literature and English has not really received much attention, due to many factors. We believe that many learners' skills will be improved based on Toulmin's model, such as: argumentation skills, providing evidence, creativity, and critical thinking.

3.2.3. Feasibility of applying Toulmin's model in assessing argumentative writing

The 2018 General Education Program issued by the Ministry of Education and Training details the educational content for each subject and educational level. Among them, for 10th-grade students, the educational content for writing skills, specifically the section on writing argumentative essays in Literature and English, is as follows:

- For Literature, students are guided to write argumentative texts with clearly presented viewpoints, logical sequences of points, and tightly structured argumentative texts, including persuasive evidence and avoiding plagiarism (Ministry of Education and Training, 2018a). For Literature, some structures of Toulmin's model are also focused on in assessing writing skills in Vietnam, such as: arguments, points, evidence, and creative thinking. This shows that there are certain intersections between the assessment criteria for Literature in Vietnam and Toulmin's model. It is these intersections that show that applying Toulmin's model in assessing learners' writing skills in Vietnam will bring many benefits.

- For English, students are guided to write simple, coherent paragraphs of about 120 - 150 words on topics of personal interest and express personal viewpoints and opinions (Ministry of Education and Training, 2018b). In the 10th-grade English curriculum in Vietnam, the elements for assessing students' argumentative writing have similarities with the elements appearing in Toulmin's model: claim, evidence, and the cohesion among arguments.

The similarity between Toulmin's model and the educational content of Literature and English in the 2018 General Education Program is the basis for the research team to build an assessment rubric for argumentative writing skills using Toulmin's model.

3.3. Proposing an assessment rubric for argumentative writing competence using Toulmin's model

3.3.1. Principles of building the rubric

The assessment rubric for argumentative writing competence using Toulmin's model for Literature and English is built on four principles:

- First, ensuring the required outcomes for Literature and English according to the 2018 General Education Program. The rubric needs to closely follow the guidelines of the Ministry of Education and Training on the required outcomes for Literature and English.

- Second, ensuring the required outcomes for the argumentative text type. The rubric needs to comprehensively assess students' argumentative writing skills, ensuring the assessment of all necessary elements in the argumentative text type.

- Third, ensuring the nature of Toulmin's model. The rubric needs to include the six elements of Toulmin's model, which are Claim, Data, Warrant, Backing, Qualifier, and Rebuttal.

- Fourth, ensuring openness. Instead of assessing students' argumentative writing skills based on traditional criteria, teachers apply the assessment rubric developed based on Toulmin's model.

3.3.2. Assessment rubric in Literature and English

In the assessment Rubric for English argumentative writing based on Toulmin's model below, the research team selects the English writing assessment criteria of the HKDSE exam to build the Rubric for argument assessment based on Toulmin's model. The assessment criteria include 3 main criteria: Content, Language & Style, and Organization. Among these 3 criteria, the Content criterion will be assessed based on Toulmin's model.

In this paper, we consistently build a Rubric describing how teachers use Toulmin's model to assess the Content criterion in learners' English and Literature argumentative writing.

Criteria / Level		Level 1	Level 2	Level 3	Level 4	Level 5
Content (60%)	**Claim (10%)**	No clear claim, or the claim is completely off-topic compared to the requirements.	Provides a claim but it is faint, lacks focus, or only touches the surface of the issue.	The claim is generally suitable but sometimes expressed vaguely, lacking sharpness.	Clear claim, detailed in most points, meets the prompt's requirements well and creates interest for the reader.	Clear, on-point, comprehensively covers the issue, shows deep understanding and grabs the reader's attention.
	Data (10%)	No evidence or the evidence is completely unsuitable for the claim.	States a few familiar pieces of evidence but they do not truly match the claim.	Provides related evidence but it is not truly outstanding or sometimes lacks specificity.	Suitable evidence, quite detailed and fully present in almost all sub-claims.	Rich, diverse evidence, accurate citations, and perfectly suitable to strongly support the claim.
	Warrant (10%)	No explanatory reasoning, broken argument, completely illogical.	Weak reasoning, mainly subjective deduction or merely listing ideas without connection to the evidence.	Explains the connection but the reasoning is sometimes forced, not deeply describing the nature of the issue.	Reasoning connects data and claims well, maintains logic and persuasiveness throughout the essay.	Provides sharp, creative reasoning; excellent and obvious logical connection between evidence and the claim.

	Backing (10%)	Completely lacks backing elements.	Very little or almost no backing to defend the reasoning.	Contains backing elements but stops at a basic level, not truly supporting the reasoning strongly.	Provides reasonable backing, supports the reasoning well.	Extremely solid backing, absolutely increasing the persuasiveness of the reasoning.
	Qualifier (10%)	Does not use any qualifiers.	Rarely uses qualifiers, the argument is often one-sided and absolute.	Begins to show awareness of using qualifiers but sometimes still formulaic or not entirely accurate.	Uses suitable qualifiers in most cases, helping the argument avoid becoming extreme.	Uses qualifiers (modal verbs, adverbs of certainty) flexibly, with a subtle awareness of the argument's scope and limits.
	Rebuttal (10%)	No critical elements, completely ignores multi-dimensional perspectives.	Only mentions opposing views without being able to refute them.	Mentions opposing views but the refutation is still simple, not thorough.	Identifies and responds to opposing views quite effectively and logically.	Predicts and refutes opposing views comprehensively, sharply, and highly persuasively.
Language & Style (20%)		- Sentence structure: Writes disjointed sentences. - Vocabulary: Extremely poor vocabulary. - Grammar: Makes serious grammar errors causing confusion for the reader. - Style: Style is completely unsuitable for the argumentative text genre.	- Sentence structure: Mainly creates simple sentences. - Vocabulary: Limited vocabulary, lots of repetition, often makes spelling errors. - Grammar: Grammar has many basic errors but some main ideas can still be understood. - Style: Style is not formal, overuses personal pronouns and	- Sentence structure: Writes simple sentences well and initially uses some basic complex sentences. - Vocabulary: Correctly uses common vocabulary from the curriculum. - Grammar: Grasps basic grammar/punctuation (still makes mistakes). - Style: Begins to show awareness of	- Sentence structure: Good use of different sentence structures. - Vocabulary: Relatively broad vocabulary, spells most words correctly. - Grammar: Sufficiently accurate grammar and punctuation, minor errors do not affect the general meaning.	- Sentence structure: Flexibly and accurately uses a variety of sentence structures (simple, compound, complex sentences). - Vocabulary: Rich vocabulary, effectively uses advanced academic words. - Grammar: Accurate grammar and punctuation, expresses

		daily communicative language.	using an objective tone although still mixed with spoken style/personal emotions.	- Style: Tone and style are mostly suitable for an argumentative essay.	subtle meanings. - Style: Excellently maintains an objective tone, formal style suitable for an argumentative essay.
Organization (20%)	- Layout: The essay lacks layout, written as a single block of text. - Paragraphing: No paragraph division. - Cohesion: Does not use linking words or seriously misuses them, failing to create cohesion.	- Layout: Can only identify the essay structure (Intro - Body - Conclusion) at a sketchy, messy level. - Paragraphing: Divides paragraphs but lacks logic, paragraphing is based on the train of thought while writing, not based on logic when analyzing the issue. - Cohesion: Sentences and paragraphs are connected with very basic linking words, making the essay disjointed.	- Layout: Can identify the Introduction - Body - Conclusion layout, the essay shows coherence in some key parts. - Paragraphing: Divides paragraphs but the arrangement of ideas within paragraphs is sometimes unreasonable. - Cohesion: Uses linking words but in a mechanical, repetitive way.	- Layout: Complete essay layout with Introduction - Body - Conclusion, coherent essay structure in most paragraphs. - Paragraphing: Effective paragraph division, helps maintain the overall flow of thought. - Cohesion: Quite successful use of cohesive devices (linking words) between sentences and paragraphs.	- Layout: Extremely tight essay layout (Introduction - Body - Conclusion), strictly follows the argumentative genre. - Paragraphing: Excellent paragraphing skills (one clear idea per paragraph). - Cohesion: Cohesion between sentences and paragraphs is smooth through a diverse system of linking words.

3.4. Significance of applying Toulmin's model in assessing argumentative writing

Applying Toulmin's argument model in building an assessment rubric for argumentative texts in Literature and English brings dual significance in terms of both assessment and teaching and learning methods. In terms of measurement, Toulmin's structure has provided an objective and standardized set of criteria, helping teachers and students accurately outline and visualize the requirements of creating argumentative texts. In terms of competence development, this model transforms the assessment tool into an effective "steering wheel" to guide learners' thinking in organizing their writing and their creative abilities. Through the rubric, students can actively identify logical gaps in their writing, thereby improving their text creation competence consistently and systematically according to universal academic standards, which here is the intersection at the international level.

4. CONCLUSION AND RECOMMENDATIONS

Conclusion

The study has specified the application of Toulmin's model to build a standardized rubric system, providing an objective and consistent measurement tool for the interdisciplinary argumentative writing competence in Literature and English of 10th-grade students. Not stopping at a testing tool, this rubric acts as a critical thinking map, helping learners shape the organizational structure of their essays according to international standards. This is a creative step, opening a new approach in innovating assessment oriented towards the comprehensive development of students' qualities and competencies in the modern educational context.

Recommendations

We hope that the application of Toulmin's model to build a rubric system will be implemented for assessment in other languages around the world. Through this, academic intersection will increasingly expand. The borders of knowledge will truly be shortened, and learners will have a clear shape in creating argumentative texts.

5. ACKNOWLEDGMENTS AND INFORMATION NOTE

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CALIXARENES: A BRIEF REVIEW OF SYNTHESIS, PROPERTIES, AND APPLICATIONS

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ABSTRACT

Calixarenes are macrocyclic compounds, or cyclic oligomers, that consist of 4 to 20 phenolic units linked by methylene bridges, forming a vase-shaped, three-dimensional structure. Calixarenes are commonly synthesized by the condensation of p-substituted phenols with formaldehyde. The synthetic methods described in this review include one-step base-catalyzed procedures, one-step acid-catalyzed procedures, one-step synthesis under neutral conditions, and multi-step synthesis, both convergent and non-convergent. The paper points out that the type of macrocycle obtained is strongly correlated with the type of solvent, the nature of the catalyst (the "template effect"), and the reaction temperature. The synthesis of homocalixarenes, oxacalixarenes, homooxacalixarenes, chiral calixarenes, and heterocalixarenes is also presented. Further derivatization at the upper or lower rim provides broad access to tailored macrocycles with tunable structural and binding properties. Esterification and etherification with monofunctional and polyfunctional reagents, dealkylation of p-alkylcalixarenes, electrophilic substitution, Claisen rearrangement, and functionalization via the p-quinonemethide and p-chloromethylation routes are also presented.

Physical properties of calixarenes (melting points, solubility, and pKa values) and their spectral characteristics (infrared, NMR, and mass spectra) are discussed in terms of the distinctive features arising from their usual conformations.

Among the traditional applications of calixarenes reviewed in this article are ion-selective electrodes (ISEs), liquid-liquid extraction for the removal of heavy metals and radioactive waste (e.g., ^{137}Cs and ^{90}Sr) from acidic industrial solutions, environmental sensors, phase-transfer catalysts, targeted drug delivery systems, and antiviral and antibacterial coatings. The paper also takes into account new and emerging applications of calixarenes, such as their use as intrinsically active drugs and in hybrid material integration, for example, by incorporating calixarenes into metal-organic frameworks or onto magnetic nanoparticles.

Keywords: calixarene, Claisen rearrangement, liquid-liquid extraction.

ORGANIC- INORGANIC HYBRID MATERIALS AND THEIR APPLICATIONS: A BRIEF REVIEW

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ABSTRACT

According to IUPAC (International Union of Pure and Applied Chemistry), a hybrid material is defined as a material formed from a close combination of inorganic and organic components, or both, that usually interpenetrate at scales below 1 μm. The synthesis of hybrid compounds is an emerging field because these materials combine organic and inorganic building blocks within a new structure, generating distinctive structural, chemical, and physical properties through the synergy between both components. The purpose of this paper is to review the best-known organic–inorganic hybrid materials from the perspective of their synthesis and their outstanding physicochemical properties.

Organic – inorganic hybrid materials presented in this review are the following:

- *Metal- decorated covalent organic frameworks (COFs)*, crystalline porous networks built from metal ions or clusters and organic linkers. They are investigated in several applications such as gas storage, environmental remediation, separation, catalysis, sensing, and energy storage.

- *Hybrid perovskites* (e.g., methylammonium lead halide) consist of an inorganic framework combined with organic cations and are especially important in optoelectronics, particularly for high-efficiency solar cells.

- *Polyoxometalate-based hybrids* are formed by combining metal-oxygen cluster anions with organic cations, ligands, or polymers; these materials are applied in catalysis, proton conduction, and electrochemical energy storage.

- *Metal-organic frameworks (MOFs)* are an emergent class of hybrid porous polymers designed by joining metal clusters with organic bridging ligands to create novel nanometric/ micrometric networks. The most important applications include gas storage, wastewater treatment, and biomedicine.

Organic Functionalized Metal/Oxide Surfaces. These are inorganic substrates (like SiO_2 or TiO_2) treated with organic molecules to alter their surface properties. Environmental remediation and water purification, gas sensing, and antibacterial surfaces are some of their applications.

Keywords: Metal-organic frameworks, hybrid perovskites.

CHEMISTRY AND PHARMACOLOGICAL APPLICATIONS OF *Allium Sativum* EXTRACTS

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ABSTRACT

The pharmacologic activity of garlic (*Allium sativum*) is fundamentally rooted in a variety of organo-sulfur compounds, notably allicin and its chemical precursor, alliin. Since allicin is responsible for the characteristic odor, dried and powdered formulations are typically standardized to alliin or allicin content. A significant pharmaceutical challenge involves the protection of alliinase, the enzyme that converts alliin to allicin, which is highly susceptible to degradation by stomach acid. To counteract this, enteric-coated delivery systems are utilized to ensure enzymatic stability and metabolic efficacy.

This work aims to analyze the chemical stability of sulfur-based derivatives and their specific impact on metabolic and cardiovascular pathways. In the presented study, it is examined how allicin and related compounds inhibit HMG-CoA reductase, a key enzyme involved in cholesterol biosynthesis. Meta-analytical data confirm this mechanism through weighted mean differences (WMDs) in total cholesterol of -15.25 mg/dL and in LDL of -6.41 mg/dL. Furthermore, the study explores the biochemical role of water-soluble organo-sulfur compounds like S-allylcysteine found in aged garlic extract (AGE), particularly their contribution to the stimulation of nitric oxide synthase.

In addition to these core mechanisms, this paper will discuss:

- The inhibition of thiol-containing enzymes as a primary antimicrobial pathway against Candida albicans and Entamoeba histolytica.
- The modulation of vascular resistance through the inhibition of angiotensin 1 converting enzyme and increased production of hydrogen sulfide.
- Critical drug interactions regarding the reduced bioavailability of saquinavir and the potential for bleeding when combined with warfarin, aspirin, or ibuprofen.

Standardization requirements for dried, powdered garlic products, focusing on a 1.3% alliin content or a 0.6% allicin-generating potential.

Keywords: *Allium sativum*, allicin, HMG-CoA reductase, organo-sulfur compounds.

PHARMACOCHEMICAL PROFILE AND THERAPEUTIC MULTITARGETING OF *Ginkgo biloba* EXTRACT

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ABSTRACT

Ginkgo biloba extract (EGb761) is a complex phytopharmaceutical prepared by concentrating 50 parts of the crude leaf to prepare one part of extract. Its biological activity is driven by a unique chemical matrix of flavone glycosides and terpenoids, specifically ginkgolides A, B, C, J, K, L, M, N, P, and Q, along with bilobalide. Due to this intricate composition, the extract functions as a multi-target agent with effects ranging from rheological modulation to potent neuroprotection.

This work evaluates the structural chemistry of *Ginkgo biloba* and its diverse mechanisms of action within the cardiovascular and central nervous systems, while addressing critical safety considerations for clinical practice.

The paper points out that the cardiovascular efficacy of ginkgo involves enhancing endogenous nitric oxide effects and antagonizing platelet-activating factor. In vitro, four biflavones-ginkgetin, isoginkgetin, bilobetin, and amentoflavone-alongside flavonoids such as quercetin and kaempferol, have been found to inhibit human thrombin at IC_{50} values of 8.05 - 82.08 μM. Furthermore, the paper discusses central nervous system effects, in which chronic administration leads to increased receptor densities for muscarinic, α2, and 5-HT1A receptors, as well as enhanced synaptosomal reuptake of serotonin and dopamine.

The importance of the flavonoid fraction's antioxidant and radical-scavenging properties against superoxide anions and hydroxyl radicals is also presented, specifically regarding the inhibition of amyloid-beta fibril formation. Finally, potential safety concerns are analyzed: ginkgo may have antiplatelet properties and should not be used in combination with anticoagulant medications like warfarin or aspirin. Additionally, the risk of seizure disorders related to seed contamination with the epileptogenic ginkgotoxin is evaluated. Ultimately, while standardized EGb761 extract shows promise in dementia management, its clinical use requires rigorous monitoring for bleeding complications and standardized dosing.

Keywords: flavone glycosides, ginkgolides, bilobalide, neuroprotection.

MOLECULAR SWITCHES: RESPONSIVE MOLECULES FOR SMART FUNCTIONAL SYSTEMS

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ABSTRACT

Molecular switches are dynamic chemical systems able to reversibly change their structure, configuration, or electronic state in response to an external stimulus. These stimuli may include light, pH, temperature, redox potential, metal ions, or specific chemical signals. Due to this reversible behavior, molecular switches represent an important class of compounds in supramolecular chemistry, materials science, nanotechnology, and biomedical research.

Their function is based on controlled transitions between two or more stable or metastable states, each state having different physical, chemical, or biological properties. Common examples include azobenzenes, spiropyrans, diarylethenes, rotaxanes, and catenanes. Among them, photoresponsive switches are especially attractive because light can be applied with high spatial and temporal precision without directly contaminating the system.

Recent studies have shown that molecular switches can be integrated into smart materials, sensors, drug delivery platforms, molecular machines, and data storage devices. In biological applications, they are used to regulate the activity of drugs, proteins, or receptors, offering new possibilities for targeted therapy and reduced side effects. In materials science, switching molecules can modify color, fluorescence, conductivity, shape, or surface wettability, allowing the development of adaptive coatings, optical devices, and responsive polymers. However, several challenges remain, including fatigue resistance, switching efficiency, thermal stability, biocompatibility, and precise control under real operating conditions.

Overall, molecular switches provide a versatile platform for designing systems capable of responding intelligently to environmental changes. Their continued development is expected to contribute significantly to next-generation smart materials, molecular electronics, and precision medicine.

Keywords: molecular switches, photoresponsive molecules, supramolecular chemistry.

SYNTHESIS AND ANTIMICROBIAL EVALUATION OF NEW PYRROLOINDOLIZINE COMPOUNDS

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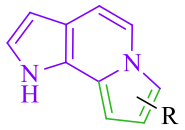
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ABSTRACT

Fused pyrroloazaheterocyclic systems are valuable medicinal scaffolds due to their rigid, highly conjugated structures and diverse biological properties, including anticancer, antimicrobial, antiviral and kinase inhibitory activities [1-3]. Despite the extensive interest in pyrrolo-fused heterocycles, pyrroloindolizine derivatives remain less investigated. In particular, the 1*H*-pyrrolo[3,2-*g*]indolizine framework has not yet been the subject of systematic studies addressing either its synthesis or its biological potential. In this context, we report the synthesis and structural characterization of a new series of pyrrolo fused derivatives with 1*H*-pyrrolo[3,2-*g*]indolizine skeleton obtained through regioselective 1,3-dipolar cycloaddition reactions.



1*H*-pyrrolo[3,2-*g*]indolizine

Structural characterization of these compounds was achieved through various spectroscopic techniques, including NMR, IR and X-ray diffraction.

Given the well-established medicinal relevance of pyrrolo-fused heterocyclic frameworks, the newly synthesized compounds were evaluated through preliminary *in silico* ADMET studies, together with *in vitro* antimicrobial assays, to assess the biological potential of this novel fused pyrroloindolizinic scaffold.

Keywords: pyrroloindolizine, 1,3-dipolar cycloaddition, antimicrobial, ADMET.

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SUSTAINABLE TOURIST DESTINATIONS AND REGIONAL BRANDS: CONNECTIONS BETWEEN PARANÁ, BRAZIL, AND WESTERN PORTUGAL

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ABSTRACT

The study identified and analyzed tourist destinations in the state of Paraná in southern Brazil and in central Portugal that have territorial brands focused on regional development. The study examined the characteristics of these brands based on the concept presented by Almeida (2018), assessing their compliance with the principles of territorial identity, government branding, brand recognition, and city recognition. The results revealed similarities and differences among the analyzed destinations in the two countries, highlighting distinct strategies for territorial management and promotion, as well as varying levels of integration between tourism, sustainability, and regional development. Furthermore, the study demonstrated that sustainable territorial brands help strengthen local identity, enhance tourism appeal, and consolidate more resilient and integrated models of territorial development. In this sense, the study contributed to scientific progress by expanding the theoretical and methodological frameworks related to sustainable territorial brands and comparative regional development. The research enabled the creation of strategies focused on strengthening territorial competitiveness, encouraging sustainable growth, and expanding social participation in regional development processes. Furthermore, it contributed to the improvement of territorial management and governance practices.

Keywords: regional brands, tourism, regional development, sustainable brands.

ALIGNING ALBANIA'S CARBON TAX WITH EU CIRCULAR ECONOMY TARGETS: OPPORTUNITIES AND OBSTACLES

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ABSTRACT

A circular economy and a robust carbon pricing mechanism are central pillars of the European Union's Green Deal. EU candidate countries, such as Albania, must align their domestic environmental policies with EU standards.

In this research, I have reviewed the alignment of Albania's carbon tax framework with the EU Circular Economy Action Plan (CEAP). I have paid particular attention to the implications of the EU Carbon Border Adjustment Mechanism (CBAM). The transition process shows opportunities and threats. Opportunities include economic modernization, enhanced export competitiveness, and accelerated EU integration. However, substantial structural obstacles persist. Among the most important threats are the carbon price gap, institutional and infrastructure deficits, and the risk of regressive economic impacts on at-risk populations and small and medium-sized enterprises (SMEs).

The research employed a mixed-methods approach on both qualitative and quantitative data from the World Bank, Eurostat, the European Environment Agency (EEA), and the International Energy Agency (IEA).

The main recommendations are: gradual alignment of carbon prices; a strategic revenue designation through a Green Transition Fund; operationalization of the 2025 Integrated Waste Management Law; strengthening monitoring, reporting, and verification (MRV) capabilities; and advancing regional cooperation.

Keywords: Albania, carbon tax, circular economy, EU accession, CBAM, Green Deal

1. Introduction

The global imperative to reduce climate change has catalyzed a significant paradigm shift from linear economic models characterized by a "take-make-dispose" approach towards circular economies, which focus on resource efficiency, waste reduction, and the continuous valorization of materials (Ellen MacArthur Foundation, 2015). At the leading edge of this transition is the European Union (EU), which has enshrined these principles in the European Green Deal and the Circular Economy Action Plan (CEAP) (European Commission, 2020a). An essential element of the EU's strategy consists of the deployment of economic instruments, notably the EU Emissions Trading System (ETS) and the recently implemented Carbon Border Adjustment Mechanism (CBAM), designed to internalize the environmental costs of greenhouse gas (GHG) emissions and prevent carbon leakage (European Commission, 2023a). For the Western Balkans, and Albania in particular, this transforming regulatory landscape provides a complex matrix of obstacles and opportunities. As an EU candidate country that successfully opened all accession negotiating chapters by late 2025 (European Commission, 2025a), Albania is under increasing pressure to harmonize its environmental legislation with the EU acquis Communautaire, specifically Chapter 27 (Environment and Climate Change). Furthermore, as a signatory to the Sofia Declaration on the Green Agenda for the Western Balkans, Albania has committed to attaining carbon neutrality by 2050 and a recycling rate above 50% by 2030 (Regional Cooperation Council, 2020). Albania's current environmental fiscal policy includes a carbon tax introduced in 2008, which has recently undergone phased reforms, specifically on the taxation of coal (World Bank, 2025a). However, the domestic carbon price remains significantly lower than the EU ETS benchmark, currently

estimated at approximately $13.11 *per ton* of CO_2-equivalent (Climate Policy Database, 2024). This variation exposes Albanian exporters to the financial levies of the CBAM, which entered its definitive phase in January 2026 (Germanwatch, 2023). Concurrently, Albania's transition to a circular economy is in its early stages, hindered by a low recycling rate of approximately 18.9%, compared with the EU average of 49%, and underdeveloped waste management infrastructure (OECD, 2024a). The nexus between carbon taxation and the circular economy is particularly salient in the Albanian context. Carbon taxes, by increasing the cost of fossil-fuel-intensive production and virgin-material harvesting, create economic encouragement for businesses to adopt circular practices such as recycling, remanufacturing, and product-as-a-service models (Panza et al., 2025). Conversely, a well-functioning circular economy reduces the overall demand for energy-intensive primary material production, thereby lowering the carbon tax burden on the economy (Wang et al., 2024). This virtuous cycle represents a persuasive policy rationale for integrating carbon pricing and circular economy strategies. This paper aims to explore this nexus within the Albanian context. It seeks to answer the following primary research question: How can Albania align its carbon tax policies with EU circular economy targets to maximize economic opportunities while lessening structural obstacles? By analyzing the differences between carbon pricing and resource efficiency and by placing Albania's current policy course within the wider EU regulatory framework, this study provides a strategic roadmap for Albanian policymakers. The paper is structured as follows: Section 2 supplies a comprehensive literature review; Section 3 outlines the methods; Section 4 analyzes the current state of Albania's environmental policy and economy; Section 5 examines the EU circular economy targets and the CBAM framework; Sections 6 and 7 analyze opportunities and obstacles, respectively; Section 8 presents policy recommendations; and Section 9 concludes.

2. Literature Review

2.1 The Theoretical Nexus Between Carbon Taxation and the Circular Economy

The relationship between environmental taxation and the circular economy has drawn increasing attention in the academic literature over the past decade. Conceptual models grounded in environmental economics argue that carbon pricing and circular economy policies are mutually reinforcing instruments for achieving sustainable development goals (Xie et al., 2023). The core logic rests on internalizing externalities: by placing a price on carbon emissions, governments correct a market failure that previously allowed firms to externalize the environmental costs of their production activities onto society. Panza et al. (2025) provide a persuasive empirical analysis showing that adopting carbon taxes incentivizes companies to adopt circular economy business models rather than linear ones, because circular models inherently generate lower CO_2-equivalent emissions and thus reduce tax liabilities. This finding aligns with earlier theoretical work by Deserno and Sterk (2025), who examine the role of resource taxes in encouraging circularity in European economies and conclude that environmental fiscal instruments are effective in shifting economic structures away from linear patterns. Similarly, Wang et al. (2024) conduct a systematic bibliometric study of the literature and affirm a predominantly synergistic relationship between circular economic practices and carbon emission reductions, with resource efficiency mechanisms and environmental taxation providing complementary policy pressures. Balsalobre-Lorente et al. (2024) extend this analysis to examine the mediating role of carbon policy and the circular economy in industrial development, finding that the interaction between these two policy domains significantly accelerates the decarbonization of manufacturing sectors. The concept of a "Circular Economy Taxation Framework," as proposed by Milios (2021), further formalizes this relationship, suggesting that tax systems should be redesigned to reward circular behaviors (e.g., through reduced VAT on repaired goods) while penalizing linear ones (e.g., through higher taxes on virgin material harvesting).

2.2 Carbon Pricing in Developing and Transition Economies

Implementing carbon taxes in developing and transition economies poses unique challenges that differ substantially from those faced by advanced economies. Research shows that while carbon pricing is effective at curbing emissions, it must be carefully designed to avoid regressive impacts on low-income households, who spend a disproportionately higher share of their income on energy and basic goods (IMF, 2024). The United Nations Development Program (UNDP, 2025) emphasizes the importance of

carefully designed policies, including transparent earmarking of revenues to support green innovation, social protection programs, and just transition initiatives for workers in affected industries. In the Western Balkans, the challenge is intensified by the region's stage of economic development, characterized by lower GDP per capita, higher production energy intensity, and greater reliance on carbon-intensive industries compared to the EU average (Joint Research Center, 2024). Studies examining carbon pricing in comparable contexts, such as those by the World Bank's Climate Policy Assessment Tool (CPAT), highlight the importance of staged implementation, revenue recycling, and complementary regulatory measures to ensure that carbon taxes achieve their environmental objectives without undermining economic growth or social equity (World Bank, 2025a).

2.3 The EU CBAM and Its Implications for Non-EU Countries

The introduction of the EU CBAM has spurred a surge in literature analyzing its impact on non-EU trading partners. The CBAM, formally established by Regulation (EU) 2023/956, is the first carbon border adjustment mechanism of its kind globally, covering imports of cement, iron and steel, aluminum, fertilizers, electricity, and hydrogen (European Commission, 2023a). By requiring importers to purchase certificates equivalent to the carbon price embedded in their products, the CBAM aims to level the playing field between EU producers subject to the ETS and foreign competitors who face lower or no carbon costs.

Research shows that countries in the Western Balkans are particularly vulnerable due to their geographic proximity to the EU and their reliance on carbon-intensive exports (Berlin Process, 2024). Germanwatch (2023) provides a detailed analysis of the CBAM's impact on the Western Balkans and Ukraine, noting that while the mechanism poses a short-term economic burden, particularly for Bosnia and Herzegovina, Serbia, and Montenegro, whose CBAM-related exports account for 4-6% of GDP, it also serves as a powerful catalyst for the energy transition and the adoption of cleaner production technologies. The ECFR (2025) further argues that the CBAM, combined with the EU's Growth Plan for the Western Balkans, creates a geopolitical incentive for the region to accelerate its green transition.

Albania's position in this landscape is distinctive. The Berlin Process Factsheet (2024) notes that Albania and Kosovo are likely to be less affected by the CBAM than other Western Balkan countries, primarily because Albania's electricity production relies almost entirely on hydropower, which lowers the carbon intensity of its exports. According to the World Bank's Relative CBAM Exposure Index, Albania may even gain competitiveness relative to the average EU producer for the goods it exports. However, this relative advantage should not lead to complacency, as the cement and aluminum sectors remain exposed.

2.4 Albania's Specific Policy Context: A Research Gap

Despite the growing body of regional literature, a significant gap remains in understanding Albania's policy landscape. Most regional studies aggregate the Western Balkans, often overlooking Albania's unique energy profile and legislative advances. The OECD's (2024a) Roadmap towards a Circular Economy for Albania is a landmark contribution, providing a detailed diagnostic of the country's circular economy landscape and proposing priority areas for reform. However, the intersection between this circular economy roadmap and Albania's carbon tax reform has not been thoroughly analyzed. This paper fills this gap by providing an in-depth analysis of Albania's carbon tax reform and its potential to serve as a fiscal lever for advancing circular-economy objectives, thereby contributing to both the academic literature and the policy discourse.

3. Methodology

This study uses a mixed-methods approach, integrating qualitative policy analysis with a quantitative review of macroeconomic and environmental data. This approach is appropriate given the complexity of the research question, which requires both an understanding of the policy landscape and empirical grounding in data.

3.1 Data Sources

Quantitative data were drawn from authoritative international and national databases. Primary sources include the World Bank's World Development Indicators, Eurostat's environmental statistics, the European Environment Agency's (EEA) Europe's Environment 2025 country profiles, the International Energy Agency (IEA) country data, and the Albanian Institute of Statistics (INSTAT). Key metrics analyzed include GDP growth and per capita income, GHG emissions by sector, energy mix and consumption patterns, municipal waste generation and treatment methods, recycling and circular material use rates, and environmental tax revenues as a percentage of GDP.

3.2 Analytical Framework

The qualitative component comprises a systematic review of recent legislative documents, policy frameworks, and institutional reports. This includes Albania's Nationally Determined Contributions (NDCs) submitted to the UNFCCC, the National Energy and Climate Plan (NECP) 2021–2030, the 2025 Integrated Waste Management Law (Law No. 57/2025), the OECD Circular Economy Roadmap for Albania, and the EU's CBAM regulations and CEAP. The analysis applies a policy coherence assessment to evaluate the congruence between Albania's current policy trajectory and the EU's 2030 targets across five dimensions: carbon pricing, waste management, resource efficiency, institutional capacity, and monitoring and reporting.

Table 1 below summarizes the key indicators used in the alignment assessment and their current values for Albania relative to EU benchmarks.

Table 1. Key indicators in alignment assessment in Albania and EU benchmarks

Indicator	**Albania (2022–2024)**	**EU-27 Target (2030)**	**Alignment Gap**
Carbon Price (USD/tCO_2-eq)	~$13.11	~€100–130	Very Large
Municipal Waste Recycling Rate (%)	18.9%	>50%	Large
Circular Material Use Rate (%)	4.2%	24%	Very Large
Renewable Energy Share (%)	44.5%	87%	Moderate
Environmental Tax Revenue (% of GDP)	2.63%	~2.40%	Aligned/Surplus
Organic Farming Share (% of agri. land)	3.5%	25%	Large
GHG Emissions Reduction vs. BAU	-10.5% (2023 est.)	-20.9% (NDC, 2030)	Moderate

Note. Data sources: World Bank (2025a); OECD (2024a); EEA (2025); INSTAT (2024); Eurostat (2022); Climate Policy Database (2024).

4. The Current State of Albania's Environmental Policy and Economy

4.1 Macroeconomic Context

Albania is a developing, open-market economy that has shown marked resilience in recent years. GDP per capita reached approximately $10,012 in 2024, a 16.76% increase over the previous year (World Bank, 2024). The economy grew 3.4% year over year in the first quarter of 2025, supported by strong foreign demand (World Bank, 2025b). The economy is driven primarily by the services sector, notably tourism, which accounts for approximately 17.4% of GDP and 20% of employment, alongside agriculture (approximately 25% of land use) and manufacturing, particularly textiles and footwear (27.8% of total exports in 2022) (INSTAT, 2024; Switch to Green, 2025).

Albania's population is approximately 2.7 million, and its GDP per capita in 2023 was about EUR 6,800, well below the EU average (Switch to Green, 2025). This economic context is critical for understanding the constraints on environmental policy ambition, as fiscal space for large-scale green investments is limited and social sensitivity to energy price increases is high.

4.2 Greenhouse Gas Emissions Profile

Unlike many of its regional peers, Albania has a relatively green electricity grid, with nearly 100% of domestic electricity generation coming from hydropower (IEA, 2023). Consequently, the country's overall GHG emissions are among the lowest in Europe, with CO_2 emissions per capita at approximately 1.5 Mt in 2021, compared with the EU average of 5.5 Mt (Switch to Green, 2025). Total GHG emissions are estimated at approximately 5.64 Mt CO_2-equivalent in 2023.

However, this reliance on hydropower creates a significant vulnerability: climate change-induced variations in precipitation and river flows are already affecting hydropower generation, threatening energy security and possibly increasing reliance on fossil-fuel backup generation. The EEA (2025) notes that Albania is among the most vulnerable countries in the region to the effects of climate change, particularly natural disasters.

As shown in Figure 1, the transport sector is the largest contributor to GHG emissions in Albania, accounting for approximately 2.10 Mt CO_2-equivalent in 2023 (about 37% of the total), followed by industry (1.28 Mt, 23%), buildings (0.86 Mt, 15%), agriculture (0.63 Mt, 11%), energy/power generation (0.42 Mt, 7%), and waste and other sectors (0.35 Mt, 6%) (IEA, 2023; EEA, 2025). This emissions profile is notably different from the EU average, where the energy sector typically dominates, underscoring the need for targeted decarbonization strategies in the transport and industrial sectors.

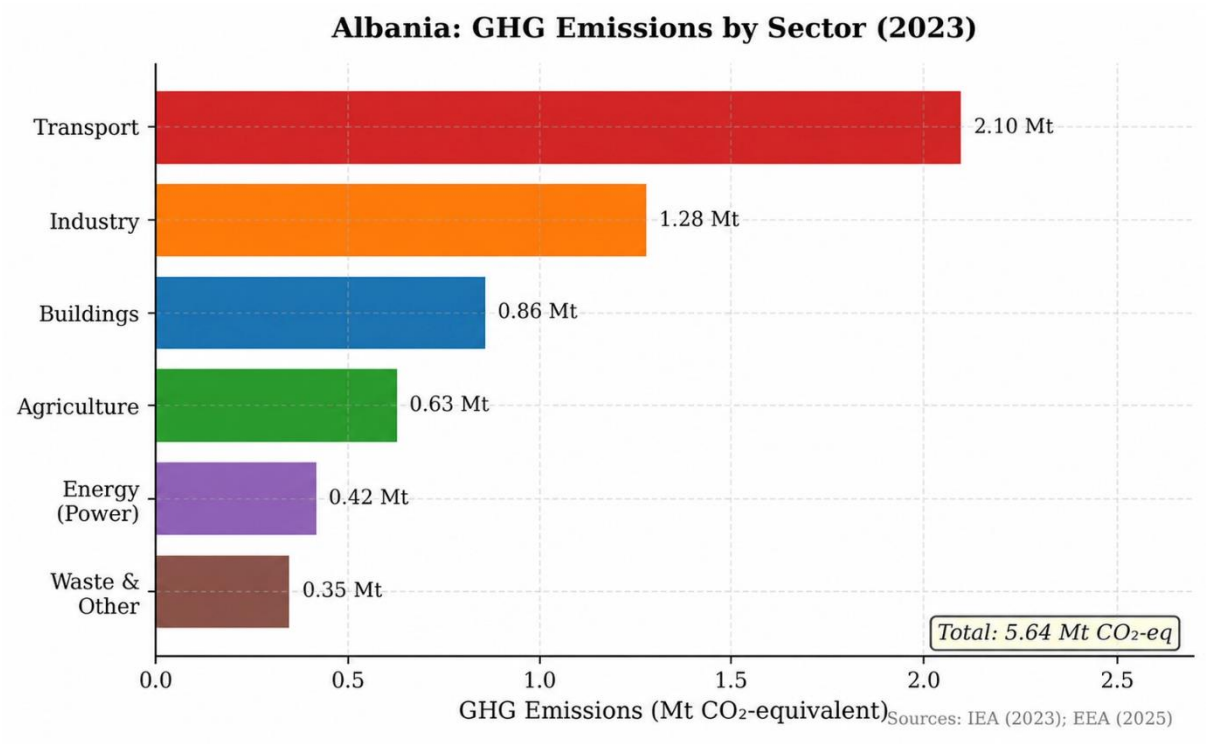


Figure 1. Albania: GHG Emissions by Sector (2023).

*Data from IEA (2023) and EEA (2025). Values in Mt CO_2-equivalent.

4.3 Waste Management and the Circular Economy Transition

Albania's transition to a circular economy is constrained by significant infrastructure inefficiencies in waste management. In 2022, the country generated over 1.2 million tons of municipal waste, with a per capita generation of approximately 381 kg, lower than the EU average of 513 kg, reflecting lower consumption levels (Switch to Green, 2025). Landfilling remains the predominant method of waste treatment, accounting for approximately 78.5% of municipal waste, while the recycling rate stands at a modest 18.9% (EEA, 2025; Eurostat, 2022). This is in sharp contrast to the EU-27 average recycling rate of 49.0%.

The low circular material use rate of 4.2%, compared with the EU's current rate of 11.8% and the 2030 target of 24%, indicates a marked reliance on virgin raw materials (OECD, 2024a). In Albania, waste composition is dominated by organic matter (58.1% of municipal waste in 2022), followed by plastics (9.2%), paper (8.9%), and textiles (5%), highlighting significant potential for composting and organic waste valorization initiatives (Switch to Green, 2025).

A particularly concerning finding is that approximately 73% of the total waste generated is discharged untreated into the Mediterranean basin, including about 20 kg of plastic per person per year (Switch to Green, 2025). This not only poses a significant environmental and public health risk but also represents a direct loss of potentially valuable secondary materials.

Figure 2 provides a comparative overview of key circular economy indicators between Albania and the EU-27 average, illustrating the magnitude of the alignment gap across multiple dimensions.

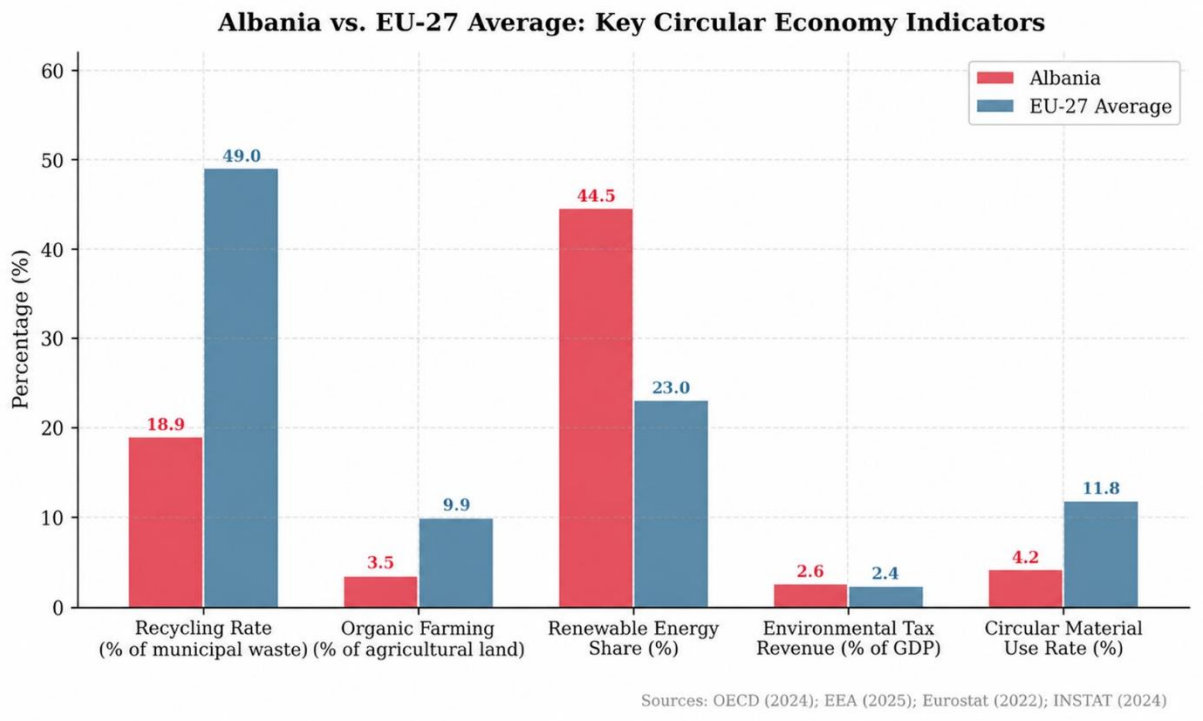


Figure 2. Albania vs. EU-27 Average: Key Circular Economy Indicators.

**Sources:* OECD (2024a); EEA (2025); Eurostat (2022); INSTAT (2024).

Despite these challenges, Albania has made notable progress in establishing a policy framework for the circular economy transition. The Ministry of Tourism and Environment has established a dedicated Directorate for Circular Economy, and the OECD (2024a) has developed a comprehensive roadmap that identifies priority areas for reform. The 2025 Integrated Waste Management Law (Law No. 57/2025) is a landmark legislative achievement, introducing the waste hierarchy, the National Waste Management Agency (AKEM), and strict rules governing transboundary waste movement (CEE Legal Matters, 2025).

Figure 3 illustrates the clear contrast in waste treatment methods between Albania and the EU-27 average.

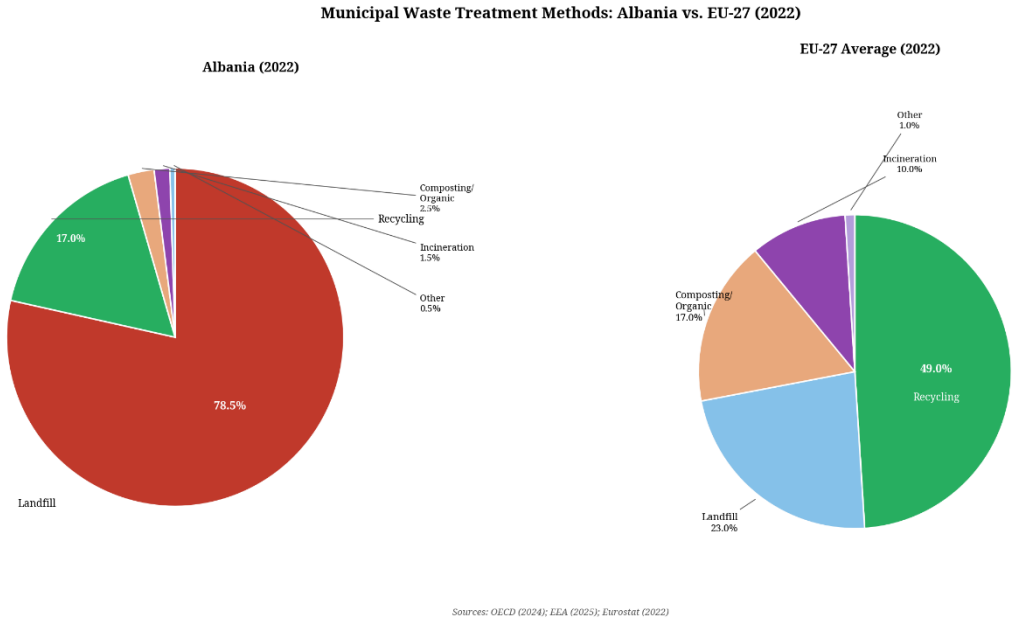


Figure 3. Municipal Waste Treatment Methods: Albania vs. EU-27 (2022).

Sources: OECD (2024a); EEA (2025); Eurostat (2022).

4.4 Environmental Taxation and Carbon Pricing

Albania introduced a carbon tax in 2008, applying it to various fossil fuels across sectors, including electricity and heat, industry, transport, buildings, and agriculture and forestry (Climate Policy Database, 2024). The tax rate is set at ALL 1,255.20 (approximately USD 13.11 per ton of CO_2-equivalent), placing it among the lowest carbon prices globally among countries with explicit carbon pricing mechanisms.

The application of this tax has been uneven. Transportation fuels (diesel and gasoline) are taxed at higher rates than fossil fuels such as coal, natural gas, and kerosene, both domestically and relative to regional peers (World Bank, 2025a). This creates a perverse incentive structure in which the most carbon-intensive industrial fuels are least penalized, undermining the tax's environmental effectiveness.

In 2024, environmental taxes accounted for 2.63% of Albania's GDP, slightly above the EU average of approximately 2.40%, marking an increase of 0.08 percentage points from the previous year (INSTAT, 2024). However, this revenue is primarily derived from energy and transport taxes rather than from a

comprehensive carbon pricing mechanism. Figure 4 illustrates the trend in environmental tax revenues from 2010 to 2024.

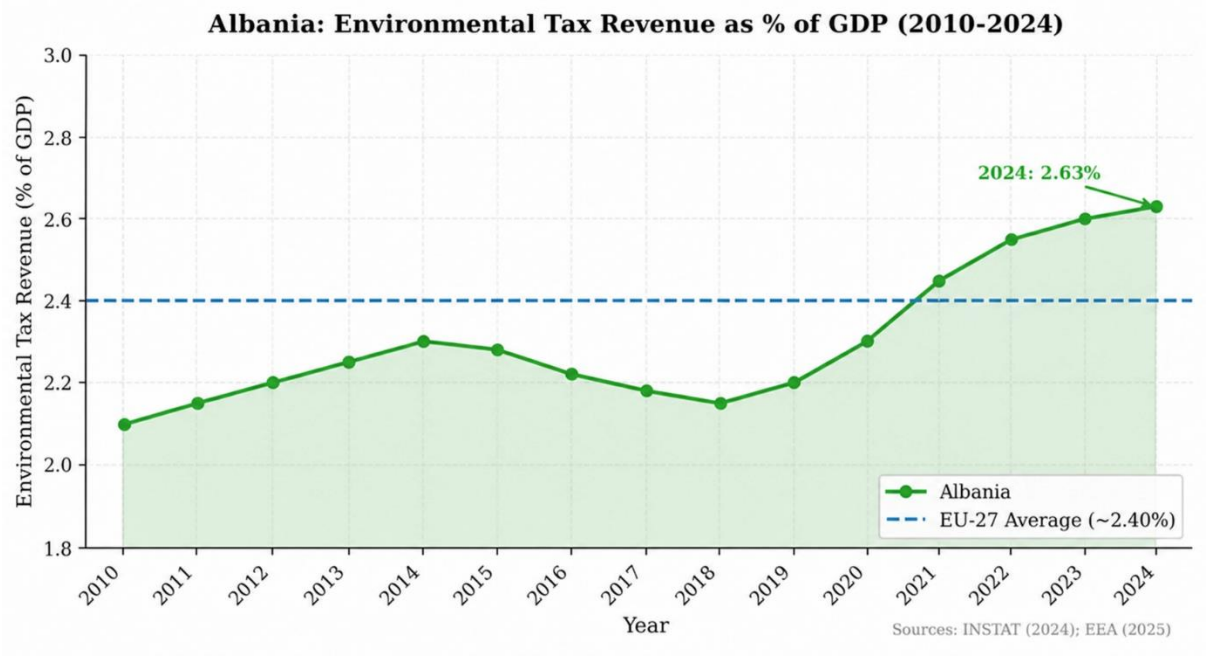


Figure 4. Albania: Environmental Tax Revenue as % of GDP (2010–2024).

Sources: INSTAT (2024); EEA (2025).

Recognizing the need to align with international climate commitments and the EU's regulatory framework, the Government of Albania (GoA) recently enacted a phased reform of the Carbon Tax on Coal (CToC). According to the World Bank's (2025a) analysis using the Climate Policy Assessment Tool (CPAT), the reform is expected to reduce GHG emissions by 8.6% relative to the business-as-usual scenario by 2030, equivalent to approximately 75% of Albania's Paris Agreement commitment, and to raise revenues of approximately 0.16–0.31% of GDP. Importantly, the analysis finds that the reform can be implemented without a detrimental impact on real GDP growth or household consumption inequality.

Table 2 summarizes the key parameters of the GoA's Carbon Tax on Coal reform trajectory.

Year	CToC Rate (ALL/GJ)	CToC Rate (USD/tCO_2-eq)	Estimated Revenue (% of GDP)	Estimated GHG Reduction (% vs. BAU)
2024	Baseline	~$10.50	0.10%	2.1%
2025	+15%	~$12.00	0.13%	4.3%
2026	+15%	~$14.00	0.16%	5.8%
2027	+15%	~$16.50	0.20%	6.9%
2028	+15%	~$19.00	0.24%	7.5%
2029	+15%	~$22.00	0.27%	8.1%
2030	+15%	~$25.00	0.31%	8.6%

Note. Estimates based on World Bank CPAT modeling. Adapted from World Bank (2025a).

However, as noted earlier, coal is not the primary source of pollution in Albania. Tax collections suggest that diesel and gasoline. Greater government willingness is needed, and work is needed to reduce carbon emissions from diesel and gasoline. Surprisingly, a well-expected result has come from the increased use of electric vehicles by Albanians. However, the government has played its favorable role by exempting from taxation the import of new EVs

5. EU Circular Economy Targets and the CBAM Framework

5.1 The EU Circular Economy Action Plan and Forthcoming Legislation

The EU's Circular Economy Action Plan (CEAP), adopted in March 2020 as a key pillar of the European Green Deal, sets ambitious targets for moving toward a resource-efficient, low-waste, and climate-neutral economy (European Commission, 2020a). CEAP launches an extensive set of legislative and non-legislative measures targeting the entire life cycle of products, from design and production to consumption and end-of-life management.

Key legislative achievements under the CEAP include the Ecodesign for Sustainable Products Regulation (ESPR), which entered into force in July 2024 and sets design requirements to improve durability, reparability, and recyclability; the Directive on the Right to Repair (July 2024); the Packaging and Packaging Waste Regulation (PPWR), which entered into force in February 2025; and the Batteries Regulation (July 2023) (European Commission, 2025b; Circle Economy, 2026).

The forthcoming Circular Economy Act, expected to be formally proposed in Q4 2026, marks the next major step in the EU's circular economy strategy. It aims to establish a single market for secondary raw materials, increase the supply of high-quality recycled materials, and stimulate demand for these materials across the EU (European Commission, 2025b). The EU's stated ambition is to double its circularity rate from the current 11.8% to 24% by 2030, a target embedded in the Clean Industrial Deal (European Commission, 2025b).

Table 3 provides an overview of the key EU circular economy targets and their relevance to Albania's policy agenda.

Table 3. Key EU circular economy targets and their relevance to Albania

EU Target / Policy	Target Year	Current EU Status	Relevance to Albania
Circularity Rate	24% by 2030	~11.8% (2023)	Albania at 4.2%; major gap
Municipal Waste Recycling	>50% by 2030	~49% (2022)	Albania at 18.9%; critical gap
Organic Farming Coverage	25% by 2030	~9.9% (2022)	Albania at 3.5%; significant gap
Renewable Energy Share	87% by 2030	~23% (2022)	Albania at 44.5%; ahead of EU avg.
GHG Reduction vs. 1990	-55% by 2030	-32% (2022 est.)	Albania NDC: -20.9% vs. BAU
Circular Economy Act	Q4 2026 proposal	Consultation phase	Accession alignment required
ESPR (Ecodesign)	In force July 2024	Implementation phase	Acquis adoption required
CBAM (Full Phase)	January 2026	Operational	Direct fiscal impact on exporters

Note. Sources: European Commission (2025b); EEA (2025); OECD (2024a); Circle Economy (2026).

5.2 The EU ETS and Carbon Price Dynamics

The EU Emissions Trading System (EU ETS) is the cornerstone of the EU's climate policy, covering approximately 40% of EU GHG emissions from the power sector, energy-intensive industries, and intra-EU aviation (ICAP, 2024). Following the 2023 reform under the "Fit for 55" package, the EU ETS has been substantially strengthened, with a higher annual reduction factor and the introduction of a new ETS for buildings and road transport (ETS 2) starting in 2027.

EU ETS carbon prices have been volatile but have trended upward overall. After peaking at approximately €87/tCO₂ in early 2023, prices fell to about €65/tCO₂ in 2024 before recovering. Projections from Enerdata (2024) and Homaio (2026) suggest that prices could reach €100–130/tCO₂ by 2030, driven by a tighter cap and the phase-out of free allowances. This trajectory is illustrated in Figure 5.

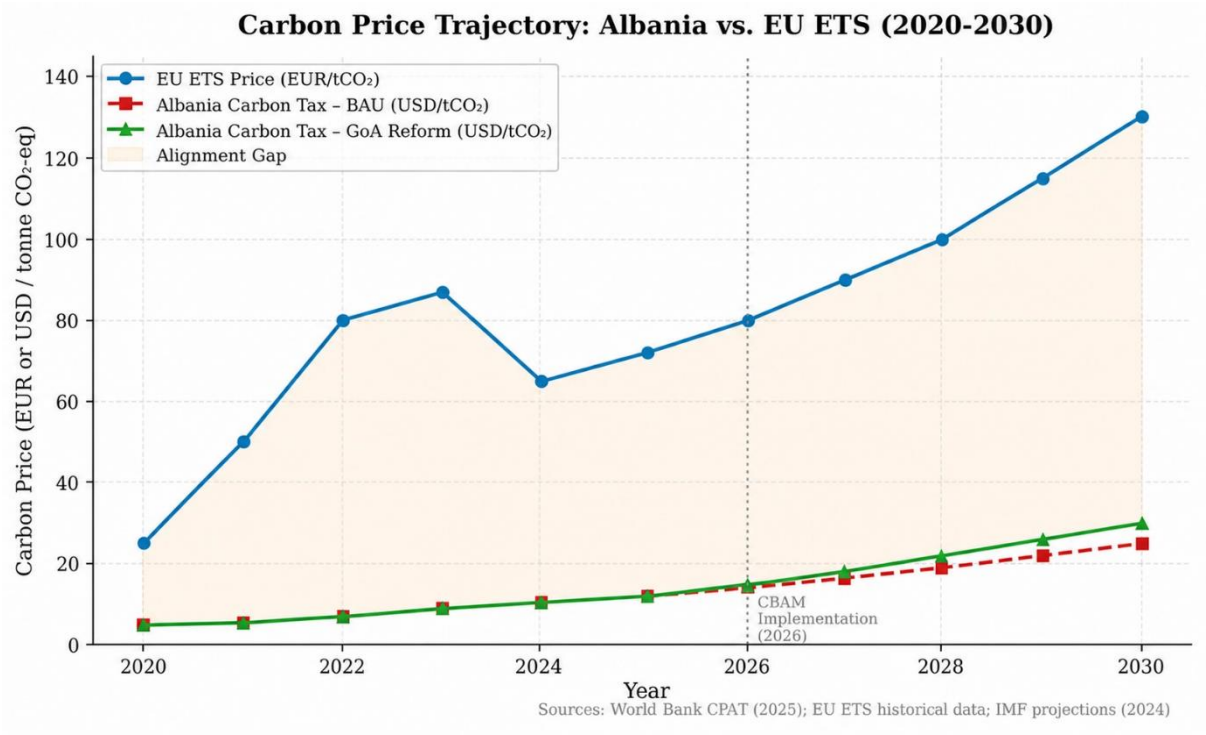


Figure 5. Carbon Price Trajectory: Albania vs. EU ETS (2020–2030).

Sources: World Bank CPAT (2025a); EU ETS historical data; IMF projections (2024); Homaio (2026).

5.3 The CBAM: Mechanics and Implications for Albania

The CBAM, established by Regulation (EU) 2023/956 and fully operational from January 2026, requires importers of six carbon-intensive goods (cement, iron and steel, aluminum, fertilizers, electricity, and hydrogen) to purchase CBAM certificates equivalent to the carbon price they would have paid under the EU ETS (European Commission, 2023a). The price of these certificates is based on the average weekly auction price of EU ETS allowances. Crucially, if a non-EU producer has already paid a domestic carbon price for embedded emissions, that amount can be deducted from the CBAM obligation, creating a direct financial incentive for non-EU countries to implement or strengthen their own carbon pricing mechanisms.

When CBAM takes effect in 2026, the EU will calculate the "Carbon Gap" (which is significant for Albania) and will trigger a high penalty tariff at the European Union border. Having a low domestic carbon tax is only an advantage if the merchant sells strictly within your own borders. As shown in

Figure 7, Albania and Kosovo face relatively lower CBAM exposure (CBAM-related exports totaling approximately 1.2% and 1.0% of GDP, respectively), whereas Bosnia and Herzegovina, Montenegro, North Macedonia, and Serbia face more significant impacts (4–6% of GDP) (Berlin Process, 2024; Germanwatch, 2023).

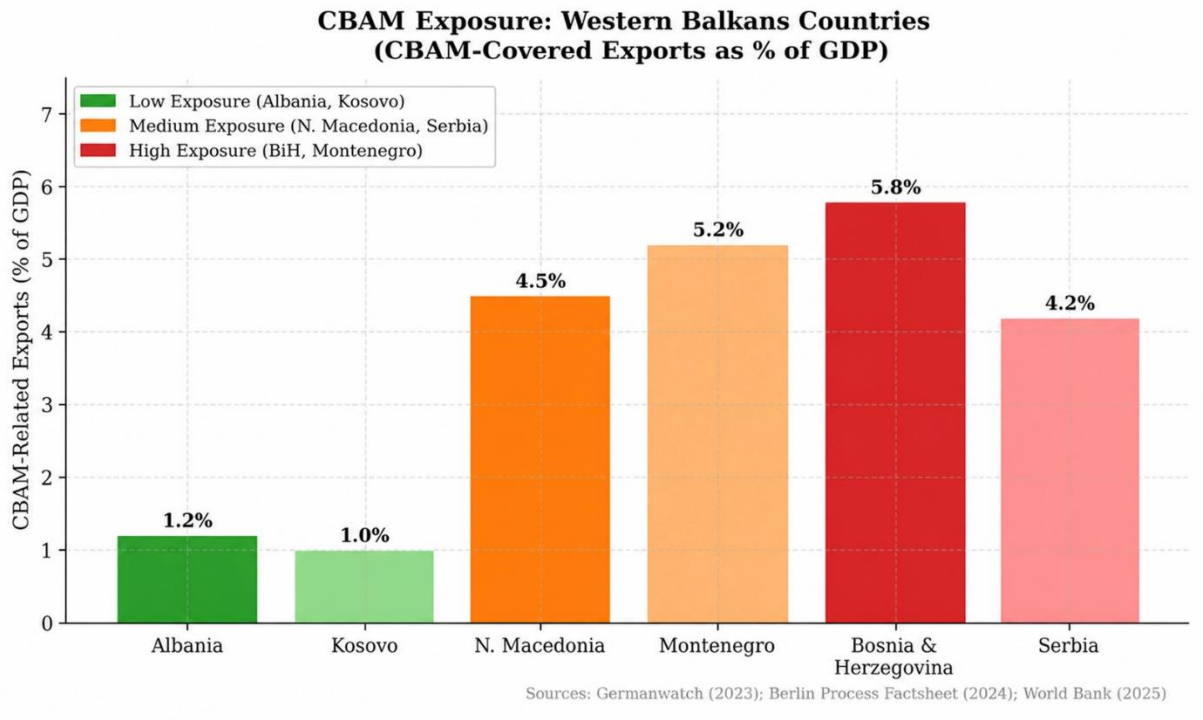


Figure 6. CBAM Exposure: Western Balkans Countries (CBAM-Covered Exports as % of GDP).

* *Sources*: Germanwatch (2023); Berlin Process Factsheet (2024); World Bank (2025a).

Albania's relatively low CBAM exposure stems largely from its hydropower-based electricity sector, which has low carbon intensity. However, it is expected to damage Albania's exports of iron and cement. According to the World Bank's Relative CBAM Exposure Index, Albania may even gain competitiveness relative to the average EU producer in its exports (Berlin Process, 2024). However, this advantage depends on maintaining and expanding the share of renewable energy in the electricity mix and on keeping the carbon intensity of industrial production low. The World Bank (2025a) notes that Albania's CBAM-related exports to the EU have increased in recent years, indicating growing exposure.

6. Opportunities for Alignment

Aligning Albania's carbon tax with EU circular economy targets offers several strategic advantages, creating a synergistic policy framework that can advance environmental, economic, and geopolitical objectives simultaneously. Figure 5 illustrates the conceptual framework for this alignment.

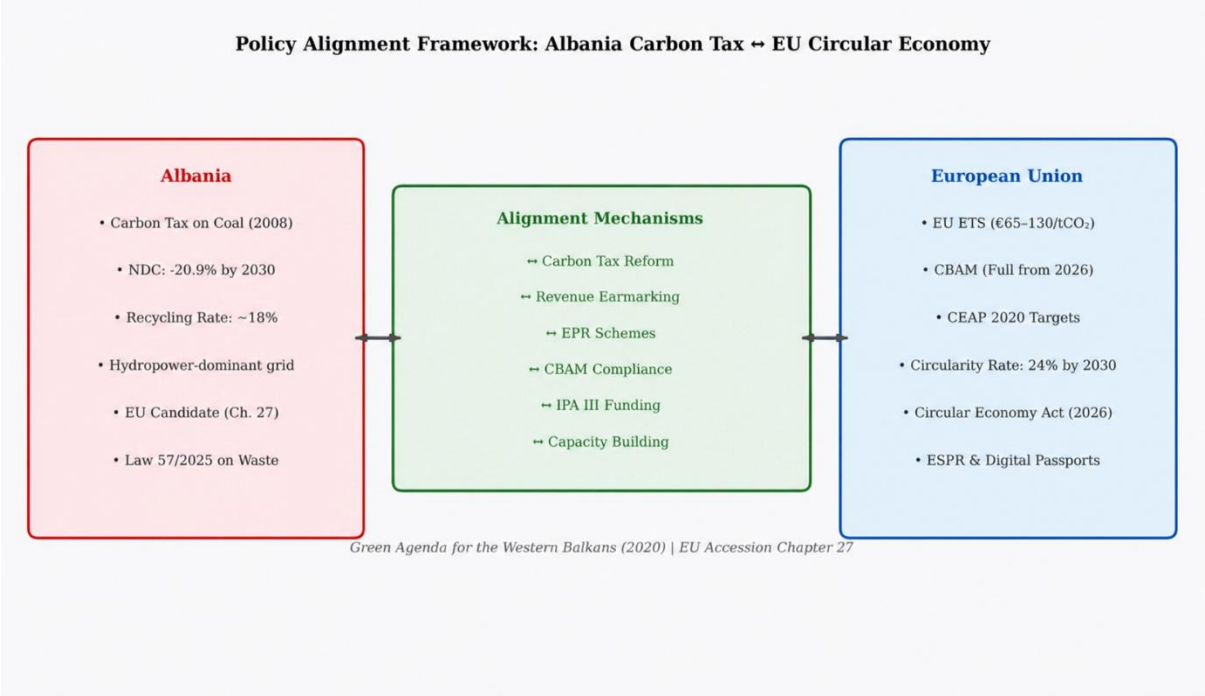


Figure 7. Policy Alignment Framework: Albania Carbon Tax ↔ EU Circular Economy.

*Author own elaboration based on research findings.

6.1 Economic Modernization and Competitiveness

The most pressing economic opportunity lies in the CBAM's incentive structure. By strengthening the domestic carbon tax and aligning it more closely with the EU ETS price, Albania can reduce the net CBAM levy paid by its exporters. The resulting domestic revenues can then be strategically earmarked to fund the transition to a circular economy, creating a positive feedback loop between fiscal reform and industrial modernization.

The Joint Research Centre (2024) emphasizes that transitioning to a circular economy reduces waste, improves resource efficiency, and generates cost savings and new business opportunities. For Albania's manufacturing sector, particularly textiles, footwear, and construction, adopting circular practices such as material reuse, take-back schemes, and remanufacturing can reduce production costs, lower reliance on volatile global commodity markets, and enhance the appeal of Albanian products in EU markets that increasingly value sustainability credentials.

The OECD (2024a) estimates that Albania's private recycling sector has a combined processing capacity of about 500,000 tons per year but operates at only 25% of capacity because of a shortage of raw materials (i.e., sorted recyclables). A higher carbon tax, combined with EPR schemes that mandate waste separation at the source, could unlock this latent capacity, creating jobs and economic value from materials that are currently landfilled.

6.2 Acceleration of EU Accession

Harmonizing environmental taxation and waste management policies directly supports Albania's progress in EU accession negotiations, particularly in Chapter 27 (Environment and Climate Change). The EU accession process is increasingly conditioned on demonstrable progress in environmental governance, and the opening of the environment cluster in September 2025 marks a critical juncture (European Commission, 2025a).

Demonstrating proactive compliance with the Green Agenda for the Western Balkans and the CBAM requirements signals a strong institutional commitment and may unlock additional financial support through the EU's Instrument for Pre-Accession Assistance (IPA III), which provides €9 billion in grants and €20 billion in guarantees for the Western Balkans (Joint Research Center, 2024). The EU's Growth

Plan for the Western Balkans, adopted in 2023, further establishes a pathway to early access to the EU single market, contingent on progress in reforms.

6.3 Synergies in Waste Management and Resource Efficiency

A higher carbon price inherently penalizes the extraction and refining of virgin materials, making secondary (recycled) materials more economically viable. This factor directly supports the objectives of the 2025 Integrated Waste Management Law and the OECD's Circular Economy Roadmap for Albania. By coupling the carbon tax with EPR schemes, Albania can incentivize manufacturers to design products for durability and recyclability, thereby reducing the volume of waste sent to landfills.

The GIZ (2025) baseline study on the circular economy in Albania identifies reusable packaging systems as a particularly promising area, noting that implementing deposit-return schemes for beverage containers could significantly increase recycling rates in the short term. When combined with a carbon tax signal, such schemes create a coherent economic framework that rewards circular behavior at both the producer and consumer levels.

6.4 Revenue Generation and Fiscal Sustainability

The World Bank (2025a) projects that the GoA's Carbon Tax on Coal reform will generate approximately 0.16–0.31% of GDP in revenue by 2030. If a more ambitious harmonization with the EU ETS price were pursued, revenues could rise to approximately 0.18–0.35% of GDP. These revenues represent a significant fiscal resource that can be deployed to address Albania's most pressing development challenges, including infrastructure investment, social protection, and education, while advancing the green transition.

The IMF (2024) and UNDP (2025) both emphasize that the social acceptability of carbon taxes is significantly enhanced when revenues are recycled transparently and visibly to citizens, either through direct transfers, reductions in other taxes (e.g., labor taxes), or investments in public services. A well-designed revenue-recycling mechanism can therefore transform a potentially regressive carbon tax into a progressive fiscal instrument.

7. Obstacles and Challenges

Despite clear opportunities, several structural obstacles impede the seamless alignment of Albania's carbon tax with the EU's circular economy targets. Figure 8 presents a radar chart that compares the relative strengths of opportunities and obstacles across key dimensions.

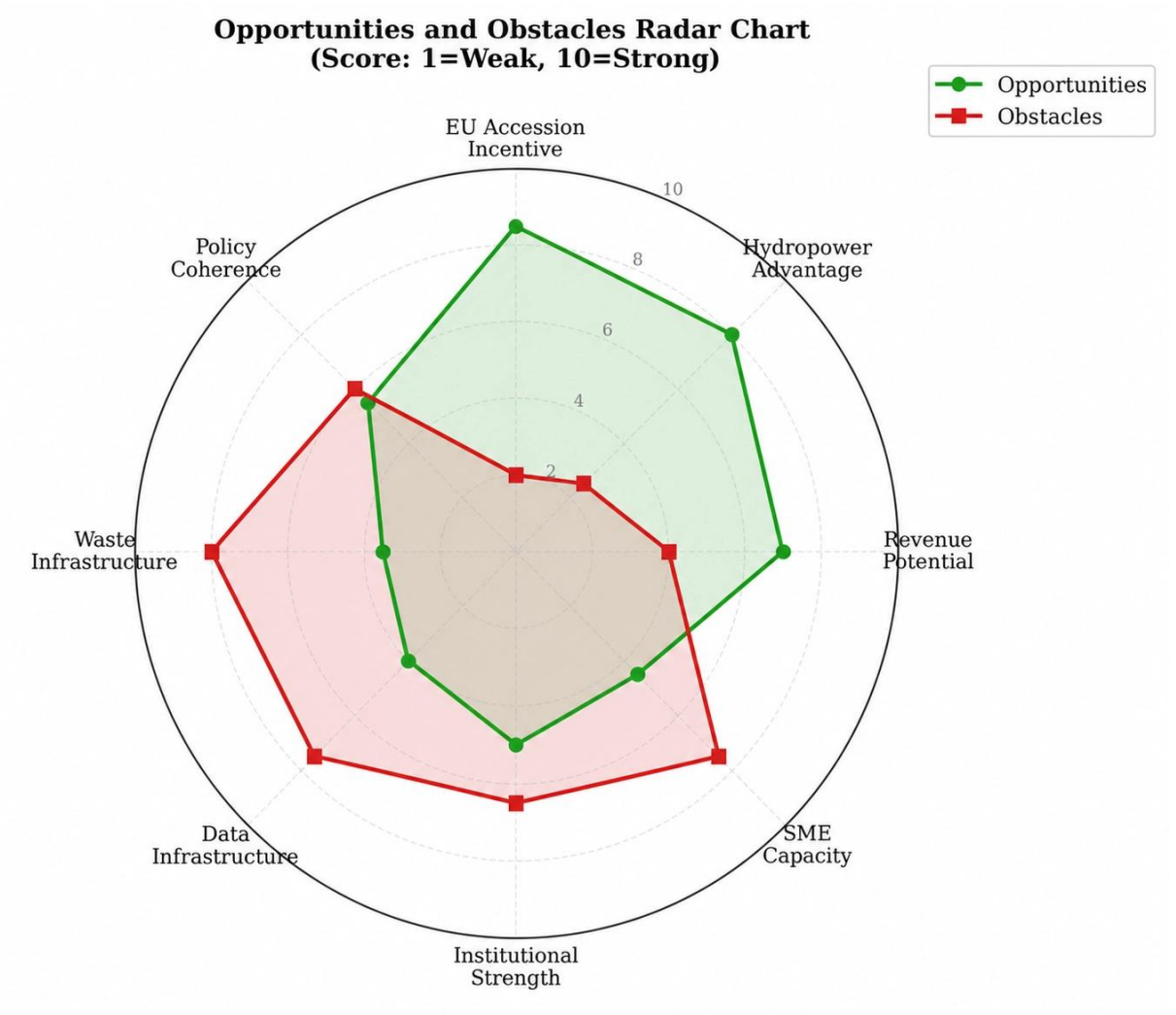


Figure 8. Opportunities and Obstacles Radar Chart (Score: 1=Weak, 10=Strong).

*Author own assessment based on research findings.

7.1 The Carbon Price Gap

The most fundamental obstacle is the significant gap between Albania's current carbon tax trajectory and the EU ETS price. As shown in Figure 5, even with the recent GoA reforms, the domestic carbon price is projected to reach only about \$25–30/tCO_2 by 2030, compared with an estimated €100–130/tCO_2 in the EU ETS (World Bank, 2025a; Homaio, 2026). This gap means Albanian exporters will continue to face CBAM levies for the foreseeable future, and the domestic price signal will remain insufficient to drive the deep structural changes required for a circular-economy transition.

Bridging this gap too quickly, however, carries its own risks. A sudden, large increase in carbon prices could impose high costs on energy-intensive industries, potentially leading to carbon leakage (the relocation of production to countries with lower carbon costs) or industrial contraction. The World Bank (2025a) analysis suggests that a trajectory aligned with the EU ETS price would reduce GHG emissions by an additional 0.9 percentage points relative to the GoA reform scenario, but would also impose higher economic costs, particularly on coal-dependent industries.

7.2 Institutional and Infrastructure Deficits

Albania's waste management infrastructure remains severely underdeveloped, particularly outside major city centers. The reliance on informal waste pickers for recycling, who account for most of the country's recycling activity, and the lack of advanced sorting and processing facilities limit the capacity to process secondary materials efficiently and to meet the quality standards required by EU markets (GFA Consulting Group, 2024).

Furthermore, institutional capacity for monitoring, reporting, and verification (MRV) of emissions and circularity metrics is insufficient to meet stringent EU standards. The EEA (2025) notes that Albania lacks data and faces difficulties preparing comprehensive ecological evaluations. Without robust MRV systems, it is impossible to accurately assess the impact of carbon tax reforms, comply with CBAM reporting requirements, or demonstrate progress toward NDC and circular economy targets to the EU and international partners.

The 2025 Integrated Waste Management Law addresses some of these institutional gaps by establishing the National Waste Management Agency (AKEM) and requiring environmental permits for waste management activities. However, effective implementation of this law will require substantial investment in human resources, digital infrastructure, and enforcement capacity, all of which take time to develop.

7.3 Economic Vulnerabilities and Energy Poverty

Raising the carbon tax raises legitimate concerns about energy poverty and the fiscal burden on SMEs, which account for 82.1% of employment in Albania (EEA, 2025). Without adequate social safety nets and targeted subsidies, higher energy and resource costs could disproportionately affect marginalized populations, particularly in rural areas where energy poverty is already widespread.

The Peace Research Institute Frankfurt (PRIF, 2026) warns that the EU's new climate policy mechanisms, including the CBAM, could worsen energy affordability pressures in the Western Balkans unless accompanied by adequate support measures. The EEA (2025) notes that although Albania's social protection strategy 2024–2030 aims to combat energy poverty through financial schemes and renewable energy promotion, only 80.2% of eligible individuals accessed these schemes in 2021, indicating implementation gaps.

7.4 Data and Monitoring Limitations

A cross-cutting challenge is the limited availability and quality of environmental and economic data in Albania. The country struggles to accurately track GHG emissions, waste flows, and material consumption, undermining the evidence base for policy design and evaluation. This data gap also complicates CBAM compliance, as Albanian exporters must accurately report the embedded carbon content of their products to EU importers.

Table 4 summarizes the key obstacles and their associated policy implications.

Obstacle	**Severity**	**Key Policy Implication**
Carbon Price Gap (Albania vs. EU ETS)	Very High	Phased, legally-binding price escalation path
Waste Infrastructure Deficit	High	Targeted public investment and PPP frameworks
Institutional/MRV Capacity	High	Digital infrastructure and capacity building
Energy Poverty Risk	Medium-High	Revenue recycling and social protection
SME Competitiveness	Medium	Targeted subsidies and circular business support
Data Availability	Medium	National statistics harmonization with EU standards
Political Economy of Reform	Medium	Stakeholder engagement and public communication

Note. Severity assessed by the author based on literature review and data analysis.

8. Policy Recommendations

To address these challenges and capitalize on the identified opportunities, this paper proposes five interconnected policy recommendations grounded in evidence.

8.1 Gradual and Predictable Carbon Price Alignment

Albania should establish a legally binding, long-term trajectory for its carbon tax, aiming to converge more closely with the EU ETS price by 2030. This trajectory should be embedded in a medium-term revenue strategy to provide the predictability industries need to plan investments in clean energy technologies. The World Bank (2025a) recommends that any future coordination with the EU ETS price be accompanied by a comprehensive impact assessment, particularly regarding distributional effects and competitiveness. The phased approach used in the Carbon Tax on Coal reform provides a useful template that could be extended to other fossil fuels, particularly natural gas and kerosene.

8.2 Strategic Revenue Earmarking Through a Green Transition Fund

Revenues from the carbon tax should be ring-fenced in a dedicated "Green Transition Fund." The fund should be governed transparently, with clear allocation criteria, and should prioritize investments in circular-economy infrastructure (e.g., advanced sorting and recycling facilities, composting plants); grants and low-interest loans for SMEs adopting circular business models; social protection programs to reduce energy poverty (e.g., direct cash transfers to vulnerable households, energy-efficiency subsidies for low-income homes); and research and development in green technologies. The UNDP (2025) and IMF (2024) emphasize that this type of revenue recycling is fundamental to maintaining the social acceptability and political sustainability of carbon pricing reforms.

8.3 Operationalize the 2025 Integrated Waste Management Law

The government must accelerate the full implementation of Law No. 57/2025, particularly the establishment and operationalization of the National Waste Management Agency (AKEM), the enforcement of EPR schemes across key sectors (packaging, electronics, textiles, and construction), the development of waste management zones and inter-municipal cooperation agreements, and the establishment of a robust permitting and licensing system for waste management operators. The OECD (2024a) recommends that EPR schemes be designed with clear recycling targets, transparent fee

structures, and strong enforcement mechanisms to ensure that producers genuinely internalize the end-of-life costs of their products.

8.4 Enhance MRV Capabilities and Data Infrastructure

Investing in digital infrastructure and capacity-building for environmental monitoring is vital for effective domestic policy and CBAM compliance. Albania ought to prioritize developing a national GHG emissions inventory system that meets UNFCCC and EU standards; a waste-tracking and reporting system aligned with Eurostat methodologies; digital tools for exporters to report under CBAM; and a circular-economy monitoring framework based on the indicators proposed in the OECD (2024a) roadmap. Collaboration with EU institutions, particularly the EEA and Eurostat, through the European Environment Information and Observation Network (Eionet), can provide technical assistance and capacity-building support.

8.5 Foster Regional Cooperation and Leverage EU Financial Support

Albania should actively participate in Western Balkans regional initiatives to develop a coordinated approach to carbon pricing and circular-economy markets. A regional approach to carbon pricing, as advocated by the Energy Community, could reduce administrative costs, improve market liquidity, and create a larger, more attractive market for green investments (Berlin Process, 2024). Albania should also maximize its use of IPA III funds and the EU's Economic and Investment Plan to finance green infrastructure projects, leveraging the EU's €9 billion in grants and €20 billion in guarantees available to the Western Balkans.

9. Conclusion

Aligning Albania's carbon tax with the EU's circular economy targets is not merely a regulatory exercise; it is essential to sustainable economic development and European integration. This paper demonstrates that the nexus between carbon pricing and the circular economy offers Albania a coherent, mutually reinforcing policy framework to achieve its climate commitments, enhance economic competitiveness, and accelerate its EU accession trajectory.

The analysis shows that Albania faces significant structural obstacles, most notably the large carbon price gap, institutional and infrastructure deficits, and the risk of regressive economic impacts. The country's distinctive energy profile, with its near-total reliance on hydropower, provides a competitive advantage under the CBAM and positions Albania favorably relative to its regional peers. The recent legislative progress, including the 2025 Integrated Waste Management Law and the phased Carbon Tax on Coal reform, demonstrates a political commitment to reform.

The five policy recommendations advanced in this paper, including gradual carbon price alignment, strategic revenue earmarking, operationalization of the waste management law, enhancement of MRV capabilities, and regional cooperation, form an integrated policy package that can transform the regulatory forces of the EU's Green Deal into a driver of Albania's green economic transformation. The successful execution of this agreement will require sustained political will, robust institutional capacity, active collaboration with the private sector and civil society, and persistent engagement with EU institutions and international financial organizations.

This study contributes to the academic literature by offering a focused, evidence-based analysis of the carbon tax–circular economy nexus in the specific context of an EU candidate country, addressing a gap in the literature that often treats the Western Balkans as a homogeneous region. Future research should examine the distributional impacts of carbon tax reform in Albania using household survey data; assess the economic feasibility of specific circular-economy business models across key sectors (tourism, textiles, construction); and evaluate the effectiveness of EPR schemes once implemented.

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THE INTERNAL OTHER: IMAGOLOGY AND THE CONSTRUCTION OF SELF-IMAGE IN SOCIALIST REALISM

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ABSTRACT

This paper examines the way in which, in the literature and art of socialist realism, the figure of the "Other" is constructed not only as an ethnic or cultural outsider, but also as an internal figure who belongs to the same society, yet is represented as a deviation from the ideological norm. In this context, the "internal Other" appears as the kulak, the saboteur, the cleric, the merchant, the Ballist, the Zogist, or the critical intellectual — figures placed in opposition to the socialist model of the "new man."

Drawing on approaches from imagology, discourse theory, and ideological analysis, the paper aims to show that the representation of this "Other" does not merely serve to portray an opponent, but rather to strengthen the collective self-image of socialist society. Through the opposition between the ideological "We" and stigmatized figures, socialist realism constructs a desired, purified identity controlled by official ideology.

The analysis focuses on how narrative and visual discourse in selected works of Albanian literature and film from the socialist period uses this figure to legitimize power, discipline the individual, and define the boundaries of collective belonging. In this way, the paper argues that the "internal Other" is not simply a negative character, but an ideological mechanism through which socialist society constructs and controls its image of itself.

Keywords: imagology, self-image, hetero-image, internal Other, socialist realism, ideological discourse, collective identity.

1. Introduction

Throughout the history of world literature, the figure of the "Other" has been a recurring element in ethnic, sociocultural, and ideological representations. Across diverse literary narratives, the Other has appeared at times as the foreigner, the enemy, or the exotic figure, and at other times as a form of internal difference—an alterity that exists within the boundaries of the self or the community. In this sense, the figure of the Other functions not merely as a narrative character, but as an ideological and cultural construct through which individual, collective, and national identities are articulated and negotiated.

In nineteenth-century French literature, for instance, Oriental characters—Arab, Turkish, or Persian—are frequently depicted as exotic and sensual, yet also irrational and backward. A canonical example of this representational logic can be found in Gustave Flaubert's Salammbô (1862). Similarly, in British literature, representations of Indians and Africans in the works of authors such as Rudyard Kipling or Joseph Conrad—most notably in Heart of Darkness—reveal a profound cultural confrontation structured by a symbolic order in which the Other is positioned as inferior and underdeveloped. Within the Russian literary context of the nineteenth and twentieth centuries, French characters are often portrayed as decadent and superficial, as in Leo Tolstoy's War and Peace, while Germans frequently appear as aggressors or cold, bureaucratic figures.

Such representations of the Other are particularly prominent in politically engaged literature, where alterity is mobilized to articulate ideological agendas, stimulate national sentiment, or legitimize forms of cultural and political hegemony. As Joep Leerssen (2007) observes, "Images of others are internal

projections that serve to shape our collective identity; they reflect our fears and desires more than they describe the other realistically" (p. 24). Leerssen therefore argues for a contextualized imagology that attends not only to the content of such images, but also to the discursive structures that produce and sustain them.

A similar argument is advanced by Edward Said (1978), who contends that Western representations of the Orient reveal far more about Western self-perception than about the Orient itself. In Orientalism, Said demonstrates how discourses of otherness function as instruments for legitimizing power, constructing a sense of superiority, and articulating a coherent and "pure" self-image. This process of othering is evident across numerous national literary traditions and has often served as a mirror through which collective identity is defined and stabilized.

This article investigates the relationship between self-image (auto-image) and hetero-image in Albanian socialist realist literature and cinema, conceptualizing this relationship as a dynamic and interdependent process rather than a unilateral one. Central to the analysis is the manner in which the figure of the Other is frequently constructed in order to reinforce the image of a collective Self, positioned in sharp contrast to ideologically sanctioned positive characters. Through this oppositional logic, the self-image becomes increasingly idealized, while the hetero-image functions as a projection of deviation, threat, or exclusion.

More specifically, the analysis focuses on a selection of Albanian films from the 1970s, including *Duel i Heshtur* (lit. *Silent Duel*, 1976), *Përballimi* (lit. *The Confrontation*, 1976), *Njeriu me Top* (lit. *The Man with the Cannon*, 1977), and *Ballë për Ballë* (lit. *Face to Face*, 1979). These works constitute a corpus in which representations of the Other are often constructed within national boundaries, producing what may be described as an "excluded internal Other." Through the denigration and marginalization of this figure, the films elevate the image of the honest citizen, the patriot, and the ideological model of the "new man."

The central hypothesis of this article is that collective self-image in socialist realist art is constructed through a strong oppositional relationship with the hetero-image, whereby the latter embodies deviation from ideological norms while the former corresponds to the idealized figure promoted by the regime. The more demonized or marginalized the Other appears, the more the collective "We" is elevated, normalized, and glorified.

2. Theoretical Framework

Within imagological studies, the concept of the "Other" is not limited to representations between nations or cultures, but may also emerge as a figure of internal division—a process closely related to the destabilization of fixed meaning and authority within the text. Roland Barthes' critique of authorial centrality is particularly relevant in this context. As he argues, "the text is a tissue of quotations drawn from the innumerable centres of culture," and the author can no longer be regarded as the primary source of meaning (Barthes, 1977, p. 146). This perspective allows for the emergence of an "Other" not solely through national or cultural difference, but also through interpretation itself.

Julia Kristeva (1982) extends this line of thought through her concept of the *abject*, a figure that unsettles internal identity and places the subject at the boundaries of the self. For Kristeva, "the abject is not an object of desire, but that which comes from within to threaten the integrity of the self" (p. 4). The abject thus functions as an internalized form of otherness, revealing how alterity may operate from within rather than from an external position.

Edward Said's analysis in *Orientalism* (1978) further demonstrates how representations of the Other serve as instruments for the legitimation of power. As Said famously notes, the Orient was constructed as an imaginary "Other" in order to define the West as rational, modern, and civilized (pp. 1–2). While Said's argument primarily addresses intercultural dynamics, the same mechanism can operate internally, when specific social groups are stigmatized in order to affirm the values and authority of a dominant group.

In this regard, Jean-Marc Moura (1999) emphasizes that imagological representation is not confined to encounters between nations, but also encompasses processes of internal identification and exclusion. As he argues, "the Other may be a neighbour, an ideological opponent, or even a rejected version of the

self" (p. 27). Moura's approach provides a crucial theoretical bridge for analyzing forms of otherness that arise within a shared national or cultural space.

Taken together, these theoretical perspectives offer a productive framework for examining socialist realism, a context in which the construction of the "new man" was frequently accompanied by the projection of an "internal Other"—an individual or group perceived as deviating from ideological norms. Within this framework, figures such as the kulak, the merchant, the *ballist*, the *zogist*, the critical intellectual, or the cleric were systematically positioned as negative counter-images, defined in opposition to the collective identity promoted by official ideology. The stigmatization of these internal Others functioned as a central mechanism through which socialist realism sought to discipline subjectivity and consolidate a homogeneous ideological self-image.

3. Methodology

Theoretical and Analytical Approach

This study adopts an integrated theoretical and analytical approach that brings together imagology, semiotics, and discourse analysis. Imagology is employed as a field concerned with the analysis of cultural representations of the "Other"; semiotics is used to examine the ways in which symbolic figures contribute to the construction of cultural identities; and discourse analysis serves to explore the relationship between language, ideology, and representation. Combined, these approaches allow for a systematic examination of how the construct of self-image is formed through contrast with hetero-image, both in literary texts and in cinematic productions.

The primary focus of this study is the analysis of representations of the "Other" in a selection of cinematic works belonging to the same historical and political period. The aim is to observe how these representations are constructed, reiterated, or, in certain cases, challenged through artistic and ideological elements that structure the works.

Corpus Selection

The corpus of this study consists of works produced during the period of socialist realism in Albania, a historical moment in which art and literature were assigned a distinctly ideological function. The selected films and theatrical works display varied constructions of the figure of the "Other," allowing for comparative analysis across different narrative and visual forms. The corpus includes:

- *Njeriu me Top* (1977), directed by Viktor Gjika;
- *Përballimi* (1976), directed by Viktor Gjika;
- *Duel i Heshtur* (1976), directed by Dhimitër Anagnosti;
- *Ballë për Ballë* (1979), directed by Piro Milkani and Kujtim Çashku.

These works were selected on the basis of a shared criterion: all belong to an ideologically unified period and contain explicit representations of the "Other," constructed primarily as individuals or groups defined in ideological opposition to the collective "We." In some cases, such as *Ballë për Ballë*, the Other appears as a foreign figure (the Russian military officer), whereas in other works the Other emerges from within Albanian society itself, distinguished from the collective by political beliefs or by alternative moral and cultural values.

4. Justification of the Comparative and Contextual Method

A comparative approach was adopted in order to identify similarities and differences in the representation of the "Other" across different media and works, while contextual analysis is essential for understanding the relationship between the figure of the "Other" and the socio-political conditions under which these works were produced. Given that these cultural productions emerged within an ideological system that sought to educate and shape the masses through art, it is crucial to examine how the figure of the "Other" functioned not only as a means of denigrating specific individuals or social

groups, but also as a tool for constructing the profile of the "new man" and reinforcing the collective self-image of socialist society.

In this respect, the study does not limit itself to narrative structures alone, but also examines directorial choices, character construction, the use of language and symbols, and the ideological messages conveyed through these elements.

4.1. Ideological Framework and the Code of the "Other" in Socialist Realist Art

In totalitarian systems, art and literature often function in direct service of ideology, becoming instruments for shaping social consciousness and constructing collective identity. Artistic production in socialist Albania was explicitly guided by political power, which clearly articulated its expectations toward writers and artists. Enver Hoxha, the central figure of the communist dictatorship, conceived art as an integral component of the ideological struggle aimed at educating and "revolutionizing" the socialist new man. In a speech delivered in 1969, he emphasized:

"The Party assigns you the great task of carrying through to the end the struggle for the spiritual revolutionization of man, so that you, as you have done until now, may influence through your works the transformation of our new man… and let me tell you that what you produce with your hands constitutes daily nourishment for hundreds of thousands of people, for the entire Albanian people. Through your writings and works realized in various artistic forms, you strive to make the Party's correct line clear to the masses in all sectors of life, materializing this line as beautifully and as effectively as possible in music, painting, literary creation, theatrical works, and so on" (Hoxha, 1969/1983, pp. 430, 442).

This ideological orientation also dictated the manner in which reality and human figures were to be represented in art. The figure of the new man was not a spontaneous construct, but an ideal projected by political power, which had to be reinforced through exemplary representations in film, literature, and theatre. Hoxha was acutely aware of the educational impact of art and frequently intervened in the interpretation of artistic works. During a visit to the family of the hero Adem Reka, whose life inspired the film *Horizonte të Hapura* (*Open Horizons*, 1969), he stated: "When I watched the film, I was at home with my children and said to them: Look how Adem Reka lived, worked, and fought—exactly like a true revolutionary" (Hoxha, 1986, p. 15). This example illustrates the deliberate selection of specific figures to be elevated as national models and, through them, the construction of a collective self-image defined by loyalty to the Party, honest labor, and sacrifice for the socialist ideal. Within this framework, the "Other"—who falls outside these parameters—was constructed as an ideological and moral threat.

From an imagological perspective, socialist discourse reveals two distinct forms of the Other: the external Other (the foreigner) and the internal Other (within the nation). The external Other is typically represented through figures symbolizing the occupier, the class enemy, or the revisionist and capitalist world. An illustrative case is the film *Plumba Perandorit* (lit. *Bullets for the Emperor*, 1980), which depicts the assassination attempt carried out by Vasil Laçi against Victor Emmanuel III... Here, imagological confrontation is clearly articulated by the communist leader himself: "Victor Emmanuel was even worse; he was the king of the fascist state" (Hoxha, 1986, p. 6). In contrast, the Albanian hero is praised as follows: "Through his bravery, courage, and heroism, despite his young age, Vasil demonstrated remarkable political and ideological maturity" (ibid.).

By contrast, the internal Other represents figures who deviate from the ideal of the socialist new man: saboteurs, speculators, remnants of the bourgeoisie, declassed individuals, or anyone positioned outside the Party's ideological line. This internal Other was not only stigmatized in artistic representations, but systematically used as a counter-figure to positively reinforce the collective self-image. The binary relationship between these two figures generated a sharp moral and ideological contrast, through which the audience was positioned as part of the collective "We," while transforming the Other into a category to be denounced, excluded, or eliminated.

4.2. Comparative Analysis of Imagological Representations

4.2.1. The Film *Njeriu me Top*

Directed by Viktor Gjika and based on the novel by Dritëro Agolli, *Njeriu me Top* represents one of the clearest cases of imagological dualism in Albanian socialist realist cinema. The film constructs a pronounced opposition between the collective self-image, embodied by the partisan characters and the patriotic peasantry, and the hetero-image, represented by the Ballist figures, collaborators of the occupier, and the figure of a Muslim cleric.

From an imagological perspective, the partisan characters—most notably the Commissar (Drini Hila) and his comrades—embody the virtues of the revolutionary ideal: commitment to the cause, simplicity, moral integrity, and an organic bond with the people. In contrast, the figure of the internal Other, exemplified by Tosun Baçi (Birçe Hasko), is constructed as grotesque and morally as well as politically delegitimized. He is portrayed as immersed in bodily pleasures, dressed in pompous attire, surrounded by ridiculous collaborators, and accompanied by a village hodja, whose presence carries the subtext of clerical collaboration with the enemies of the nation.

Semiotic Elements and Visual Codes

In one of the central scenes, the Ballists are positioned in front of the mosque, eating and drinking in a festive atmosphere. This spatial code connotes an alliance between religion and reactionary forces, placing the sacrosanct space of the mosque in stark contrast with the moral degradation of the figures who occupy it. Religion, in this context, is not only politicized but also instrumentalized as part of the construction of the Other. The representation of the Muslim clergy—at a time preceding the official anti-religious campaign of 1976—demonstrates that the Oriental Other had already been framed as problematic within socialist realist discourse, supporting the claim that "Orientalism has been fundamental to the modernizing cultural processes of forging a modern Albanian nation" (Sulstarova, 2012, p. 134).

This logic of exclusion is further reinforced through explicit dialogue. "Ti kauri i derrit je i ardhur në këtë fshat" ("You Christian pig, you are an outsider in this village"), declares the Ballist commander Uncle Pilo. This line introduces a particularly bold articulation for its time, reinforcing the division between "Us" and "the Other," whereby the progressive and patriotic segment of society is implicitly associated with Christian identity, while the Other is aligned with an Orientalized Muslim identity within Albania.

The Symbolism of Food and the Body

The Ballists are shown seated at a table, eating greedily and drinking excessively. Food, in this scene, functions as a semiotic marker of hedonism and self-indulgence. This visual sign stands in sharp contrast to the ascetic portrayal of the partisan characters, who appear shortly thereafter descending from the mountain—a vertical spatial code symbolizing their moral elevation in the historical confrontation with the Other.

Song as a Collective Sign and Identity Code

As the partisans descend from the mountain, they sing collectively. In this context, collective song carries a powerful symbolic function: it expresses unity, enthusiasm, and the emancipatory mission of the ideological "We." It operates as an acoustic sign that deepens the division between the two camps—Us and the Other.

Exclusionary Language in Dialogue

The imagological division is articulated explicitly in Tosun Baçi's line: "Ne të Ballit Kombëtar dhe ju komunistët" ("We of the National Front and you communists") (Gjika, 6:39). This discursive separation, voiced by the Other himself, clearly marks the boundary between two irreconcilable universes: one portrayed as backward, egoistic, and morally corrupt; the other as revolutionary, committed, and purified of individualism.

4.2.2. The Film *Përballimi*

Directed by Viktor Gjika and written by Teodor Laço, *Përballimi* constitutes a paradigmatic example of imagological binarism between the socialist collective "We" and the "Other," represented by kulaks, speculators, and social groups overturned by the communist revolution. Rather than positioning a foreign Other in ethnic or national terms, the film centers on the internal Other, portrayed as an ideological and moral threat to the new socialist society.

Spatial and Symbolic Framework

From the opening scene, in which the Party Secretary (Bujar Lako) visits the flour factory, the film establishes a climate of ideological vigilance. A guard carrying a rifle on his shoulder appears immediately—a visual sign signaling internal danger and the necessity of constant surveillance. The factory bears the name "Red Star," a clear ideological symbol, while its walls are covered with quotations from Enver Hoxha. This combination of textual and visual codes produces an ideologically saturated atmosphere in which every physical space is transformed into a political one.

Language and Ideological Symbolism in Dialogue

In one of the early scenes, a worker mocks his colleague by saying, "Why are you praying like in a mosque, you derëbardhë!" (03:50), ironically marking the socialist new man's detachment from religious belief and ridiculing any remnants of the traditional world. The collective laughter that follows reinforces ideological consensus and affirms the modernist orientation of the communist "We." In his study of Orientalism and communist identity in the work of Ismail Kadare, Enis Sulstarova notes that "the author tries to give his readers the impression that the landowners and Muslim clerics collaborated with the foreign enemies of the people, and that they were reactionaries who opposed the historical progress that communism stands for" (Sulstarova, 2012, p. 142). This mechanism of identifying the clergy and traditional social strata as obstacles to social progress—outlined by Sulstarova in a literary context—finds a clear cinematic expression in Përballimi through the construction of the figure of the Other.

The Party Secretary emphasizes, "The state belongs to the people," while a worker adds, "Today it is difficult to tell who is the people and who is a speculator." These lines foreground class tension and underscore the ideological necessity of distinguishing between legitimate members of the collective and those marked for exclusion.

Direct Confrontation: "We" versus the "Other"

The conflict is articulated explicitly in the confrontation between the Party Secretary and representatives of the excluded class. A lawyer defending the interests of the Other is met with the Secretary's unequivocal declaration: "You measure things with the old yardstick, but for us, above all else, stands the dictatorship of the proletariat" (09:07). This statement functions as a clear ideological code, affirming the hegemony of the new political order and the exclusion of those unwilling or unable to adapt to it.

In another scene, Xhezoja (Jani Riza), caught trading grain, insists, "I am not a kulak," to which the Party Secretary responds curtly, "Kulaks do not have horns." This exchange exemplifies the naturalization of the internal enemy: the Other bears no visible distinguishing marks but is defined instead by class position and ideological stance.

Semiotics of Lighting and Spatial Positioning

Characteristically, scenes involving positive figures are brightly lit and unfold in public or open spaces, despite the cold winter setting. In contrast, the Other—kulaks, speculators, and representatives of the overthrown classes—operate in darkness, basements, or enclosed spaces. This visual code associates light with truth and ideological transparency, while darkness becomes the natural environment of dubious, concealed, and regressive subjects.

Character Structure and Casting

Positive characters include the Party Secretary (Bujar Lako), Miti Kozari (Sander Prosi), Tarja (Stavri Shkurti), and Martini—figures that embody virtue, sacrifice, and class justice. Opposed to them are Nazifi (Kadri Roshi), Xhezoja (Jani Riza), the trader (Spiro Karaxha), and Klea (Antoneta Papapavli), all constructed as morally and ideologically tainted figures. Significantly, the actors portraying the Other frequently assume similar roles across different films, becoming typified bodies for the projection of ideological negativity.

Conclusion

In conclusion, *Përballimi* operates as both an imagological and pedagogical platform for the ideological division of Albanian society. Through visual and discursive codes, it systematizes the relationship between the collective "We" (the proletariat, the common people, the Party) and the "Other" (kulaks, traders, and overthrown social strata), rendering tangible the reciprocal relationship between self-image and hetero-image as a mechanism of ideological legitimation and social education.

4.2.3. The Film *Duel i Heshtur*

Duel i heshtur, directed by Dhimitër Anagnosti and written by Nasho Jorgaqi, is based on a real historical event that is treated in an idealized and pedagogical manner. The film aims to elevate the figure of the obedient and morally upright soldier in opposition to the "Other," who embodies internal danger and ideological betrayal. Unlike representations of an external enemy, this film constructs an internal Other—one who speaks Albanian, yet thinks differently and acts against collective interests.

Spatial and Iconographic Symbolism

The film opens with images of a naval shipyard, followed by a camera movement that lingers on a portrait of Enver Hoxha in military uniform, prominently displayed as "Commander-in-Chief." This iconographic sign establishes the film's ideological framework, saturating it with explicit references to political hierarchy and the dominant ideological order.

Semiotic Codes of "Positive" Reality

The scene depicting Mekur Kalo's meeting with his fiancée on the seashore presents an image of a happy, simple, and harmonious life, emblematic of the Albanian "new man." This sequence represents the ideological "We," associated with moral purity and the promise of a socialist future.

Coding the "Other" through Marked Negative Characterization

In contrast, the three characters who plan to defect—Corporal Ramiu (Ndrek Luca), Selamiu (Reshat Arbana), and Pepini (Bujar Kapexhiu)—are constructed to embody the negative traits of the internal Other.

- Ramiu is portrayed as materialistic and willing to serve anyone who offers financial gain: "I have no nation. I work for whoever pays me better" (13:36).
- Selamiu appears as a violent and aggressive figure, driven by class resentment and revengeful impulses against the regime.
- Pepini is characterized as weak, cowardly, and morally unstable.

Heroic Contrast: The Figure of Skënder

Skënder (Rikard Ljarja), as the representative of the ideological "We," is depicted as silent, devoted, and loyal to the ideals of the homeland. In the final scene, the ideological confrontation is resolved through spatial symbolism: the three enemies are confined to the darkness of the ship's hold, while Skënder stands on deck, in the light, steering the vessel toward Albanian shores. This spatial opposition symbolizes the triumph of patriotism and loyalty to communist ideology.

4.2.4. The Film *Ballë për Ballë*

Ballë për Ballë, directed by Piro Milkani and Kujtim Çashku and based on Ismail Kadare's novel *Dimri i Madh*, offers one of the most complex representations of the figure of the "Other" in Albanian socialist realist cinema. Unlike the previous cases, this film presents a dual configuration of the hetero-image:

the external Other (the Soviets) and the internal Other (representatives of the overthrown classes), both positioned in antagonism to the Albanian self-image, embodied by Commander Mujo Bermema and other representations of Albanian society.

Spatial Codes and Historical References

The film opens with a symbolically charged sequence: the grave of an Ottoman pasha located within the territory of a military base. This image foreshadows the fate of all foreign powers that have sought to control this space, suggesting that domination inevitably leads to failure and death. An archaeologist states: "The base is 2,400 years old and, in a way, reflects the entire history of wars fought in Albania." This historical metaphor conveys the idea of the enduring resistance of the Albanian nation against occupying Others.

Military Confrontation as a Clear Representation of "Us" versus "Them"

The Albanian commander Mujo Bermema (Bujar Lako) confronts the Russian commander Zheleznov (Sulejman Pitarka) with dignity and heroism. This confrontation functions as a narrative of national empowerment:

- Zheleznov represents a superpower, marked by long military experience and institutional prestige.
- Bermema, by contrast, embodies the Albanian military figure, characterized by bravery, loyalty, and determination in defending national sovereignty.

Discursive Oppositions

The recurring formulation of "us and them" clearly establishes the ideological division between the two camps, where "We" denotes Albanian society and "They" refers to former allies who now symbolize betrayal and coercive domination.

Binary Structuring of Secondary Characters

This imagological binarism extends beyond the military confrontation:

- Albanian intellectuals (the archaeologist, the journalist) are depicted as engaged and ideologically committed.
- In contrast, the Russian intellectual, Sergei, appears drunk, despondent, and emotionally unstable—a figure symbolizing moral decadence and the decline of the Soviet model.

A similar division is evident in the representation of women:

- Albanian women and young girls are portrayed as strong and resolute in the confrontation between the Albanian state and the Soviet Union.
- Russian women, by contrast, are depicted as insecure, passive, and often afflicted by depression—representations that signal the ideological weakness of the system they embody.

The People as an Ideological Guarantee: The Case of Belul Gjenomadhi

The figure of the elderly Belul Gjenomadhi (Kadri Roshi) appears as a representative of the people who firmly support the Party and the Albanian army. By endorsing the Party's decisions and standing on what is presented as the "right side of history," he reinforces the idea that the collective "We" encompasses not only the political and intellectual elite, but also the popular base.

From Dimri i madh to Ballë për ballë: A Shift in Perspective

The change in title from the novel *Dimri i Madh*, (lit. *The Great Winter*) to the film *Ballë për Ballë*, (lit. *Face to Face*) is not accidental. *Dimri i Madh* suggests an introspective experience and an internal crisis, whereas Ballë për ballë shifts attention to direct ideological confrontation between "us" and "them." The film title thus reinforces a clear alignment of opposing sides, legitimizing the Albanian perspective as morally and historically victorious.

Conclusion

Ballë për Ballë represents the most complex case of Other-construction analyzed in this study, operating simultaneously on two levels: the external Other (Soviet military figures) and the internal Other (reactionary elements hoping for the overthrow of the regime). Through the systematic use of visual codes, ideological discourse, and binary character structuring, the film functions both as a propagandistic platform and as a narrative manual for national and ideological self-legitimation within the Albanian socialist regime of the period.

5. Discussion

The analysis of the four films from Albanian socialist realism confirms that the relationship between self-image and hetero-image is central to the formation of the period's ideological and identity discourse. These representations are neither uniform, static, nor incidental; on the contrary, they are deliberately constructed through a sophisticated symbolic, narrative, and visual apparatus mobilized to serve the political and ideological function of reinforcing the profile of the "socialist new man."

Across all the works examined, the figure of the Other - whether embodied by ballists, kulaks, individuals labeled as socially dangerous, or representatives of foreign states - is constructed in direct opposition to the collective self-image of the ideological "We," which represents the rest of society. The more grotesque, distorted, treacherous, or decadent the Other appears, the more elevated, heroic, and morally pure the protagonist embodying the desired collective identity becomes. In this sense, representations of the Other function as a means of projecting and confirming self-representation - not as a passive act of reflection, but as an active process of identity construction grounded in exclusion and delegitimation.

These representational strategies do not emerge within a neutral vacuum, but are deeply conditioned by the political context of the period, by direct directives from power, and by the explicitly pedagogical function assigned to art in the service of ideology. As Enver Hoxha's statements demonstrate, artists were entrusted with the task of "influencing, through their works, the transformation of the new man"—a mission that manifests clearly in casting choices, lighting schemes, dialogic structures, and thematic selection.

At the same time, a particularly significant aspect of these representations lies in the fact that many figures of the Other do not represent an absolute exteriority. They are not always ethnically or nationally foreign; rather, they are often internal figures - members of the same society who, for class-based, ideological, or moral reasons, are declared alien and dangerous. In this way, the boundary between "We" and the "Other" is not solely external, but cuts through the social body from within. This constitutes one of the most acute features of the imagological system of socialist realism: the production of an internal otherness that legitimizes control and exclusion in the name of ideological purity.

Such mechanisms are particularly evident in films such as *Përballimi*, where kulaks, speculators, and their supporters are depicted as regressive, morally tainted figures operating in darkness, while protagonists representing the working class and the Party move through illuminated and open spaces. This visual coding underscores the antagonism between two irreconcilable worlds. Similarly, in *Duel i Heshtur*, the confrontation between an honest soldier and those attempting to defect becomes a metaphor for the moral and ideological steadfastness of the Albanian "We" in the face of betrayal and corruption embodied by the Other. In *Ballë për Ballë*, where representations of the Other extend beyond national borders, the narrative constructs a scenario in which the power of a superpower (the USSR) fails to break the integrity of a small yet resilient and proud nation.

Overall, this analysis demonstrates that self-image and hetero-image are not separate constructs, but rather two poles of the same symbolic and ideological relationship. The strengthening of one occurs through the devaluation of the other; as in the imagological frameworks discussed by Said (1978) and Leerssen (2007), the Other does not exist autonomously, but functions primarily as a figure through which self-definition is achieved. What distinguishes the Albanian cases examined here is the near-ritual function of these representations in the construction of ideological consensus, offering audiences a clear and immutable vision of what one ought to be—and what one must never become.

6. Conclusions

This study focused on analyzing the relationship between self-image and hetero-image in selected films and theatrical works of Albanian socialist realism, examining these representations within an imagological, semiotic, and discursive framework. The findings demonstrate that, in these works, representations of the "Other" do not merely serve to characterize narrative antagonists, but rather to configure a polarized ideological schema in which the desired collective identity is constructed and legitimized through the exclusion and delegitimation of the Other.

The self-image—embodied by figures such as the partisan, the Party secretary, the worker, or the ordinary soldier—represents moral virtue, ideological purity, sacrifice, and commitment. This image is constructed through a series of visual codifications (light, open spaces), semiotic markers (collective song, ideological symbols), and discursive strategies (divisive dialogue, rhetorical figures). By contrast, the hetero-image—whether represented by ballists, kulaks, collaborators, traitors, or foreigners—signifies moral regression, decadence, and danger to socialist society. The figure of the Other is consistently positioned in enclosed spaces, darkness, or contexts that emphasize the impossibility of integration or reform.

Another important conclusion is that the division between "We" and the "Other" is not based solely on ethnic or cultural boundaries, but is constructed primarily as a class-based and ideological distinction. The figure of the internal enemy—the kulak, the speculator, the trader, the believer, or the suspicious intellectual—is portrayed as equally dangerous as the external Other and often more central to narratives of control and vigilance. This underscores the persistent presence of representations designed to shape collective belief and regulate public morality.

Furthermore, the analyses reveal that cinema and theatre of the period did not function merely as forms of entertainment or historical narration, but were transformed into ideological apparatuses with a distinctly pedagogical function. Casting choices, the repetition of motifs, and the binary structuring of conflicts demonstrate a high degree of consistency in the ways artistic production served the construction of a specific form of collective consciousness.

In conclusion, this study emphasizes that self-image and hetero-image are not simply reflections of their historical moment, but active instruments in the processing of memory, the construction of national identity, and the legitimation of a particular political and cultural vision. From this perspective, imagological representations should not be understood solely as products of ideology, but also as powerful forms of cultural intervention in social consciousness—forms that remain relevant today as objects of critical study and interpretation.

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CHIRAL COPPER(I) N-ACYLTHIOUREA COMPLEXES: FROM SYNTHESIS TO HIGH HELICAL TWISTING POWER IN NEMATIC LIQUID CRYSTALS

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ABSTRACT

This paper reports the synthesis and characterization of novel chiral copper(I) complexes, generated by the reaction of enantiopure N-acylthiourea ligands with copper(II) halides. Spectroscopic investigation (NMR, IR, UV-Vis) revealed the monodentate coordination of the ligands through the sulfur atom to the Cu(I) ion, confirming the formation of the mononuclear complexes.

The functional evaluation focused on applying these compounds as chiral dopants in the commercial nematic liquid crystal E7. Polarized optical microscopy (POM) and differential scanning calorimetry (DSC) confirmed the formation of a stable chiral nematic (N*) phase in all doped mixtures. The helical twisting power (HTP) was quantified using the Grandjean–Cano method. While the free ligand exhibited low HTP, the copper(I) complexes demonstrated substantial enhanced efficacy. This significant boost is attributed to the increased molecular weight and structural rigidity of the coordination complexes. The tight helical pitches induced by the complexes correspond to selective reflection in the near-infrared region (NIR), whereas the ligand induces a larger pitch. These results highlight the potential of these complexes for advanced photonic applications in the NIR and establish chiral copper(I) N-acylthiourea complexes as a promising new class of chiral dopants, with future prospects for achieving selective reflection in the visible region.

Building on our previous work [1], this study expands the ligand diversity and structural complexity of copper(I) complexes.

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RECOGNITION AND PRODUCTION OF IDIOMS AND COLLOCATIONS AMONG ALBANIAN SECONDARY SCHOOL STUDENTS

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ABSTRACT

This research paper investigates the recognition and production of idioms and collocations among the Albanian secondary school students and explores the challenges associated with them. When learning idioms and collocations, the students often encounter difficulties due to their congruency, semantic transparency, lack of exposure and other factors as well. Both of these phraseological units play a crucial role in achieving fluency in the target language. Collocations are a group of words that naturally go together whereas idioms on the other hand are phrases in which the words do not mean what they ought to mean. However, due to their semantic transparency and cultural dependency, idioms and collocations present different levels of difficulty for EFL learners.

In this paper a mixed methodology has been employed which includes: recognition and production tests as well as a short questionnaire on learning strategies. The tests and the questionnaire were distributed on different days to the secondary school students.

The findings are expected to reveal that students experience greater difficulty in recognizing and producing idioms than collocations due to their figurative meaning and reliance on cultural context. The results of this research paper contribute to a better understanding of the challenges that students face when dealing with these linguistic elements and recommend differentiated and explicit teaching strategies for each of them.

Keywords: idioms, collocations, semantic transparency, cultural context, Albanian students

1. INTRODUCTION

Vocabulary knowledge is widely recognized as a prerequisite of EFL language proficiency. It is a central component that determines fluency and language comprehension. As Nation (2001) argues, “vocabulary knowledge enables language use; language use enables the increase of vocabulary knowledge and knowledge of the world enables the increase of vocabulary knowledge and language use” (p. 1).

Yet, within vocabulary learning there are multi-word expressions such as idioms and collocations which play a crucial role in achieving fluency and accuracy in communication. This means that a strong command of idioms and collocations is key to reaching native-like proficiency. According to many linguists, phraseological units are word combinations the meaning of which is not defined by the meaning of each individual part but rather by the whole expression. Idioms are known as figurative language units. They are typically defined as fixed expressions, the meaning of which are not deducible from the meanings of their individual components. For instance, “break a leg” has the non-literal meaning “good luck” (often used in theatre) and it does not involve any literal leg breaking. Due to the lack of transparency as shown in the example of “break a leg”, the idioms are difficult to comprehend and to produce.

In contrast, collocations are word combinations that naturally co-exist in language and they appear more transparent as compared to idioms. This means that even if the students are unfamiliar to certain combinations. They usually can deduce the meaning of the collocation. However, collocations are often arbitrary in nature and must be learned as chunks. As they have been defined in the Oxford Collocations

Dictionary for Students of English (McIntosh, Francis and Poole 2009): the way words combine in a language to produce natural – sounding speech and writing. For example, in English we say "heavy rain" or "light rain" as these two words pair naturally with the word "rain". However, it would not be normal to say "mild rain" or "strong rain".

Despite their importance in language learning, both idioms and collocations present considerable challenges for learners of English as a Foreign Language (EFL). One of the main difficulties associated with idioms lies in their semantic opacity. This has to do with their meanings which cannot be inferred from the individual words. As a result, this often leads learners to interpret them literally and use them incorrectly. Moreover, idioms are culture-bound elements of language. This means that they often reflect traditions, beliefs, and social practices that may be totally unfamiliar to language learners. As Moon (1998) points out, idiomatic expressions are deeply embedded in cultural context, which makes them particularly difficult for non-native speakers to acquire and use appropriately.

Collocations, on the other hand are more transparent than idioms but not necessarily easier to master. Their difficulty stems from their arbitrary nature and the lack of clear rules regarding word combinations. Learners often rely on their first language (L1) when using and producing collocations which leads to unnatural or incorrect combinations. This issue is particularly evident among Albanian learners of English, whose native language follows different lexical and syntactic patterns. For example, in English we say "make a decision" and its Albanian equivalent is "marr një vendim". The verb "marr" translates in English as "take" so an Albanian student is more likely to translate this collocation as "take a decision" instead of the correct English collocation "make a decision". These kind of direct translation strategies may result in non-native-like expressions due to differences between Albanian and English collocational systems. As Lewis (2000) emphasizes in the Lexical Approach, successful language learning depends largely on the acquisition of lexical chunks as they are, particularly collocations, which form the basis of fluent and natural communication.

In the Albanian education system, English is a core subject from an early stage and remains so throughout the compulsory education. However, despite this early exposure, language teaching in the Albanian classrooms places a high emphasis on single-word units and grammatical structures, leaving aside formulaic language like idioms and collocations. They receive less attention and space in the lesson planning. As a result, students in the Albanian education system lack the ability to produce natural English and struggle to express themselves in English due to their limited exposure with authentic phraseological language.

Applied linguistics has given a considerable amount of attention to idioms and collocations. Some linguists have focused more on the way learners perceive and interpret idioms while some others have studied how collocations are acquired and used. However, a direct comparison between the two with the purpose of addressing the difficulties that secondary students encounter when learning idioms and collocations, remains relatively scarce in EFL contexts in Albania. This research papers aims at filling this particular gap by comparing the level of difficulty associated with both idioms and collocations among the Albanian learners of English at the early secondary level. More specifically, it addresses the following questions:

1) Which of these two lexical categories is more challenging for secondary EFL learners?

2) What factors account for any differences in perceived difficulty within the Albanian context?

The value of this study lies in its potential to place a great contribute to more effective and differentiated classroom practices. By identifying the specific challenges that the students face when working with idioms and collocations, teachers may be better equipped to address these difficulties more effectively. The study also aims to examine not only which is more difficult to learn idioms or collocations, but also why such differences arise and what teaching strategies to implement when teaching them. The two key arguments will be put forward here: first, the explicit instruction of collocations and idioms is an effective approach to fostering the acquisition of these formulaic sequences in an L2 classroom. Second, the features of congruency and semantic transparency play important roles in the acquisition of formulaic sequences. A better understanding of the effects of these features will allow for more effective selection of target phrases for L2 courses.

2. LITERATURE REVIEW

2.1 LEARNING AND PROCESSING OF IDIOMS IN EFL CONTEXTS

The studies conducted on idioms so far have shown that their difficulty lies not only in their figurative meaning but also in the cognitive processes that are employed to interpret them. What this means is that since the learners move away from literal translation, their efforts to understand, interpret and use idioms increases their cognitive load. According to Raymond W. Gibbs Jr. (1994), idiom comprehension involves complex mental processing that connects linguistic input with conceptual and cultural knowledge.

Another key factor influencing idiom learning is familiarity and exposure. It is widely known that the more exposure to a certain language aspect (idioms in this case), the better it is. Learners are more likely to understand and use those idioms that they have encountered often during their learning process than the ones which are unfamiliar to them. The latter are interpreted literally, resulting in incorrect usage and understanding of them. As Norbert Schmitt (2000) emphasizes, frequency of exposure plays a crucial role in vocabulary acquisition. However, in many EFL settings, including Albanian secondary schools, idioms are often introduced in isolation and with limited contextual support. This reduces learners' ability to internalize their figurative meanings and use them appropriately.

Cultural background also plays a significant role in idiom comprehension. Idioms are often deeply rooted in cultural practices and shared knowledge, which may not be accessible to learners in foreign language contexts. For Albanian secondary school learners, this cultural gap can create additional barriers, as they may lack exposure to authentic English-speaking environments. As a result, learners may avoid using idioms altogether or rely on literal interpretations, leading to misunderstanding or incorrect usage.

2.2 ACQUISITION OF COLLOCATIONS IN EFL LEARNING

In contrast to idioms, research on collocations has focused more on their role in developing fluency and natural language production. Collocational competence is widely considered an essential component of advanced language proficiency. According to Michael Lewis (2000), language is largely made up of prefabricated chunks, and the ability to use these chunks automatically is what enables fluent communication.

One of the main challenges in acquiring collocations is their unpredictability. Learners cannot rely solely on grammatical rules to form correct word combinations, which makes collocations difficult to learn systematically. As Batia Laufer (1997) notes, learners often transfer patterns from their first language when producing collocations, resulting in errors due to negative transfer.

This issue is particularly evident among Albanian secondary school learners, whose first language differs significantly from English in terms of lexical patterns and verb usage. Albanian has completely different language rules and constructions and as a result, learners may produce non-native-like expressions when translating from Albanian into English. Furthermore, collocations are often not explicitly taught in Albanian classrooms, which limits learners' opportunities to practice and internalize correct word combinations.

Another challenge identified in the literature is the gap between receptive and productive knowledge. Learners may recognize correct collocations when reading or listening but struggle to produce them accurately in speaking or writing. In the Albanian secondary school context, this gap is often reinforced by teaching practices that emphasize recognition over active use, leading to limited development of productive collocational competence.

2.3 COMPARATIVE DIFFICULTY AND RESEARCH GAP

Although both idioms and collocations are essential components of lexical competence, research suggests that they pose different types of learning challenges. Idioms are generally considered more difficult due to their figurative meaning and cultural dependency, while collocations, although more transparent, require extensive exposure and repeated use to be mastered.

According to John Sinclair (1991), language users rely heavily on prefabricated patterns, yet not all patterns are equally accessible to learners. Idioms require deeper semantic processing and cultural understanding, whereas collocations depend more on frequency and usage patterns. For learners in the Albanian secondary schools, these differences may be even more pronounced due to the limited exposure to authentic language input. Teachers still rely to traditional teaching practices such as: repetition, learning by heart etc.

Despite the growing number of research on both idioms and collocations, there is still a lack of studies that directly compare their level of difficulty among early secondary EFL learners, particularly within specific educational contexts such as Albania. Most existing research has focused on adult or advanced learners, leaving a gap in understanding how younger learners develop competence in these areas.

This study aims to address this gap by examining which of these linguistic elements is more challenging among Albanian secondary school learners. By focusing on this specific context, the study provides insights that are directly relevant to classroom practice in Albania.

3. METHODOLOGY

3.1 RESEARCH DESIGN

This study employed a mixed-methods research design combining quantitative and qualitative approaches. The quantitative component consisted of recognition and production tests. The recognition test aimed at measuring the learners' ability to recognize and identify idioms as well as collocations in different sentence structures. The production test, on the other hand, assessed productive knowledge. In other words, it intended to measure whether learners can use correctly idioms and collocations in writing. For example, asking students to rewrite the given sentences using the key words in brackets. The qualitative component involved a short questionnaire investigating learners' perceptions when learning these phraseological units.

The mixed-methods approach was selected because it provides a more comprehensive understanding of students' performance and allows for the comparison of measurable test results with learners' reported experiences.

3.2 PARTICIPANTS

The participants in this study were 50 Albanian secondary school students studying English as a Foreign Language (EFL). The sample consisted of:

- 25 students from Grade 7
- 25 students from Grade 8

The participants were selected from a private school in Albania where English is taught as a compulsory subject. All students had received several years of formal English instruction prior to the study.

3.3 INSTRUMENTS

Three instruments were used to collect data:

❖ Recognition Test

The recognition test consisted of sixteen items divided equally between idioms and collocations. Students were required to identify the correct meaning or usage of each expression. The maximum score was eight points for idioms and eight points for collocations. The purpose of this test was to check how familiar are the students with the idioms and collocations and how much they have been exposed to them.

❖ Production Test

The production test contained sixteen items requiring students to complete sentences using appropriate idioms and collocations. As with the recognition test, students could obtain a maximum of eight points for idioms and eight points for collocations. The purpose of this test was to check the use and production of idioms and collocations.

❖ Questionnaire

A short questionnaire was administered to gather information about students' perceptions of difficulty, exposure to idioms and collocations and learning strategies used when encountering unfamiliar expressions.

3.4 PROCEDURE

Data collection was conducted over 2 classroom sessions. The recognition and production tests were administered first, while the questionnaire was distributed on a separate day to avoid fatigue and ensure more reliable responses. Students were instructed clearly on how to complete the tests as well as the questionnaire and their identities remained confidential. They completed all tasks individually under teacher supervision. The tests were scored according to predetermined answer keys and results were recorded for statistical analysis.

3.5 DATA ANALYSIS

The test results were analyzed using descriptive statistics. Mean scores were calculated for:

- Recognition of idioms
- Recognition of collocations
- Production of idioms
- Production of collocations

The performance of Grade 7 and Grade 8 students was compared to identify differences between age groups and language proficiency levels.

4. RESULTS AND FINDINGS

The results indicate that students generally performed better on collocations than on idioms across both recognition and production tasks.

TABLE 1. GRADE 7 RESULTS

Test Section	*Mean Score (out of 8 questions)*	*Percentage*
Recognition of Idioms	2.52	31.5%
Recognition of Collocations	3.24	40.5%
Production of Idioms	2.16	27.0%
Production of Collocations	3.52	44.0%

The Grade 7 students achieved their highest score in the production of collocations (44.0%), followed by recognition of collocations (40.5%). Performance on idioms was considerably lower, particularly in the production section (27.0%). These findings suggest that collocations were generally easier for grade 7 students than idioms.

TABLE 2. GRADE 8 RESULTS

Test Section	*Mean Score (out of 8)*	*Percentage*
Recognition of Idioms	2.56	32%
Recognition of Collocations	4.56	57%
Production of Idioms	2.12	26.5%
Production of Collocations	5.08	63.5%

Grade 8 students demonstrated considerably stronger performance in collocations, particularly in production tasks. Although their idiom scores were slightly higher than those of Grade 7 students in production, overall performance remained relatively low.

TABLE 4. OVERALL RESULTS (ALL 50 STUDENTS)

Test Section	*Percentage*
Recognition of Idioms	32.0%
Production of Idioms	29.5%
Recognition of Collocations	48.8%
Production of Collocations	53.8%

Table 3 shows that students performed significantly better on collocations than on idioms. Recognition of collocations reached 48.8%, compared to 32.0% for idioms, while production of collocations reached 53.8% compared to 29.5% for idioms. The low scores for idioms suggest that students struggle with both understanding the linguistic components. These findings indicate that idioms are more challenging than collocations for Albanian secondary school learners.

4.3TABLE 4. QUESTIONNAIRE RESULTS

Statement	*Agree*	*Neutral*	*Disagree*
Idioms are difficult to understand.	72%	18%	12%
Collocations are difficult to understand	13%	20%	74%
I use context to guess the meaning of idioms and collocations.	68%	21 %	11%
I often translate English idioms directly from Albanian when speaking or writing.	88%	7%	5%
I sometimes understand a collocation but still make mistakes when using it.	40%	34%	26%
Teachers should dedicate more classroom time to idioms and collocations.	100%	0%	0%
English movies and social media help me understand idioms and collocations better.	71%	20%	9%

Responses to the questionnaire indicate that idioms are perceived as considerably more difficult than collocations**.** A large majority of participants (72%) agreed that idioms are difficult to understand, while only 12% disagreed. In contrast, only 13% agreed that collocations are difficult to understand whereas 74% disagreed with this statement. These findings are consistent with the test results, which showed significantly lower scores for idiom recognition and production than for collocations.

Regarding learning strategies, 68% of the students reported that they use contextual clues to infer the meanings of unfamiliar idioms and collocations. Only 11% disagreed with this statement, suggesting that context is one of the primary strategies learners rely on when encountering phraseological expressions.

The questionnaire also revealed that first language transfer is common among learners. A substantial majority (88%) agreed that they often translate English idioms directly from Albanian when speaking or writing, while only 5% disagreed. This finding may explain the relatively low production scores for idioms, as literal translation frequently results in non-native or incorrect expressions.

Students also reported difficulties with the productive use of collocations. Although collocations were generally perceived as easier than idioms, 40% agreed that they sometimes understand a collocation but still make mistakes when using it, compared with 26% who disagreed and 34% who remained neutral.

This suggests that receptive knowledge of collocations does not always translate into accurate productive use.

There was unanimous agreement (100%) that teachers should devote more classroom time to teaching idioms and collocations. This strong consensus highlights learners' awareness of the importance of phraseological competence and their need for more explicit instruction in this area.

Finally, most participants (71%) agreed that exposure to English through movies and social media helps them understand idioms and collocations better while only 9% disagreed. This finding suggests that authentic language input outside the classroom plays an important role in developing learners' phraseological knowledge.

Overall, the questionnaire findings reinforce the quantitative test results. Students perceive idioms as considerably more challenging than collocations; frequently rely on contextual clues to interpret unfamiliar expressions, and often experience first-language interference when producing idioms. Furthermore, learners recognize the value of explicit classroom instruction and authentic language exposure in improving their understanding and use of idiomatic and collocational expressions.

5. DISCUSSION

The findings support previous research suggesting that idioms represent a greater challenge for EFL learners than collocations. Students achieved lower scores in both recognition and production of idioms, confirming the observations of Gibbs (1994) and Moon (1998) regarding the cognitive and cultural complexity of idiomatic language.

One explanation for these results is the semantic opacity of idioms. Since their meanings cannot be inferred directly from the meanings of individual words, learners often interpret them literally. This finding is consistent with previous studies emphasizing the role of figurative meaning in idiom difficulty.

Collocations, by contrast, were generally easier for students to recognize and produce. Their relative semantic transparency allowed learners to infer meaning even when they had not encountered a particular collocation before. However, errors still occurred, often due to first-language transfer, supporting Laufer's (1997) findings regarding the influence of the native language on collocational competence.

The stronger performance of Grade 8 students may be explained by increased exposure to English and a larger vocabulary base. Nevertheless, the relatively low idiom scores in both grades suggest that greater instructional attention should be devoted to figurative language.

The findings also support Lewis's (2000) Lexical Approach which emphasizes the importance of teaching lexical chunks explicitly. Students appear to benefit from repeated exposure to collocations, while idioms require additional contextual and cultural support.

6. CONCLUSION AND PEDAGOGICAL IMPLICATIONS

This study investigated the recognition and production of idioms and collocations among Albanian secondary school learners of English. The results demonstrate that idioms present greater challenges than collocations in both recognition and production tasks.

Several factors appear to contribute to this difference:

- *Semantic opacity of idioms*
- *Cultural dependency of idiomatic expressions*
- *Limited exposure to authentic language*
- *First-language interference*
- *Lack of explicit instruction*

The findings suggest that teachers should adopt differentiated approaches when teaching idioms and collocations. While collocations may benefit from frequent recycling and lexical chunk practice, idioms require explicit explanation, contextualized examples and opportunities for meaningful use.

To improve learners' phraseological competence, teachers should:

1. *Integrate idioms and collocations systematically into lessons.*
2. *Provide authentic examples through reading and listening materials.*
3. *Encourage students to learn expressions as lexical chunks rather than isolated words.*
4. *Use visual aids, stories and cultural explanations when teaching idioms.*
5. *Create communicative activities that require active production of phraseological units.*

Future research could involve larger samples, additional educational settings and longitudinal studies examining the impact of explicit instruction on idiom and collocation acquisition over time.

7. LIMITATIONS

This study has several limitations that should be considered when interpreting the findings. First, the sample consisted of only fifty students from a single private school in Albania. As a result, the findings cannot be generalized to all Albanian secondary school learners, particularly those studying in public schools or in different regions of the country where educational conditions and levels of English exposure may vary.

Secondly, the study relied on a relatively small number of test items for both idioms and collocations. Although the tests provided useful insights into students' recognition and production abilities, they may not fully represent the broad range of phraseological competence required in authentic language use. A larger and more varied set of items could provide a more comprehensive assessment of learners' knowledge.

Third, the research focused on students' performance at a single point in time. Since the data were collected during a limited period, the study cannot account for changes in learners' abilities over time or measure the long-term effects of instruction and exposure on idiom and collocation acquisition.

Another limitation concerns the questionnaire data. Students' responses were based on self-reporting and may therefore reflect personal perceptions rather than actual learning behaviors. Some participants may have overestimated or underestimated their familiarity with idioms and collocations or the strategies they use when encountering unfamiliar expressions.

Furthermore, the study did not investigate additional factors that may influence phraseological competence such as: motivation, proficiency level, reading habits, exposure to English outside the classroom or the influence of digital media and social networks. Examining these variables could provide a more complete understanding of the challenges learners face.

Finally, the study primarily employed descriptive statistics and did not include more advanced statistical analyses to determine the significance of differences between groups or test sections. Future studies could use larger samples and inferential statistical methods to provide stronger evidence regarding the relationship between learners' recognition and production of idioms and collocations.

Despite these limitations, the study offers valuable insights into the difficulties Albanian secondary school learners experience when dealing with idiomatic and collocational language and provides a foundation for future research in this area.

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FACIAL ASYMMETRY ACROSS DIFFERENT ANGLE MALOCCLUSIONS USING STRUCTURED LIGHT 3D SCANNING

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ABSTRACT

Background/Objectives: The aim of this study was to assess soft tissue asymmetry in Kosovo children and adolescents with Angle malocclusions using structured light scanning technology. Methods: This cross-sectional study was conducted in 180 children and adolescents aged 6-9 and 10-14 years. Facial scans were obtained using the MetiSmile facial scanner, while intraoral scans were obtained using the Aoralscan 3. Gnathion soft tissue deviation from the midsagittal plane was assessed and categorized as left- or right-sided deviation. Associations between gnathion asymmetry, sex, age group, and Angle malocclusion classification were analyzed using chi-square, Fisher's exact, Mann-Whitney U, and Kruskal-Wallis ANOVA by Ranks analysis tests. Results: Right-sided gnathion deviation was prevalent in both children (66.7%) and adolescents (72.2%). Slightly greater values of transverse deviation were observed on the right side in both age groups. However, no statistically significant differences were identified by sex, age group, or Angle malocclusion classification ($p > 0.05$). Conclusions: Within the limitations of this cross-sectional study, mild gnathic soft tissue asymmetry appears to represent a common feature of normal craniofacial variation and not a characteristic specifically associated with the type of Angle malocclusion. Three-dimensional facial scanning may provide a clinically applicable and noninvasive method for assessing facial asymmetry in growing orthodontic patients.

Keywords: 3D facial analysis; gnathion asymmetry; facial asymmetry; digital orthodontics; Angle malocclusion; structured-light facial scanner; craniofacial morphology

AUTOMATION OF DATA ANALYSIS USING SQL AND BUSINESS INTELLIGENCE (BI) TECHNOLOGIES

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ABSTRACT

In the era of digital transformation, organizations generate vast amounts of data from various operational, financial, and customer-related processes. Efficient processing and analysis of this data have become a critical factor for informed decision-making and competitive advantage. This study explores the automation of data analysis processes using Structured Query Language (SQL) and Business Intelligence (BI) technologies, focusing on how these tools enhance data processing efficiency, accuracy, and accessibility.

SQL remains one of the most widely used languages for managing and manipulating relational databases. It enables users to extract, transform, and aggregate data efficiently from large datasets. However, traditional SQL-based analysis often requires manual query execution and repeated reporting tasks, which can be time-consuming and prone to human error. To address these limitations, BI technologies introduce automation, visualization, and interactive analytics capabilities that significantly improve the usability of data.

Business Intelligence platforms, such as Power BI, Tableau, and similar systems, provide automated data pipelines, scheduled refresh mechanisms, and dynamic dashboards that transform raw data into meaningful insights. By integrating SQL databases with BI tools, organizations can establish a seamless data flow where SQL handles data extraction and preprocessing, while BI systems focus on visualization and analytical interpretation. This integration reduces manual intervention and ensures real-time or near real-time data analysis.

The research highlights key advantages of combining SQL with BI technologies, including improved decision-making speed, enhanced data accuracy, reduced operational workload, and better data-driven strategy development. Furthermore, automation enables organizations to standardize reporting processes and minimize inconsistencies across different departments.

The study also emphasizes the role of data modeling and optimized query design in improving system performance. Properly structured SQL queries contribute to faster data retrieval, while BI tools enhance user interaction through dashboards, charts, and key performance indicators (KPIs). The synergy between these technologies supports scalable and efficient data ecosystems suitable for modern enterprises.

In conclusion, the integration of SQL and Business Intelligence technologies represents a powerful approach to automating data analysis. It not only streamlines data processing workflows but also

empowers organizations to make timely, evidence-based decisions. Future developments in artificial intelligence and machine learning are expected to further enhance automation capabilities, enabling more advanced predictive analytics and intelligent decision-support systems.

Keywords : Data Analysis Automation,SQL (Structured Query Language),Business Intelligence (BI),Data Integration ,Data Visualization,Decision Support Systems,Real-time Analytics.

1. Introduction

In the era of digital transformation, organizations generate and store vast amounts of data from various operational systems, business processes, and online platforms. The growing volume and complexity of data have increased the need for efficient analytical solutions that can support timely and informed decision-making. Traditional manual approaches to data analysis are often time-consuming, error-prone, and insufficient for handling large-scale datasets.

Structured Query Language (SQL) has become a fundamental technology for managing, retrieving, and processing data stored in relational database systems. At the same time, Business Intelligence (BI) platforms such as Microsoft Power BI and Tableau provide advanced capabilities for data visualization, reporting, and interactive analytics. The integration of SQL-based data processing with BI technologies enables organizations to automate analytical workflows, reduce manual effort, and improve the accuracy and consistency of business reporting.

Automated data analysis involves several interconnected processes, including data extraction, transformation, aggregation, visualization, and report distribution. By implementing automated analytical pipelines, organizations can gain real-time insights, improve operational efficiency, and enhance strategic decision-making capabilities.

The main objective of this study is to examine the role of SQL and Business Intelligence technologies in automating data analysis processes. The research explores key architectural components, implementation approaches, and practical benefits of integrating database technologies with modern BI platforms. Furthermore, the paper discusses current challenges, opportunities, and future trends in automated data analytics.

2. Literature Review

2.1. Data Analysis and Business Intelligence

Business Intelligence (BI) refers to a set of technologies, methodologies, and processes used to collect, analyze, and present business data in a meaningful way. The concept of BI has evolved significantly over the past decades, moving from traditional reporting systems to advanced analytical platforms capable of supporting real-time decision-making. Modern organizations increasingly rely on BI solutions to transform raw data into actionable insights that enhance operational efficiency and strategic planning.

Data analytics plays a critical role in organizational performance by enabling managers to identify trends, monitor key performance indicators (KPIs), and make evidence-based decisions. The growing availability of digital data has further increased the importance of analytical capabilities, making Business Intelligence an essential component of modern information systems.

2.2. SQL as a Foundation for Data Management

Relational database management systems (RDBMS) remain one of the most widely used technologies for storing and managing organizational data. Structured Query Language (SQL) serves as the standard language for interacting with relational databases and provides powerful mechanisms for data retrieval, manipulation, and administration.

SQL enables organizations to perform complex queries, filtering operations, aggregations, and calculations on large datasets. Functions such as JOIN, GROUP BY, stored procedures, views, and triggers support efficient data preparation and transformation processes. As a result, SQL plays a

fundamental role in data warehousing, reporting systems, and business analytics environments. The ability to extract and prepare high-quality data makes SQL a critical component in any data-driven decision-making framework.

2.3. Business Intelligence Technologies

The rapid growth of data-driven business environments has contributed to the development of advanced Business Intelligence platforms such as Microsoft Power BI, Tableau, and Qlik Sense. These tools provide organizations with intuitive interfaces for data visualization, interactive reporting, and dashboard development.

Power BI is widely recognized for its seamless integration with Microsoft technologies and cloud services, while Tableau is known for its powerful visualization capabilities and user-friendly design. These platforms enable users to create interactive dashboards that support real-time monitoring of business performance. Self-service analytics features further empower non-technical users to explore data independently without requiring extensive programming knowledge. Consequently, BI technologies have become indispensable tools for transforming complex datasets into understandable and actionable information.

2.4. Data Analytics Automation

Automation has become a key trend in modern data analytics. Automated analytics involves the use of technologies that perform data extraction, transformation, loading (ETL), analysis, and reporting with minimal human intervention. This approach reduces operational costs, minimizes errors, and increases the speed of information delivery.

Several studies highlight the benefits of integrating SQL-based data processing with automation tools and BI platforms. Technologies such as Apache Airflow, Microsoft Power Automate, and cloud-based workflow services enable organizations to schedule and manage complex analytical processes automatically. Practical implementations demonstrate that automated analytics significantly improves productivity, supports real-time decision-making, and enhances organizational competitiveness. As digital transformation continues to accelerate, automation is expected to play an increasingly important role in the future of business intelligence and data analytics.

3.Research Methodology

The research methodology of this study is designed to investigate the automation of data analysis using SQL and Business Intelligence (BI) technologies. The approach integrates both qualitative and quantitative methods to ensure a comprehensive understanding of data processing workflows, system architecture, and analytical outcomes.

3.1. Research Design

The study adopts a mixed-method research design, combining qualitative analysis of existing literature with quantitative evaluation of data processing efficiency. The qualitative component focuses on understanding theoretical frameworks, concepts, and best practices related to SQL-based data management and BI systems. The quantitative component evaluates the performance improvements achieved through automation, including reduced processing time, increased accuracy, and enhanced reporting efficiency.

3.2. Data Sources

The research utilizes multiple data sources to ensure reliability and relevance. Primary data is obtained from relational databases and transactional systems, which represent structured organizational data. Additionally, external data sources such as open datasets and cloud-based repositories are considered to demonstrate the scalability of automated analytics systems. These diverse data sources allow for realistic simulation of enterprise-level data processing environments.

3.3. Technologies and Tools

The implementation of the proposed analytical framework relies on modern database and BI technologies. SQL Server, PostgreSQL, and MySQL are used as relational database management systems for data storage and processing. These systems support complex querying, data aggregation, and transformation operations.

For data visualization and reporting, Business Intelligence tools such as Microsoft Power BI and Tableau are employed. These platforms enable interactive dashboards, real-time reporting, and user-friendly data exploration. In addition, ETL (Extract, Transform, Load) tools such as Apache Airflow and Microsoft Power Automate are used to automate data workflows, ensuring efficient scheduling and execution of data pipelines.

3.4. Analytical Framework

The analytical framework of this study consists of four main stages: data collection, data transformation, data visualization, and automated reporting. In the first stage, data is extracted from multiple sources using SQL queries and stored procedures. In the second stage, data is cleaned, transformed, and aggregated to ensure consistency and analytical readiness.

The third stage involves visualization, where processed data is represented through interactive dashboards and graphical reports in BI tools. Finally, the automated reporting stage ensures continuous delivery of insights through scheduled refreshes and report distribution mechanisms. This structured framework enables efficient, scalable, and automated data analysis suitable for modern data-driven organizations.

4. Architecture of Automated Data Analysis

The architecture of automated data analysis represents a structured framework that integrates database systems, data processing mechanisms, and Business Intelligence (BI) tools to enable efficient, scalable, and real-time analytics. This architecture is typically organized into four main layers: data extraction, data transformation, data visualization, and automated reporting.

4.1. Data Extraction Layer

The data extraction layer serves as the foundation of the analytical architecture. In this stage, data is retrieved from relational databases and various operational systems using Structured Query Language (SQL). SQL queries, views, and stored procedures are widely used to extract relevant datasets based on predefined business requirements. This layer ensures that raw data from multiple sources is efficiently collected and prepared for further processing. The reliability and accuracy of this stage are critical, as it directly influences the quality of downstream analytics.

4.2. Data Transformation Layer

The data transformation layer is responsible for converting raw data into a structured and analysis-ready format. This process includes data cleansing, validation, integration, and aggregation. Data cleansing ensures that inconsistencies, missing values, and duplicates are properly handled. Validation techniques are applied to maintain data integrity, while aggregation processes summarize large datasets into meaningful metrics. This layer is often supported by ETL (Extract, Transform, Load) tools such as Apache Airflow or Power Automate, which automate workflows and ensure consistency in data processing.

4.3. Data Visualization Layer

The data visualization layer focuses on presenting processed data in a meaningful and interactive format. Business Intelligence tools such as Microsoft Power BI and Tableau are commonly used at this stage to create dashboards, Key Performance Indicators (KPIs), and graphical reports. These visualizations enable users to explore data patterns, trends, and relationships in an intuitive manner. Interactive dashboards allow end-users to filter, drill down, and analyze data dynamically, thereby improving decision-making efficiency and reducing dependency on technical specialists.

4.4. Automated Reporting Layer

The automated reporting layer represents the final stage of the architecture and is responsible for delivering insights to stakeholders. This layer supports scheduled data refreshes, automated report generation, and distribution through email or cloud-based platforms. By automating reporting processes, organizations eliminate manual intervention, reduce reporting delays, and ensure that decision-makers always have access to up-to-date information. This layer plays a crucial role in maintaining continuous monitoring and supporting real-time business intelligence.

Overall, the integration of these four layers creates a robust and scalable architecture for automated data analysis. It enhances operational efficiency, improves data accuracy, and enables organizations to adopt a data-driven decision-making culture.

5. Practical Implementation: SQL and Power BI Integration

The practical implementation of automated data analysis demonstrates how SQL-based data management systems can be effectively integrated with Business Intelligence tools such as Microsoft Power BI. This integration enables organizations to transform raw data into meaningful insights through structured database design, advanced SQL processing, interactive visualization, and automated reporting workflows.

5.1. Database Design

The foundation of the implementation is a well-structured relational database schema. The database typically consists of core entities such as Students, Departments, Courses, and Enrollments. Each table is designed with primary and foreign key relationships to ensure data integrity and consistency. The schema supports normalization principles to eliminate redundancy and improve query performance. This structured design allows efficient data storage and provides a solid base for analytical operations.

5.2. SQL-Based Data Processing

SQL plays a central role in data processing within the system. Stored procedures are used to automate repetitive operations such as data insertion, updates, and complex business logic execution. Views are implemented to simplify data access and provide aggregated insights, such as total enrollments per department or average performance metrics. Additionally, user-defined functions are applied to perform reusable calculations, such as age computation or performance classification. These SQL components significantly enhance data processing efficiency and ensure consistency across analytical outputs.

5.3. Power BI Dashboard Development

Power BI is utilized to design interactive dashboards that visualize key performance indicators (KPIs) and analytical results. These KPIs may include student enrollment trends, departmental performance, course popularity, and academic achievement distribution. Visualization techniques such as bar charts, line graphs, pie charts, and matrix tables are used to present data in an intuitive and user-friendly format. The interactive nature of Power BI allows users to filter and drill down into specific data segments, enabling deeper analytical insights and improved decision-making capabilities.

5.4. Workflow Automation

Automation is a critical component of the integrated system. Data workflows are configured to ensure automatic data refresh, eliminating the need for manual updates. Power BI's scheduled refresh functionality enables dashboards to display real-time or near real-time data. In addition, scheduled reporting mechanisms allow the automatic distribution of reports to stakeholders via email or cloud services. This level of automation ensures that decision-makers always have access to up-to-date and accurate information, thereby improving organizational responsiveness and operational efficiency.

Overall, the integration of SQL and Power BI creates a powerful analytical environment that supports end-to-end data processing, visualization, and automation. This approach enhances productivity, reduces manual workload, and enables data-driven decision-making across the organization.

5.5 Practical Example: Student Performance Analytics Dashboard (SQL + Power BI)

To demonstrate the practical application of automated data analysis, consider a university analytics system that monitors student performance, departmental distribution, and academic progress using SQL and Power BI.

Scenario Description

A university collects data from multiple systems:

- Student registration system
- Course enrollment system
- Academic performance records

The goal is to automate reporting and provide real-time insights for decision-makers such as faculty members and administrators.

1. SQL Data Processing Example

Average Score per Department

```
SELECT
    d.DepartmentName,
    COUNT(s.StudentID) AS TotalStudents,
    AVG(s.Score) AS AverageScore
FROM Students s
JOIN Departments d
    ON s.DepartmentID = d.DepartmentID
GROUP BY d.DepartmentName;
```

Picture 1. Average Score per Department

```
SELECT
    StudentID,
    FirstName,
    LastName,
    Score
FROM Students
WHERE Score >= 90;
```

Picture 2. High-Performing Students (Scholarship Candidates)

2. **Power BI Dashboard Visualization**



Picture 3. Student Performance & Department Analytics Dashboard

3. **FULL SQL PROJECT: University Analytics System — Short Description**

The University Analytics System is a SQL Server–based database project designed for managing and analyzing academic processes within a university environment. It collects and processes data related to students, departments, courses, and enrollments, enabling the generation of analytical reports and KPI dashboards.

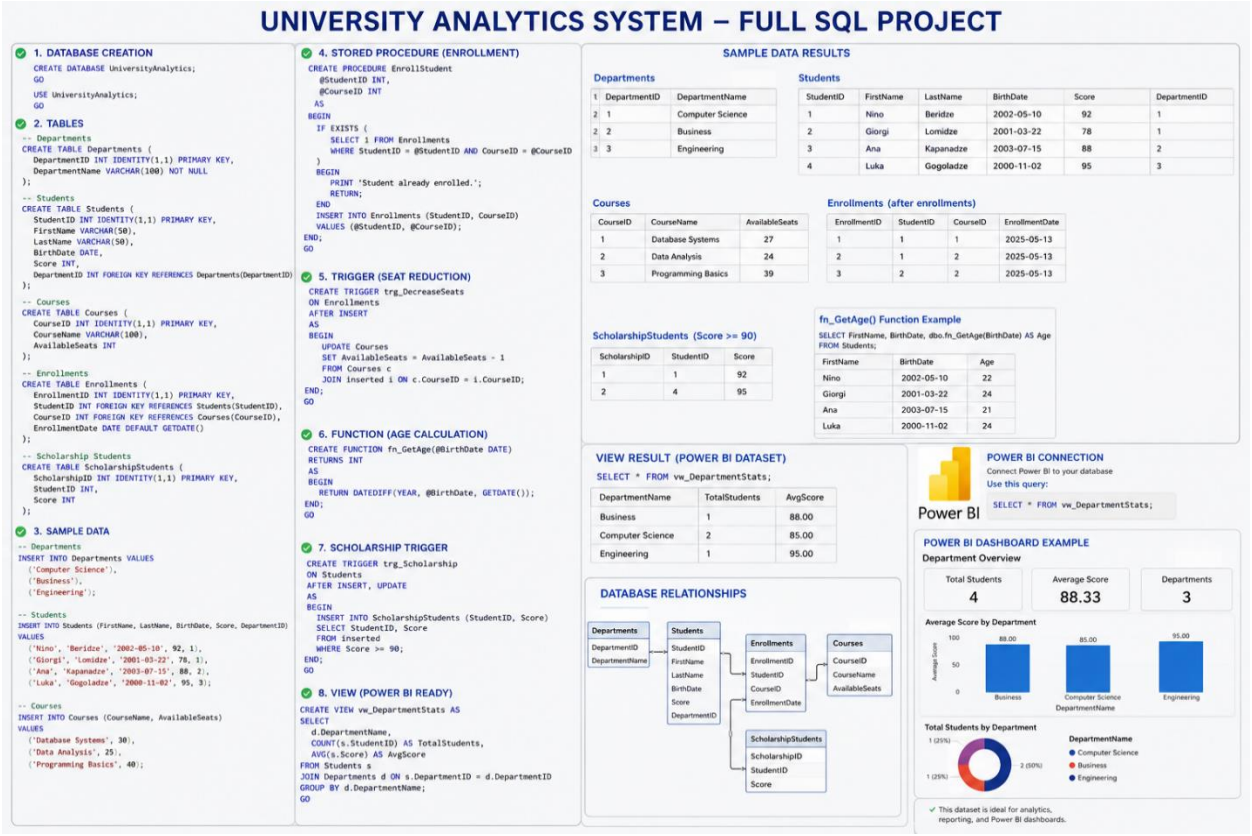
The main goal of the system is to support data-driven decision-making in education, such as:

- Evaluating students' academic performance
- Comparing department-level results
- Identifying scholarship (GPA-based) candidates
- Analyzing learning trends over time

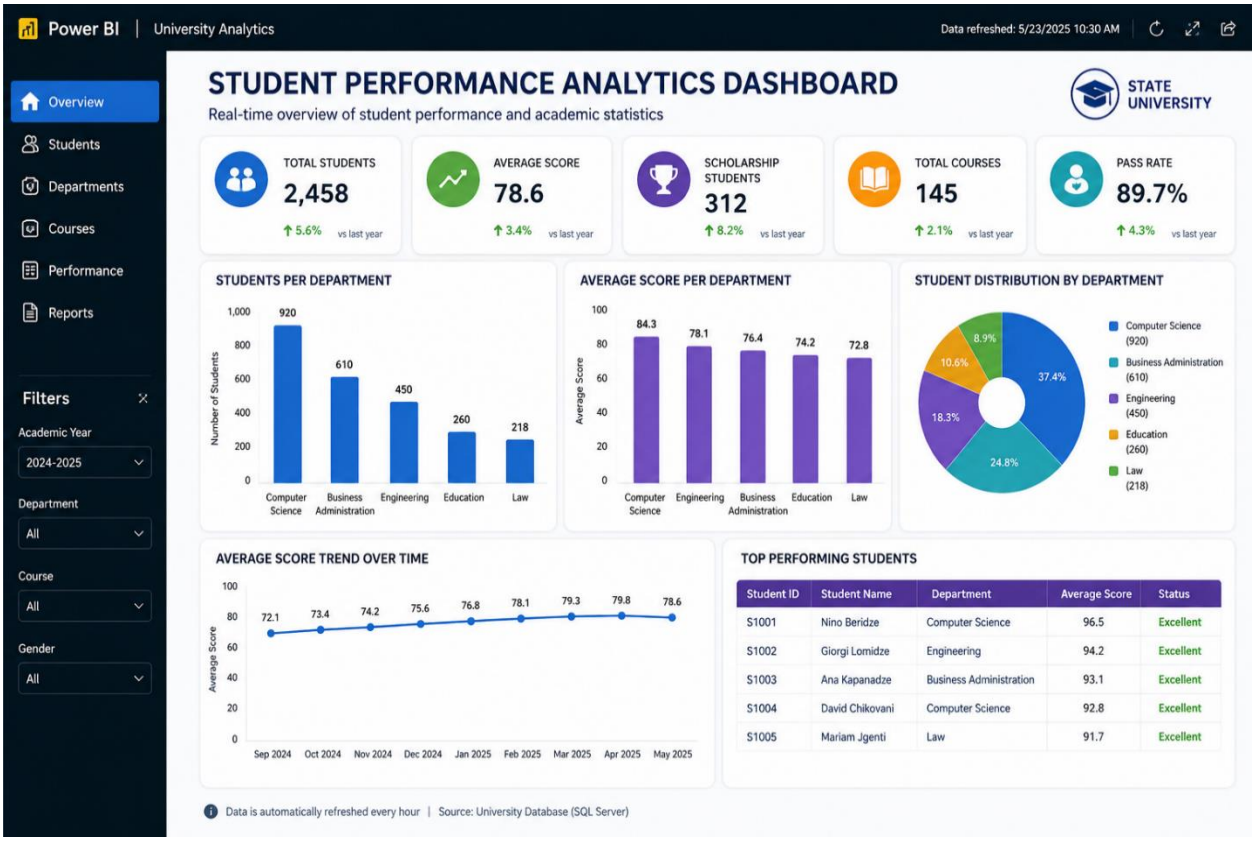
The system typically includes the following core components:

- **Departments** – academic faculties or departments
- **Students** – student records and personal data
- **Courses** – academic subjects offered by the university
- **Enrollments** – student registrations and grades
- Additional **views, triggers, and indexes** for analytics and performance optimization

This project is widely used as a practical example in SQL Server training, demonstrating key concepts such as JOIN operations, VIEW creation, stored procedures, triggers, and analytical querying for business intelligence purposes in education systems.



Picture 4. FULL SQL PROJECT: University Analytics System — Short Description



Picture 5. STUDENT PERFORMANCE INSIGHTS / UNIVERSITY ANALYTICS

Figure 5 presents a Power BI–created "Student Performance Analytics Dashboard", which shows the analysis of students' academic data at the university.

The dashboard combines both quantitative and qualitative indicators of student performance and enables real-time monitoring of academic results. The visualizations display the total number of students, average score, scholarship students, number of courses, and pass rate. It also analyzes the distribution of students across faculties, compares average scores between departments, and shows the trend of performance over time. Additionally, a list of top-performing students is presented.

In conclusion, the dashboard helps university administration make fast, data-driven decisions and improve the quality of education.

6. Results and Discussion

The implementation of automated data analysis using SQL and Business Intelligence (BI) technologies demonstrates significant improvements in organizational data processing and decision-making capabilities. One of the primary benefits of automation is the substantial reduction in manual effort required for data extraction, transformation, and reporting. By utilizing SQL-based procedures and BI tools, organizations can streamline analytical workflows and ensure consistent data processing across different systems.

Another important advantage is the improvement in productivity and accuracy. Automated systems reduce the risk of human error, which is common in manual data handling processes. SQL queries and stored procedures ensure standardized data manipulation, while BI platforms provide validated and real-time visualizations. As a result, organizations can rely on more accurate and reliable information when making strategic decisions.

The reduction of manual workload is also a key outcome of automation. Employees no longer need to perform repetitive tasks such as data collection and report generation, allowing them to focus on more

strategic and analytical activities. This shift contributes to improved operational efficiency and better resource allocation within organizations.

Furthermore, automation significantly enhances the speed of decision-making processes. Real-time dashboards and automatically updated reports enable managers to access up-to-date information instantly. This capability supports faster responses to business changes and improves overall organizational agility. However, despite these advantages, certain challenges and limitations remain, including system complexity, integration issues, and the need for skilled personnel to manage and maintain automated pipelines.

7. Future Trends

The future of Business Intelligence and data analytics is strongly influenced by emerging technologies such as Artificial Intelligence (AI). AI integration in BI systems enables advanced data interpretation, anomaly detection, and automated insights generation, further enhancing decision-making capabilities.

Predictive and prescriptive analytics are also becoming increasingly important. Predictive analytics focuses on forecasting future trends based on historical data, while prescriptive analytics provides recommendations for optimal actions. These advanced analytical approaches are expected to become standard features in modern BI platforms.

Cloud-based analytics platforms represent another significant trend, offering scalability, flexibility, and cost efficiency. Cloud environments allow organizations to store and process large volumes of data without the limitations of traditional on-premise systems. Additionally, real-time data processing is gaining importance, enabling continuous data streaming and immediate insights for time-sensitive decision-making.

8. Conclusion

This study highlights the importance of integrating SQL and Business Intelligence technologies for automating data analysis processes. The findings demonstrate that automation improves data accuracy, increases productivity, reduces manual workload, and accelerates decision-making processes.

The integration of SQL-based data management with BI tools such as Power BI and Tableau provides a comprehensive framework for modern data-driven organizations. It enables efficient data processing, advanced visualization, and automated reporting, which are essential for competitive advantage in today's digital environment.

Organizations are recommended to invest in scalable database systems, adopt modern BI platforms, and implement automated workflows to enhance analytical efficiency. Future research should focus on the integration of artificial intelligence, machine learning techniques, and real-time analytics to further improve the capabilities of automated data analysis systems.

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PLEASURE BEFORE PARTICIPATION TIKTOK USES AND GRATIFICATIONS AMONG ALBANIAN ADOLESCENTS

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ABSTRACT

This paper examines how Albanian adolescents aged 14–18 use TikTok and what gratifications they derive from the platform, drawing on Elihu Katz's Uses and Gratifications theory. The study explores TikTok not merely as a social media application, but as a contemporary communication environment where entertainment, identity expression, social belonging, information-seeking, and emotional escape intersect. Methodologically, the paper is based on a mixed approach and the quantitative data were collected through a structured questionnaire with 149 adolescents from schools in Tirana, Durrës, and Dibër, while qualitative insights were gathered through semi-structured interviews with experts in communication, sociology, psychology, and media studies. The findings show that TikTok is used primarily for entertainment, emotional gratification, stress relief, and the consumption of short-form humorous and musical content. Although 91.3% of respondents report being regular TikTok users, the majority appear to be passive consumers rather than active content producers. The study also identifies a tension between TikTok's creative and educational potential, and the risks associated with excessive use, weak time management, emotional dependence, privacy concerns, exposure to unreliable information, and reduced engagement with offline activities such as studying, sports, artistic creation, and family interaction. The paper argues that TikTok should be understood as a key site of adolescent digital culture in Albania, where new forms of communication, self-presentation, and peer belonging are being shaped. It concludes that media literacy, parental guidance, and the critical integration of digital culture into education are essential for transforming TikTok from a passive entertainment platform into a space for creative, informed, and responsible participation.

Keywords: TikTok, adolescents, Uses and Gratifications, Gen Z, digital communication, media literacy

1. Introduction

TikTok has become one of the most influential platforms in the everyday media lives of adolescents. Its short videos, algorithmic personalization, music-based trends, humorous formats, and participatory tools have created a new communication environment in which young users do not simply receive content, but also encounter models of identity, belonging, emotional expression, and social interaction. For adolescents, TikTok is not only an entertainment application; it is also a space where peer culture is produced, circulated, imitated, and normalized.

In the Albanian context, the growing popularity of TikTok among teenagers raises important questions for communication studies, media literacy, education, and youth development. Adolescents aged 14–18 are in a crucial phase of identity formation, social comparison, emotional development, and peer belonging. Their relationship with a platform built around speed, visibility, performance, and algorithmic repetition therefore deserves careful academic attention.

This paper investigates how Albanian adolescents use TikTok and what kinds of gratifications they derive from it. The study is based on a thesis that examined TikTok use among 149 adolescents aged 14–18 from schools in Tirana, Durrës, and Dibër, supported by interviews with five experts in communication, sociology, psychology, and media studies. The analysis is framed through Elihu Katz's Uses and Gratifications theory, which understands media audiences as active users who choose media

to satisfy specific needs, including entertainment, information, social interaction, identity construction, escape, and self-expression.

The central argument of this paper is that, among the adolescents surveyed, TikTok is primarily a platform of pleasure before participation. Although TikTok is often described as an interactive and creative platform, the findings suggest that Albanian adolescents mostly use it as passive consumers of entertaining content rather than as active producers. This distinction is important because it challenges the assumption that access to participatory platforms automatically produces active, creative, or critically engaged users. Therefore, the paper wants to understand what motivates Albanian adolescents to use TikTok? Which gratifications dominate their use of the platform? To what extent do they use TikTok for information, social interaction, identity formation, and content creation? And what risks and opportunities emerge from their patterns of use?

2. Theoretical Framework: Uses and Gratifications in the TikTok Era

Uses and Gratifications theory provides a useful framework for understanding why adolescents choose TikTok and what they gain from using it. Rather than asking what media do to audiences, this approach asks what audiences do with media. It assumes that media users are not passive receivers, but active individuals who select media according to their needs, motivations, and expectations. Classical Uses and Gratifications theory identifies several key motives for media use, including entertainment, information, social interaction, personal identity, self-expression, escape from reality, passing time, and validation. These categories remain relevant in the digital age, but platforms such as TikTok reshape how these gratifications are experienced.

In the TikTok environment, gratification is not only connected to content, but also to the speed, format, and emotional intensity of delivery. The endless scroll, short videos, music, humor, repetition of trends, and algorithmic recommendation system create a media experience that is immediate, personalized, and emotionally engaging. For adolescents, TikTok becomes especially powerful because it offers quick pleasure, connection to peer culture, and continuous exposure to what appears socially relevant or "current." At the same time, TikTok modifies the traditional distinction between producer and audience. In theory, every user can become a creator through tools for recording, editing, remixing, commenting, duetting, and sharing. Yet access to these tools does not necessarily lead to active participation. Users may still primarily watch rather than create, consume rather than interact, and imitate rather than critically produce.

Studies conducted with the Uses and Gratifications (U&G) theory have helped many scholars understand how people's needs are being fulfilled today by new technologies. The theory has also been used to explain why traditional media, including print media, have increasingly adapted to online formats and social media. Research based on U&G criteria shows that audiences actively engage with media experiences by selecting content according to the gratifications they seek and the perceived ability of different media sources to fulfill those needs. Wu et al. (2018). While U&G was traditionally applied to radio, television, and the internet, scholars have argued that it is also suitable for examining new communication technologies. In this study, applying U&G to TikTok helps explain how adolescents use this platform to fulfil needs and achieve different gratifications. Kaye & Johnson (2002).

Katz, Blumler, and Gurevitch (1973–1974) identified five core categories of user needs: (1) cognitive needs, related to information acquisition; (2) affective needs, associated with emotional and aesthetic experiences; (3) personal integrative needs, linked to self-esteem and credibility; (4) social integrative needs, reflecting the desire for social interaction and belonging; and (5) tension-release needs, which involve escape, relaxation, and diversion. Although initially developed in the context of traditional mass media, these categories remain highly applicable to contemporary digital environments. With the rise of computer-mediated communication, the relevance of U&G has further expanded. Ruggiero (2000) argues that characteristics such as interactivity, demassification, and a synchronicity make digital media particularly suitable for U&G-based analysis, as they enhance user agency in selecting and shaping media experiences (as cited in Hajdarmataj & Paksoy, 2022, p. 29).

In this sense, users are no longer passive audiences but active participants who construct personalized media environments aligned with their motivations. Building on this perspective, subsequent studies

have reaffirmed the continued relevance of U&G in explaining social media use. Sheldon (2015) emphasizes that the framework has been widely applied to understand why individuals choose specific platforms and content types, particularly in digital contexts. Unlike theories such as cultivation theory, which emphasize media effects on audiences, U&G focuses on the active role of users in selecting media to fulfill diverse informational, social, and psychological gratifications.

This framework is especially relevant for Generation Z, the first generation to grow up fully immersed in digital technology. Gen Z users are among the most active users of social networks, especially TikTok, and they use such platforms to fulfil needs related to entertainment, learning, identity, belonging, and self-expression.

For Generation Z, social media is closely linked to identity performance. Users actively construct and present idealized versions of themselves through photos, stories, and reels, seeking social approval through likes and comments (Sheldon & Bryant, 2016; Djafarova & Rushworth, 2017). This reflects "personal integrative" gratifications, particularly visible on Instagram, where visual self-presentation and status signaling are central (Menon, 2022, p. 3). Users also engage in "surveillance" gratifications by observing others' lives for curiosity and social comparison (Menon, 2022, p. 5). These dynamics are also important for understanding TikTok, where adolescents consume and imitate trends, observe peers and influencers, and negotiate their sense of identity through visual and performative content.

The shift from traditional media to social media creates an important theoretical gap. In traditional media, content is controlled and distributed by institutions, while in social media, content is produced, shared, and circulated by users themselves. Social media also allows more personalized interaction through comments, likes, direct communication, and algorithmic content recommendations. Unlike traditional media, platforms such as TikTok personalize content according to user preferences and enable real-time circulation of information, trends, and influencer-driven communication. This has changed not only how individuals communicate, but also how companies, brands, and public figures reach audiences.

For this reason, theories originally developed in relation to traditional media need to be re-examined in the context of social media and, more specifically, in relation to individual platforms. Each platform sharpens different user needs and gratifications. In the case of TikTok, the dominant gratification is pleasure. TikTok intensifies entertainment, emotional escape, trend participation, identity exposure, and passive gratification. Users may feel active because they scroll, choose, like, follow, or imitate trends, but this activity does not necessarily translate into creative production or critical engagement. Therefore, TikTok offers a particularly important case for updating Uses and Gratifications theory in the digital age.

3. Methodology

The study used a mixed-method approach combining quantitative survey data with qualitative expert interviews. The quantitative component consisted of a structured questionnaire administered to 149 adolescents aged 14–18. Participants came from ten schools in three Albanian regions: Tirana, Durrës, and Dibër. The sample included students from grades 9 to 12. The questionnaire was distributed online, mainly through WhatsApp, due to the accessibility of smartphones and the widespread use of this communication channel among adolescents.

The questionnaire contained 22 closed questions focused on demographic data, TikTok use, time spent on the platform, types of content consumed, motivations for use, emotional impact, information-seeking practices, interaction with others, content sharing, and perceived influence on daily life. Ethical considerations were particularly important because the respondents were minors. Participation was voluntary, data were anonymous, and the questionnaire avoided highly personal or intrusive questions. The study also acknowledged the possibility that some adolescents might provide socially acceptable answers or underreport sensitive aspects of their media use.

The qualitative component consisted of semi-structured interviews with five experts: Dr. Saemira Pino, sociologist; Dr. Elvin Luku, media and communication scholar; Savjola Konja, school psychologist; Dr. Lorena Licenji, lecturer in political and legal sciences; and Dr. Fitim Zekthi, journalist and

communication lecturer. The interviews explored the reasons adolescents are attracted to TikTok, the platform's impact on communication and identity formation, possible risks, the role of parents and educators, and TikTok's potential contribution to digital and media skills. This combination of survey data and expert interpretation allows the paper to move beyond descriptive statistics and toward a broader understanding of TikTok as a social, emotional, educational, and cultural phenomenon among Albanian adolescents.

4. Findings

4.1 TikTok as entertainment and emotional escape

The strongest finding of the study is that TikTok is primarily used for entertainment and emotional gratification. Among the 149 adolescents surveyed, 136 respondents, or 91.3%, reported that they were regular users of TikTok. Only 8.7% stated that they did not use the platform, even though they had access to a smartphone. This confirms TikTok's strong presence in the daily media routine of Albanian adolescents.

The time spent on the platform is also significant. A total of 33.6% of respondents reported using TikTok for one to two hours per day, 26% for two to three hours per day, 22.1% for less than one hour, and 18.1% for more than three hours per day. These figures suggest that for many adolescents, TikTok occupies a substantial portion of their free time. The study further found that 34.2% of respondents often spent more time on TikTok than they had initially planned, while only 20.8% appeared able to manage their time boundaries effectively.

This pattern points to one of the central characteristics of TikTok use: the platform is experienced as pleasurable, but also difficult to regulate. The design of short videos and the constant flow of personalized content encourage prolonged use. For adolescents, TikTok becomes a space of emotional escape, distraction, and stress relief. When asked whether time spent on TikTok could be considered a pleasure or a way to avoid stress and problems, 47.7% of respondents agreed, while another 27.5% partially agreed. This indicates that TikTok is not used only to "pass time," but to manage mood, boredom, and emotional pressure.

The preferred content categories confirm the dominance of entertainment. The most followed content was humor and comedy, selected by 63.1% of respondents, followed by songs and music at 49%, current trends such as fashion at 35.6%, challenges and games at 27.5%, and dance or artistic performances at 15.4%. These preferences show that TikTok's appeal lies in its capacity to provide light, fast, emotionally accessible content that does not require deep concentration.

From a Uses and Gratifications perspective, entertainment emerges as the dominant gratification. TikTok satisfies the need for pleasure, relaxation, and emotional diversion. However, this gratification is not neutral. When entertainment becomes highly personalized, endlessly available, and socially reinforced through trends, it can reshape adolescents' attention, time management, and relationship with offline activities. The survey also found that TikTok use had reduced certain activities among respondents. Studying was the most frequently reduced activity, mentioned by 31.5% of respondents, followed by sports at 30.9%, artistic creation at 25.5%, and time with friends and family at 22.1%. This does not mean that TikTok directly causes these reductions in every case, but it does suggest that time spent on the platform competes with activities that are important for adolescent development.

4.2 TikTok as a source of information, but of limited trust

Although TikTok is mostly used for entertainment, the study shows that it also functions as a source of information for adolescents. A total of 36.9% of respondents stated that they receive information from TikTok every day, while 26.2% reported using it for information several times a week. This finding complicates the idea that TikTok is only a platform of humor, music, and trends. For a considerable number of adolescents, TikTok is part of their information ecosystem.

The types of information followed by adolescents include fashion, technology, career advice, and education. Fashion-related content was followed by 47.7% of respondents, technology-related information by 45%, and career and education advice by 39.6%. These categories reveal that adolescents

use TikTok not only to be entertained, but also to orient themselves toward lifestyle, skills, future opportunities, and social trends. However, the study also reveals a credibility problem. When asked whether information on TikTok is reliable, 49.7% of respondents stated that only some information is trustworthy, 34.9% said they do not consider TikTok a reliable source of information, and only 15.4% believed that most information on TikTok is trustworthy. This shows that adolescents are aware, at least partially, of the platform's limitations as an information source.

This creates an important paradox: adolescents use TikTok for information even though they do not fully trust it. The platform's speed and accessibility make it attractive, but its lack of verification, context, and editorial control creates risks of misinformation and superficial understanding. The issue is not simply whether adolescents receive information from TikTok, but whether they have the critical tools to evaluate what they receive. This finding has strong implications for media literacy. TikTok increasingly participates in how young people learn about the world, yet adolescents may not always distinguish between entertainment, opinion, advertising, misinformation, and verified knowledge. For this reason, media literacy cannot be limited to traditional media or news literacy alone. It must include algorithmic platforms, influencer culture, short-form video, and the emotional appeal of visual information.

4.3 Passive consumption and limited content production

One of the most important findings of the study is the gap between TikTok's participatory promise and the actual behavior of the surveyed adolescents. TikTok is commonly described as a creative platform that allows users to produce, remix, and share content. Yet the majority of respondents in this study appear to use the platform mainly as passive consumers.

When asked how often they share their own videos or content on TikTok, 59.7% of respondents stated that they never do so. Only 9.4% reported sharing content every day, 14.1% several times a week, and 16.8% rarely or only a few times per month. Similarly, 51.7% of respondents said they never comment on other people's videos, while only 4% comment daily. These findings indicate a relatively low level of active participation.

The same tendency appears in relation to followers and social validation. A large majority, 77.2%, stated that TikTok does not significantly influence their connection with followers, while only 4% reported a strong influence. This suggests that many adolescents are not deeply involved in the platform as public performers seeking recognition, but rather as viewers who consume content without necessarily entering into visible interaction.

This pattern is analytically important. It suggests that TikTok's participatory infrastructure does not automatically produce participatory behavior. Adolescents may feel connected to trends and online culture without actively producing content. They may experience belonging through watching rather than posting, through recognizing references rather than contributing to them.

In this sense, TikTok may function for many adolescents like a personalized form of television: always available, algorithmically adapted, emotionally engaging, and socially relevant, but not necessarily participatory. The difference is that unlike television, TikTok creates the feeling of interactivity even when the user remains largely passive. Scrolling, liking, and watching may create a sense of agency, but this is not the same as creative production or critical engagement. The expert interviews help explain this passivity. Some experts pointed to parental control, fear of judgment, lack of media literacy, limited technical knowledge, and the absence of original ideas as possible reasons why adolescents consume more than they create. Others emphasized that Albanian schools have not yet integrated TikTok or short-form video culture into educational practice, leaving adolescents to navigate the platform without structured guidance.

5. Discussion

The findings confirm the continued relevance of Uses and Gratifications theory, but they also show that TikTok requires a more nuanced understanding of gratification in the digital age. Adolescents use TikTok because it satisfies several needs at once: entertainment, escape, information, peer belonging, trend awareness, identity observation, and sometimes self-expression. However, the dominant

gratification is pleasure. TikTok is first and foremost experienced as enjoyable, fast, humorous, musical, and emotionally relieving.

At the same time, the study shows that pleasure does not necessarily lead to participation. This is the central contribution of the paper. TikTok offers the technical possibility of creativity, but the adolescents surveyed mostly use it as consumers. These finding challenges optimistic assumptions about social media as automatically empowering or participatory. Access to digital tools does not by itself produce digital agency.

The first major tension is therefore between creativity and consumption. Dr. Elvin Luku emphasizes TikTok's potential to develop multimedia thinking, symbolic expression, and creative communication. From this perspective, TikTok could be used educationally, especially if schools asked students to transform ideas, texts, or social topics into short video productions. This would move students from passive reception to active creation. However, the survey results suggest that this potential remains underused among Albanian adolescents.

The second tension is between information and credibility. TikTok is increasingly used as a source of information, yet adolescents do not fully trust the information they receive there. This gap points to the need for media literacy that is adapted to the platform culture of Gen Z. Adolescents need to understand not only whether a source is reliable, but also how algorithms prioritize content, how influencers build authority, how emotional formats shape belief, and how misinformation can circulate through entertainment.

The third tension is between identity expression and identity distortion. TikTok gives adolescents opportunities to observe, imitate, perform, and sometimes express themselves. It can support creativity, visibility, and self-confidence, particularly when young people use it to share talents or interests. However, experts in the study also warn that TikTok can encourage comparison, imitation, distorted self-presentation, and dependence on external validation. Savjola Konja and Dr. Lorena Licenji both emphasize that online self-presentation may not reflect the real adolescent, creating a gap between lived identity and performed identity.

The fourth tension concerns emotional impact. Many adolescents report that TikTok does not significantly affect their emotions, yet some experts argue that the influence may be unconscious. Dr. Fitim Zekthi offers the most critical interpretation, arguing that image-based communication may weaken deeper thinking and reduce adolescents' capacity for critical interpretation. While this view is more pessimistic than the others, it raises an important point: adolescents may not always be able to recognize the emotional or cognitive effects of platforms they use every day.

Taken together, these tensions suggest that the problem is not TikTok itself, but the absence of critical mediation around TikTok. Prohibition alone is unlikely to be effective, especially when the platform is already embedded in adolescent culture. At the same time, uncritical acceptance would ignore real concerns related to time management, misinformation, emotional vulnerability, privacy, and passive consumption.

The most productive approach is educational integration. TikTok and similar platforms should be addressed through media literacy, digital creativity, critical thinking, and guided production. Schools should not treat TikTok only as distraction or danger, but as a cultural form that students already understand and use. Parents should also move beyond simple control and toward dialogue, helping adolescents set boundaries, evaluate content, and reflect on the difference between online performance and real-life identity.

6. Conclusions

This paper examined TikTok use among Albanian adolescents aged 14–18 through the lens of Uses and Gratifications theory. The findings show that TikTok is deeply embedded in adolescent media routines and is used primarily for entertainment, emotional escape, trend awareness, and the consumption of short-form humorous and musical content. While the platform also functions as a source of information and a possible space for identity expression, its creative and educational potential remains only partially realized.

The study's central conclusion is that, among the surveyed adolescents, TikTok is a platform of pleasure before participation. Most respondents use TikTok regularly, but many do not post their own content, do not comment frequently, and do not strongly relate their use of the platform to follower interaction or public recognition. This means that TikTok's participatory design does not automatically produce active participation. For many adolescents, TikTok operates as a personalized entertainment environment rather than a creative public sphere.

At the same time, TikTok cannot be dismissed as merely harmful or superficial. It offers real possibilities for creativity, self-expression, multimedia communication, and informal learning. The challenge is to transform these possibilities into meaningful practices. This requires media literacy, educational innovation, parental dialogue, and critical awareness of how algorithmic platforms shape attention, emotion, identity, and social belonging.

Future research should further explore gender differences, rural-urban differences, the role of algorithms in adolescent media habits, and the long-term impact of TikTok on identity formation, emotional wellbeing, and digital citizenship in Albania. More qualitative research with adolescents themselves would also help explain the gap between heavy use and low self-reported emotional impact. Ultimately, TikTok should be understood as one of the key cultural spaces where Albanian adolescents negotiate pleasure, belonging, identity, and visibility. The task for educators, parents, and researchers is not simply to reject this space, but to help young people inhabit it more critically, creatively, and responsibly.

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TOWARDS DEEPER INSIGHTS INTO FRACTIONAL PROBLEMS

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ABSTRACT

In this study, we explore a new category of separated boundary value problems for non-linear fractional differential equations where the non-linear term f relies on a lower-order fractional derivative given by:

$$c_{D_{0^+}^{\alpha}} x(t) = f\left(t, x(t), c_{D_{0^+}^{\beta}} x(t)\right) \quad , \quad t\epsilon[0,T], 1 < \alpha \leq 2 , 0 < \beta \leq 1$$

subject to separated fractional boundary conditions :

$$a_1 x(0) + b_1 \left(c_{D_{0^+}^{\gamma}} x(0)\right) = c_1 \quad , \quad a_2 x(T) + b_2 \left(c_{D_{0^+}^{\gamma}} x(T)\right) = c_2 \quad , \; 0 < \gamma < 1$$

Here $c_{D_{0^+}^{\alpha}}$, is the Caputo fractional derivative, $f : [0,T] \times R^2 \rightarrow R$ is a continuous function, and a_i, b_i, c_i ,$i = 1, 2$ are real constants satisfying: $a_1 \neq 0$ and $T > 0$.

The aim of this work is to study the existence and uniqueness of solutions to the separated fractional boundary value problem using the Schauder fixed point theorem, which is a topological theorem that asserts a relatively compact map has a fixed point that is not necessarily unique. Therefore, it is not necessary to establish estimates on the function, but rather on its compactness.

To conclude, an example is presented to illustrate the application of this theorem.

Keywords: fractional differential equation, separated fractional boundary conditions, Schauder fixed point theorem, existence.

INDIAN DIASPORA ABROAD: A STUDY OF THE POLITICAL AND ECONOMIC STRUGGLE, ACHIEVEMENTS AND CONTRIBUTIONS OF THE INDIAN DIASPORA IN ZIMBABWE AND ZAMBIA

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ABSTRACT

Diaspora communities play a pivotal role in the international as well as domestic politics and economic development of various countries of the world including India. Considering such aspects, it is very important to understand the involvement of Indian diaspora in their host countries of Zimbabwe and Zambia and its impact on the economy and politics of the home country India. The existing studies on Indian diaspora largely covered the socio-economic and political situation of Indian diaspora in South and East Africa but very little attention paid to socio-economic and political situation of Indian diaspora in Central African countries especially Zimbabwe and Zambia in many ways remained unexplored. So, this paper attempts to study the economic and political journey, the struggle, survival as well as the contributions of Indian diaspora in Zimbabwe and Zambia. The Indian diaspora also contributed to the national movement of these countries. Although the number of Indians are miniscule in both these countries but they made remarkable contributions in the political as well as in the economic spheres. Within this backdrop, this paper attempts to study the economic and political struggle and challenges of Indian diaspora in the Zimbabwe and Zambia from historical perspectives. Secondly, it attempts to study the achievements and the contributions of Indian diaspora at the economic and political sphere. Thirdly, the paper will study the diaspora politics and policies of both the host countries Zimbabwe and Zambia and the home country India on the Indian diaspora.

PERSONALIZED PROSTHETIC PRESCRIPTION IN TRANSTIBIAL AMPUTEES: THE EFFECTS OF AGE, GENDER, AND ACTIVITY LEVEL ON PROSTHESIS SELECTION AND FUNCTIONAL OUTCOMES

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ABSTRACT

Prosthetic prescription following transtibial amputation is a complex process that requires consideration of individual characteristics and functional needs. This review aims to examine the influence of age, gender, and activity level on prosthetic selection and functional outcomes in transtibial amputees based on current evidence. Age is a key factor in prosthetic prescription. In younger and more active individuals, energy-storing prosthetic feet, dynamic socket systems, and sport-specific components are commonly preferred. In contrast, among older adults, priorities tend to focus on safe ambulation, balance, fall prevention, and overall comfort. Gender should also be considered as an important variable, as differences in body composition, socket geometry, and gait biomechanics may influence prosthetic management. Furthermore, cosmetic expectations and satisfaction with the prosthesis may vary between genders. Activity level represents another major determinant in prosthetic prescription. It is typically assessed using the K-level classification system and serves as a guide for selecting appropriate prosthetic feet, sockets, and componentry. Personalized prosthetic prescription extends beyond prosthesis selection and also informs rehabilitation planning. In this context, an individual's functional capacity, occupational and social demands, and psychosocial status should be taken into consideration. The findings of this review suggest that prosthetic prescription in transtibial amputees should not be regarded solely as a technical decision. Rather, personalized approaches that account for age, gender, and activity level may contribute to improved participation in daily life, greater independence, enhanced comfort, and better quality of life.

Keywords: Transtibial amputation; Prosthetic prescription; Activity level; Functional outcomes.

PREDICTING USER SENTIMENT FROM MOBILE BANKING EXPERIENCE DIMENSIONS: A MULTILINGUAL NLP STUDY OF RAIFFEISEN BANK REVIEWS IN ALBANIA AND KOSOVO

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ABSTRACT

This study explores how different dimensions of user experience shape the emotional tone of reviews left for a mobile banking application, with a particular focus on what drives sentiment rather than star ratings. Using a combined corpus of reviews collected from Raiffeisen Bank's mobile application in Albania and Kosovo, we apply a natural language processing pipeline that moves through sentiment classification, automatic topic discovery, and regression analysis to uncover which aspects of the user experience matter most to how people actually feel and express themselves about the app. Client reviews were analyzed using multilingual BERT for sentiment classification and BERTopic for identifying latent user experience dimensions. The resulting topic probability scores were then used as predictors in a Hierarchical Multiple Linear Regression model, structured into three blocks to assess the incremental explanatory contribution of each set of variables.

The findings reveal a clear pattern: *technical problems* dominate the picture. When the application fails to function as expected, user sentiment declines markedly, while technical issues have a stronger impact than usability or satisfaction-related factors.

Beyond its empirical findings, this study offers a methodological template for sentiment-driven experience analysis in linguistically underrepresented digital markets particularly within the Western Balkans

Keywords: mobile banking, sentiment prediction, BERTopic, multiple linear regression, mBERT, Albania, Kosovo, NLP, Western Balkans, user experience

1 INTRODUCTION

Mobile banking has become one of the most frequent points of contact between customers and financial institutions fundamentally reshaping how banking services are delivered and experienced globally [6,12]. Unlike a branch visit or a phone call, a banking app is available around the clock, and when it works well, it quietly earns trust. When it fails, the frustration tends to be immediate and visceral and increasingly, users share that frustration publicly through app store reviews. These reviews have attracted growing research attention as a source of unsolicited, authentic user feedback [9,10].

Most studies in this space have focused on predicting star ratings from thematic content, treating numerical satisfaction scores as the outcome of interest [13]. This study takes a different angle. Rather than asking what predicts how many stars a user gives, we ask what shapes how they feel as reflected in the sentiment of what they write. The distinction matters: a five-star review written with mild approval and a five-star review written with genuine enthusiasm carry different informational content, and collapsing both into the same outcome measure loses that signal [9].

We focus on Raiffeisen Bank's mobile application in Albania and Kosovo, two Albanian-speaking markets that share a language and significant cultural overlap while operating under different regulatory and banking infrastructure conditions. Together, they offer a natural setting for studying user sentiment

in an underrepresented linguistic context, using a combined corpus that is large enough to support meaningful analysis while remaining grounded in a specific, coherent review corpus [10].

The resulting topic probabilities are then incorporated into hierarchical regression models to estimate the expected sentiment polarity associated with different user experience dimensions. Beyond identifying statistically significant predictors, this approach allows us to quantify the relative contribution of technical, usability, and satisfaction-related factors in explaining variation in user sentiment. From a practical perspective, the resulting model can provide actionable insights for mobile banking providers by identifying which aspects of the user experience are most strongly associated with positive or negative user sentiment and therefore deserve priority attention in application development and maintenance.

The research questions are:

• Which user experience dimensions identified through BERTopic significantly predict the sentiment polarity across the hierarchical regression models?

• How does the explanatory power of sentiment prediction change across the three hierarchical models (Model 1, Model 2, and Model 3)?

• Which user experience dimensions demonstrate the strongest independent effect on sentiment polarity in the final model?

2 METHODOLOGY

This study integrates natural language processing techniques with regression modelling to examine how user experience dimensions extracted from BerTopic to provide authentic feedback reflecting real user experiences and perceptions. A hierarchical multiple regression with Enter method was employed to assess the incremental contribution of each block of variables based on theoretical considerations [5,15].

2.1 Data Collection and Preparation

Reviews were collected from the official Raiffeisen Bank mobile applications on Google Play and the App Store for Albania and Kosovo using the google-play-scraper Python library. Three hundred reviews were targeted per market, yielding an initial dataset of 600 reviews. Preprocessing involved lowercasing, removal of URLs and special characters, elimination of reviews shorter than five characters, and deduplication, resulting in a final analytical dataset of 482 reviews [9]. Table 1, presents the main characteristics of the dataset, including collection statistics, preprocessing outcomes, and descriptive rating distributions.

Table 1. Dataset Description Raiffeisen Bank Albania and Kosovo

Characteristic	Raiffeisen Albania	Raiffeisen Kosovo	Total
Reviews collected	300	300	**600**
After preprocessing	237	245	**482**
Source	Google Play + App Store		—
Language	Albanian + English		—
Rating 1 (%)	22.8%	21.7%	22.8%
Rating 5 (%)	64.2%	68.8%	68.8%

2.2 Sentiment Classification mBERT

Sentiment classification was performed using the multilingual transformer model (nlptown/bert-base-multilingual-uncased-sentiment), implemented via the Hugging Face Transformers API [2]. The model

produces five ordinal sentiment classes (1–5 stars), which were subsequently aggregated into three polarity categories: Negative (≤1–2 stars, encoded as −1), Neutral (3 stars, encoded as 0), and Positive (≥4 stars, encoded as +1). This numerical encoding serves as the dependent variable throughout the regression analysis. The model produces class probabilities for the sentiment categories. To obtain a continuous outcome variable suitable for regression analysis, a sentiment polarity score was calculated as the difference between the predicted probability of positive sentiment and the predicted probability of negative sentiment:

$$\text{Sentiment_Score} = \text{Probability(Positive)} - \text{Probability(Negative)}$$

The resulting score ranges from −1 to +1, where higher values indicate more positive sentiment and lower values indicate more negative sentiment. This continuous sentiment polarity score was used as the dependent variable in all regression analyses.

Classification quality was assessed against *silver-standard* labels derived from user provided star ratings which are commonly used as *proxy ground truth* in sentiment analysis tasks when manual annotation is not available. Classification performance was evaluated against silver-standard labels derived from user-provided star ratings. Evaluation was conducted using standard classification metrics, including precision, recall, F1-score, accuracy, and Cohen's kappa (κ), which measures agreement beyond chance [5]. Table 2 presents the full evaluation results.

Table 2. mBERT Sentiment Validation Pooled Corpus (n=482)

Metric	Negative	Neutral	Positive	Assessment
Accuracy	—	—	—	**75.5%**
Cohen's κ	—	—	—	**0.558**
Precision	0.69	0.03	0.95	—
Recall	0.90	0.7	0.69	—
F1-Score	0.77	0.05	0.79	—
F1 Weighted	—	—	—	**0.77**

Note. *The low F1-Neutral (0.05) reflects the limited number of 3-star reviews in the bimodally distributed corpus. Cohen's κ = 0.558 corresponds to Moderate agreement [17]. Accuracy 75.5% and weighted F1 0.77 are acceptable for a bilingual corpus.*

The mBERT sentiment classifier achieved an overall accuracy of 75.5% and a weighted F1-score of 0.77, with Cohen's κ = 0.558 indicating moderate agreement with proxy labels [17] while precision and recall were strong for the Negative (0.69/0.90) and Positive (0.95/0.69) classes, the Neutral class performed poorly (F1 = 0.05), reflecting the scarcity of three-star reviews in the bimodally distributed corpus.

2.3 Topic Modeling BERTopic

BERTopic was applied using sentence-transformer embeddings, UMAP dimensionality reduction, and HDBSCAN clustering [4]. BERTopic was selected due to its ability to capture contextual semantic relationships in short and noisy textual data, making it particularly suitable for app store reviews and social media-style text [3]. Compared with traditional probabilistic topic modeling approaches such as Latent Dirichlet Allocation (LDA), transformer-based topic models generally demonstrate improved semantic coherence and contextual sensitivity in short-text environments [3]. The number of topics was not predefined, allowing the model to determine the optimal topic structure. Six coherent dimensions emerged, each of them was labeled manually after inspection of the top keywords and representative review documents [4]. Table 3 summarizes the extracted user experience dimensions.

Table 3. User Experience Dimensions BERTopic Applied to Pooled Corpus (n=482)

Topic	Label	Top Keywords	Representative Review
0	**Technical_Issues**	nuk, the, it, to, me, app	*"app doesn't function properly"*
1	**General_Satisfaction**	shum, mir, shume, super, jam	*"shum e mir", "shum i mir"*
2	**Banking_Service**	bank, banking, Raiffeisen	*"raiffeisen bank is the best"*
3	**Ease_of_Use**	very, easy, use, useful, application	*"love this app easy and useful"*
4	**Positive_Appraisal**	app, great, wonderful, excellent	*"great app", "wonderful app"*
5	**Technical_Failures**	nuk, punon, work, hapet, funksionon	*"nuk punon", "nuk hapet"*

2.4 Multicollinearity Diagnostics and Assumption Cheks

Before fitting the regression model, predictor independence was assessed using Variance Inflation Factors (VIF) and pairwise Pearson correlations [5,15]. The VIF for predictor $i=(1,2,...,5)$ is defined as:

$$VIF_i = 1 / (1 - R^2_i) \qquad (1)$$

Values below 5.0 indicate no multicollinearity concern [5]. The results indicate that all predictors fall within acceptable thresholds, indicating no severe multicollinearity.The negative correlations among topic variables reflect their probabilistic nature: since topic probabilities sum to 1.0 per review, one dimension gaining probability mass necessarily reduces it for others. Despite this property, diagnostic tests indicated acceptable levels of collinearity. No pairwise correlation exceeded |r| = 0.379, suggesting that the predictors remain suitable for regression analysis [15]. The correlation structure supports the validity of including all variables in the regression analysis. Figures 2 and 3 present the the multicollinarity diagnostic results.

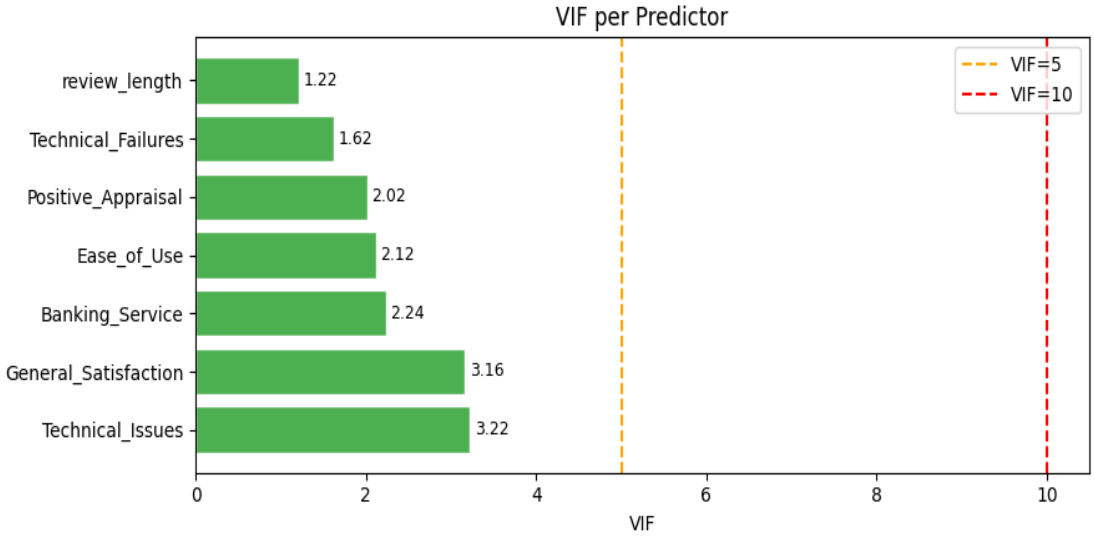


Figure 1. Variance Inflation Factors (VIF) for all predictors

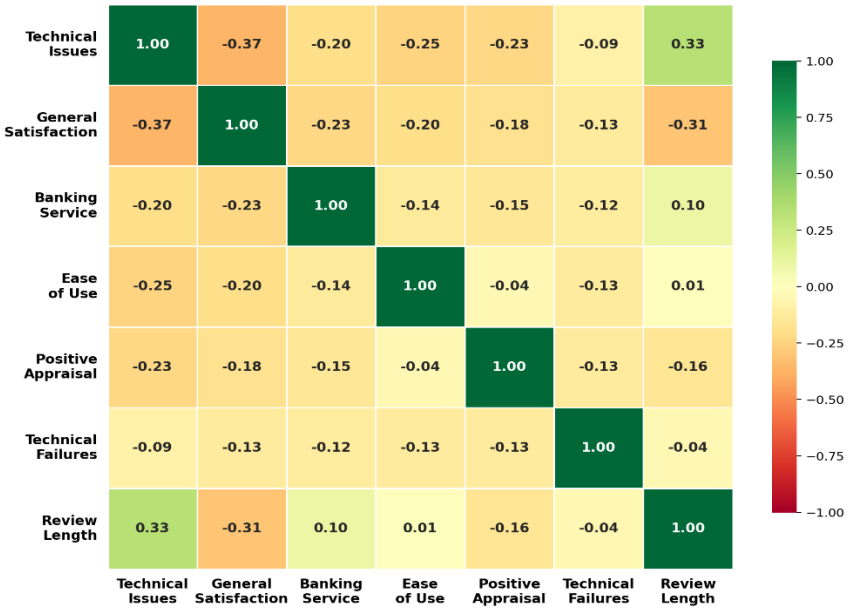


Figure 2. Pearson Correlation Matrix All Predictors**.**

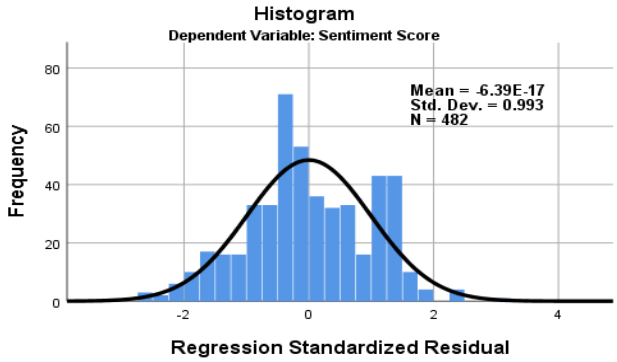
2.5 Hierarchical Multiple Regression Analysis Results

A Multiple Linear Regression (MLR) model was employed to examine the relationship between user experience dimensions and sentiment polarity derived from mBERT outputs. MLR is a widely used statistical technique for modeling the linear relationship between a dependent variable and multiple independent predictors [1]. The dependent variable is the continuous sentiment polarity score derived from mBERT class probabilities, while the independent variables consist of six BERTopic topic probability scores and review length. All continuous predictors were standardized using z-score normalization prior to estimation.

In hierarchical regression analysis, the Enter procedure was applied, where seven variables were entered into the model in a structured manner in three consecutive blocks, with the aim of assessing the additional contribution of each group of variables in explaining the dependent variable Y, namely sentiment polarity. In Block 1, the control variables were included, forming the basic Model 1 given by the equation (1). In Block 2, the main explanatory variables were added, expanding the model as shown in equation (2) and testing the increase in explanatory power. At the last third Block, additional dimensions of the user experience were included, forming the Model 3 presented in equation (3).

At each step of the analysis, the change in the coefficient of determination (ΔR^2) was estimated, to identify the additional contribution of each block in explaining the variation in sentiment. This approach allows for a more in-depth interpretation of the influencing factors, showing not only the individual effect of the variables, but also the progressive improvement of the explanatory power of the model. The objective is to elucidate how variations in latent experience dimensions correlate with changes in the anticipated sentiment conveyed in user reviews, rather than to predict future behavior.

2.6 Diagnostic Checks



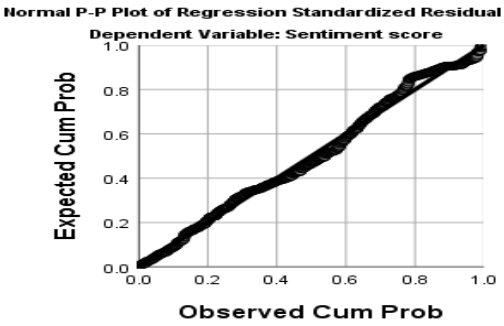


Figure 3. The histogram of standardized residuals **Figure 4.** The Normal P–P plot of standardized residuals

The histogram of standardized residuals (Figure 3.) indicates that the residuals are approximately normally distributed, with a mean close to zero and a standard deviation close to one. Although minor deviations from normality are observed in the right tail, these are not substantial enough to violate regression assumptions [5]. Therefore, the normality assumption of the regression model is considered satisfied.

The Normal P–P plot of standardized residuals (Figure 4) indicates that the observed cumulative probabilities closely follow the expected diagonal line, suggesting that the residuals are approximately normally distributed. Minor deviations are observed at the tails; however, these are not substantial enough to violate the normality assumption [15]. Combined with the histogram results, the assumption of normality is considered satisfied.

The Durbin–Watson statistic, DW = 1.893 (Table 4) is close to the ideal value of 2, indicating that there is no evidence of autocorrelation among residuals. This suggests that the independence assumption of the regression model is satisfied, supporting the validity of the inferential results [5].

Overall, these diagnostic results indicate that the assumptions of linear regression (normality of residuals and independence) are sufficiently met supporting the validity of subsequent inferential interpretations [15].

2.7 Hierarchical Regression Overview

A hierarchical multiple regression was conducted to examine the incremental explanatory power of different groups of predictors on the continuous sentiment polarity score. Table 5 presents the overall model fit indicators across the three hierarchical steps.

Table 4. Overall Quality Indicators of the Hierarchical Regression Models

Indicator	Model 1	Model 2	Model 3
Predictors Included	Review_ Length	+ Technical_Issues,Technical_Failures	+ General_Satisfaction, Banking_Service,Ease_of_Use, Positive_Appraisal
R	0.37	0.697	0.743
R^2	**0.137**	**0.486**	**0.552**
Adjusted R^2	0.135	0.483	0.545
R^2 Change (ΔR2)	**0.137**	**0.349**	**0.066**
F Change	76.356	161.966	17.519
Sig. F Change	0	0	0
Std. Error of Estimate	0.694	0.537	0.503
Durbin-Watson	—	—	**1.893**

The results in Table 4 show a clear improvement in model performance across the three hierarchical steps. In Model 1, the control variable *Review Length* explains only 13.7% of variance in sentiment polarity (R^2=.137). In Model 2, a large increase in explanatory power is observed (ΔR^2=.349), reaching 48.6% of the explained variance. This indicates that dimensions related to *technical problems* are the main factors in shaping user sentiment. Model 3 adds variables related to *user experience* and *satisfaction*, bringing a further, but more moderate increase (ΔR^2=.066), with a final value of R^2=.552. This suggests that, although positive user factors contribute to explaining sentiment, their impact is more limited compared to technical problems. The standard error of the estimate decreases progressively from Model 1 (0.694) to Model 3 (0.503), indicating improved predictive accuracy as additional predictors are included.

Overall, the hierarchical model shows that negative factors (technical problems) have greater explanatory weight than positive user experience factors.

3 Results of the Experiment

The results are presented across three hierarchical regression models. The first model includes only the control variable R*eview Length*, establishing a baseline level of explanatory power for sentiment polarity. The second model introduces *technical complaint* related dimensions identified through BERTopic, allowing assessment of the additional variance explained by *operational and functional problems*. The third and final model incorporates usability and *satisfaction* related dimensions, enabling evaluation of whether positive user experience factors contribute explanatory power beyond technical issues alone. This hierarchical structure allows examination of the incremental contribution of each theoretically motivated block of predictors to sentiment polarity.

3.1 OLS Enter Model 1

The first hierarchical regression model included only the control variable review length in order to establish a baseline level of explanatory power for sentiment polarity.

$$Sentiment = \beta_0 + \beta_1(Review_{Length}) + \varepsilon \quad (1)$$

Table 5. Regression Results for Model 1: OLS Enter (n=482)

Model	Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95 % Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	0.220	0.042		5.270	0.000	0.138	0.302
	Review_Length	-0.017	0.002	-0.370	-8.738	0.000	-0.021	-0.013

Model 1 examined the effect of review length on sentiment polarity. The results show that *Review Length* is statistically significant and has a negative effect ($\beta = -.370$, $p < .001$). This means that reviews are associated with more negative sentiment polarity. This result suggestes that user tend to write more when they experience dissatisfaction, expressing it in more detail. However, the explanatory power of the model is limited (R^2=.137), indicating that text textual length alone as a basic indicator of user behaivor in expressing dissatisfaction.

3.2 Model 2

In Model 2, the dimensions identified through BERTopic related to technical issues (*Technical_Issues* and *Technical_Failures*) are added, along with *Review Length*. The results show a significant improvement in the model ($\Delta R^2 = .349$, $p < .001$). This indicates that *technical issues* are the dimensions most strongly associated with variation in user sentiment.

$$Sentiment = \beta_0 + \beta_1(Review_{Length}) + \beta_2(Technical_{Issues}) + \beta_3(Technical_{Failures}) + \varepsilon \quad (2)$$

Table 6. Regression Results for Model 2: OLS Enter (n=482).

Model	Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95 % Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
2	(Constant)	0.550	0.038		14.601	0.000	0.476	0.624
	Review_Length	-0.009	0.002	-0.191	-5.456	0.000	-0.012	-0.006
	Technical_Issues	-1.250	0.078	-0.563	-16.062	0.000	-1.403	-1.097
	Technical_Failures	-1.533	0.165	-0.307	-9.307	0.000	-1.856	-1.209

After adding technical problem related topics in Model 2, both *Technical_Issues* ($\beta = -.563$, $p < .001$) and *Technical_Failures* ($\beta = -.307$, $p < .001$) are statistically significant and have negative effect in sentiment. These results show that users react strongly negatively to *functional issues and application failures*. Also, the effect of Review_Length decreases (from $\beta = -.370$ to $\beta = -.191$), suggesting that part of the effect of Review Length is explained by content related to technical issues. Overall, Model 2 confirms that the technical quality of the application is the most important factor in the formation of negative sentiment.

3.3 Model 3. Full User Experience and Satisfaction Model

The third hierarchical regression model incorporated usability- and satisfaction-related dimensions in addition to the variables retained from the previous models. Specifically, *General_Satisfaction*, *Banking_Service*, *Ease_of_Use* and *Positive_Appraisal* were added in order to evaluate whether broader user experience perceptions contribute additional explanatory power beyond technical complaint-related dimensions.

The final model incorporated satisfaction and usability-related variables:

$$Sentiment = \beta_0 + \beta_1(Review_{Length}) + \beta_2(Technical_{Issues}) + \beta_3(Technical_{Failures}) + \beta_4(General_{Satisfaction}) + \beta_5(Banking_{Service}) + \beta_6(Ease_{of\,Use}) + \beta_7(Positive_{Appraisal}) + \varepsilon \quad (3)$$

Table 7. Regression Results for Model 3: OLS Enter (n=482).

Model	Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95 % Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
3	(Constant)	0.244	0.102		2.384	0.018	0.043	0.446
	Review Length	-0.009	0.002	-0.195	-5.725	0.000	-0.012	-0.006
	Technical Issues	-0.964	0.116	-0.434	-8.327	0.000	-1.192	-0.737
	Technical Failures	-1.162	0.186	-0.232	-6.233	0.000	-1.529	-0.796
	General Satisfaction	0.069	0.118	0.030	0.581	0.561	-0.163	0.300
	Banking Service	0.173	0.138	0.056	1.254	0.210	-0.098	0.443
	Ease of Use	0.925	0.179	0.212	5.160	0.000	0.572	1.277
	Positive Appraisal	0.943	0.177	0.223	5.324	0.000	0.595	1.292

In Model 3, extends the previous specification by including the dimensions of user experience and satisfaction, namely *Ease_of_Use, Positive_Appraisal, Banking_Service and General_Satisfaction*. The results show that the model explains **55.2**% of the variance in sentiment polarity (Adjusted R^2 = .545), with a statistically significant increase compared to Model 2 (ΔR^2 = .066, p < .001). Among the new variables included, *Positive_Appraisal* ($\beta = 0.223, p < 0.001$) and *Ease_of_Use* ($\beta = 0.212, p < 0.001$) results as significant positive predictors of sentiment polarity. These findings indicate that users' positive emotional expressions and perception of the ease of use of the application play an important role in shaping overall sentiment. In contrast, *General_Satisfaction* ($\beta = 0.030, p = 0.561$), *Banking_Service* ($\beta = 0.056, p = 0.210$), are not statistically significant in the final model. This suggests that their effect are absorbed by more specific variables such as usability and direct expressions of positive sentiment, indicating a conceptual and statistical overlap between the constructs. Compared to Model 2, the standardized coefficient of *Technical_Issues* decreases from $\beta = -0.563$ to $\beta = -0.434$, suggesting a partial overlap of variance between technical issues and broader dimensions of user experience. However, this factor remains statistically significant and has a strong effect, confirming its dominant role in shaping sentiment. Overall, the results of Model 3 indicate that sentiment formation in mobile *banking reviews* is influenced by both negative *technical experiences* and *positive perceptions of usage*. However, technical problems have a stronger and more lasting impact, reflecting an asymmetry in how users evaluate digital banking services.

4 Discussion

The hierarchical regression results reveal a consistent pattern across all models. Sentiment in reviews of the Raiffeisen Bank is primarily related to *technical reliability*, followed by *usability and satisfaction*-related perceptions.

Model 1 confirms that *review length* is a modest but significant predictor of sentiment, indicating that dissatisfied users tend to produce longer and more detailed reviews [9, 10].

Model 2 demonstrates a substantial increase in explanatory power, highlighting technical issues as the strongest predictor of sentiment polarity. This finding aligns with established mobile banking literature emphasizing system reliability as a core driver of customer satisfaction [6,11,12].

Model 3 shows that usability and satisfaction variables contribute additional explanatory power; however, their effects are smaller compared to technical factors. This asymmetry is consistent with expectancy-disconfirmation theory and negativity bias, where negative experiences exert stronger psychological influence than positive ones [7,11].

Importantly, the consistency of results across Albania and Kosovo suggests that technical reliability is a robust determinant of sentiment in Albanian-speaking mobile banking users, despite differences in institutional and regulatory environments.

The practical ramifications of these findings are especially pertinent to digital banking administration. The regression model quantifies the anticipated change in sentiment linked to each user experience dimension, thereby facilitating evidence-based prioritization of software development resources. The findings suggest that advancements in application stability, error management, and transaction dependability are expected to yield greater increases in user sentiment than improvements concentrated exclusively on interface design or supplementary features. The amalgamation of sentiment classification, topic modelling, and regression analysis establishes a framework that can function as an early-warning monitoring system, enabling banks to identify nascent technical issues via user reviews prior to their significant impact on overall customer satisfaction metrics.

5 Conclusion

The proposed framework transcends mere descriptive sentiment analysis from a practical standpoint. This approach integrates multilingual sentiment classification, topic modelling, and hierarchical regression, allowing banks to assess the anticipated sentiment linked to various user experience dimensions and to pinpoint areas with the highest potential influence on customer perception. This information may facilitate strategic decisions concerning software maintenance, enhancement of service quality, and prioritization of digital banking investments.This study examined which dimensions of user experience predict sentiment polarity in reviews of the Raiffeisen Bank mobile application, using a hierarchical approach that combines sentimental classification with multilingual BERT, BERTopic topic modeling, and Hierarchical Multiple Linear Regression analysis applied to 482 reviews collected from Albania and Kosovo [2,3,4].

The empirical results presented in Table 4 (summary of hierarchical models) show a clear and systematic improvement in explanatory power in all three models. In Model 1, where only *Review Length* is included, a limited part of the variance in sentiment is explained ($R^2 = 0.137$). This result is also confirmed in Table 5, where Review Length is statistically significant, indicating that longer reviews are associated with more negative sentiment [9]. Model 2 brings the greatest increase in explanatory power ($\Delta R^2 = 0.349$), bringing the explained variance to 48.6%, as shown in Table 6. This increase comes from the inclusion of the technical issues dimension. In Table 6, both *Technical_Issues* and *Technical_Failures* result in strong negative predictors of sentiment, confirming that technical issues are the main factor in shaping users' attitudes. Model 3 further increases the explanatory power of the model to $R^2 = 0.552$ (Adjusted $R^2 = 0.545$), with a smaller but statistically significant increase ($\Delta R^2 = 0.066$), as seen in Table 6. According to Table 7, the variables Ease_of_Use and Positive_Appraisal result in significant positive predictors of sentiment. Meanwhile, General_Satisfaction and Banking_Service are not statistically significant, suggesting that their effect overlaps with more specific constructs of user experience. Overall, the results from Tables 5–7 show a clear hierarchical pattern: sentiment is initially influenced by behavioral characteristics (review length), then dominated by technical system factors, and finally complemented by usability and emotional expression dimensions. The dominance of technical issues in all models confirms that system stability is the most important factor in shaping sentiment, as evidenced by the standardized coefficients in Tables 6 and 7. Although usability and satisfaction factors contribute to improving the model, their impact remains secondary, reflecting a clear asymmetry in how users evaluate digital banking services. From a practical perspective, these results suggest that for Raiffeisen Bank, improving application stability, backend functionality, error handling, and transaction reliability is likely to have a greater impact on user sentiment than adding new features or improving the interface's aesthetics.

Beyond the empirical contributions, the study also demonstrates the methodological value of combining transformer models for sentiment analysis, BERTopic for topic modeling, and hierarchical regression for statistical analysis of textual data in multilingual environments with limited resources. The progressive increase in explanatory power shown in Table 4 supports the validity of this integrated approach. Finally, several limitations should be highlighted, including the focus on a single banking institution, the use of "silver-standard" labels for sentiment validation, and the cross-sectional nature of

the data. Future research could extend this framework to several banks in the Western Balkans region, include temporal analysis, and apply more advanced sentiment models at the aspect level.

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VI. International

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6. International British Congress "disiplinlerarası bilimsel araştırmalar ve uygulamaları" 18-21 Haziran 2026 tarihleri arasında Londra, İngiltere'de 26 farklı ülkenin akademisyen/araştırmacılarının katılımıyla gerçekleşmiştir. Kongre kapsamında sunumu yapılan 146 bildirinin 59 adeti Türkiye'den katılımcılar tarafından; 87 bildiri ise 26 ülkeden katılımcılar tarafından sunulmuştur. 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,
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LONDON SOVEREIGN SCHOOL

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February 13, 2026

This Official Protocol Declaration is hereby issued by London Sovereign School (hereinafter referred to as "the Institution"), a duly constituted academic and research entity operating within the United Kingdom and possessing full legal personality under applicable UK law.

Pursuant to the Institutional Charter, Academic Regulations, and Internal Statutes, the Senate of the Institution, at its duly convened session held on **14 January 2026**, did hereby adopt and enact Resolution **No. 2026/7**, whereby it is formally decreed that the scientific event specified hereunder shall be organized under the official auspices and academic supervision of the Institution. The said event shall be deemed an official academic undertaking of London Sovereign School and shall be conducted in strict conformity with principles of academic integrity and all applicable legal and regulatory provisions in force.

By virtue of the aforesaid Resolution, the academicians and designated officials serving within the Organizing Committee, Scientific Committee, Advisory Board, and related academic bodies have been duly nominated and ratified by the Senate. The list of appointed members constitutes an integral and legally operative part of this Declaration.

This Declaration shall enter into force upon issuance and remain in full force and effect unless otherwise amended by Senate resolution.

Dr. Mariam S. OLSSON
Deputy President

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