

I. ULUSLARARASI NESEBAR BİLİMSEL ARAŞTIRMALAR VE İNOVASYON KONGRESİ KONGRE KİTABI

14-15 ŞUBAT 2026

BULGARİSTAN



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**1. INTERNATIONAL NESSEBAR SCIENTIFIC RESEARCH
AND INNOVATION CONGRESS BOOK
14-15 February/2026, BULGARIA**

**EDITOR
Assoc. Prof. Dr. Erkan DİKİCİ**

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CONGRESS ID
CONGRESS TITLE

1. INTERNATIONAL NESSEBAR SCIENTIFIC RESEARCH AND INNOVATION CONGRESS,

DATE and PLACE

14-15 February/2026, BULGARIA

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14-15 February/2026

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15.02.2026
TÜRKİYE Local Time: 16:30-18:30

HEAD OF SESSION: Doç. Dr. Ruhangiz Aliyeva

SESSION-1 HALL-1

AUTHORS	AFFILIATION	TOPIC TITLE
Kaan Düzdemir	<i>Yakın Doğu Üniversitesi</i>	<i>İLKEL TOPLUMDAN DEVLETLİ YAPIYA GEÇİŞTE SİYASAL ÖRGÜTLENMENİN TARİHSEL VE KURAMSAL ANALİZİ</i>
Kaan Düzdemir	<i>Yakın Doğu Üniversitesi</i>	<i>DEMOKRATİK TEMSİL AÇISINDAN SEÇİM BARAJININ GÜNCELLENMESİ GEREKLİLİĞİ</i>
<i>Azerbaycan Bakü, Ruhangiz Aliyeva</i>	<i>Azerbaycan Üniversitesi</i>	<i>DİJİTAL EKONOMİDE KADINLARIN KAPSAYICI KATILIMI: AZERBAYCAN ÖRNEĞİ</i>
<i>Doç. Dr., Yeliz YEŞİL Eyüphan ATEŞ Sude GÜLER Nazife Serra GÜREL</i>	<i>Trakya Üniversitesi</i>	<i>KADIN YOKSULLUĞUYLA MÜCADELEDE KADIN İSTİHDAMININ ARTTIRILMASINA YÖNELİK UYGULAMALARIN DEĞERLENDİRİLMESİ</i>
<i>Ulviyya Mehdiyeva</i>	<i>Azerbaycan Üniversitesi</i>	<i>AZERBAYCAN'DA DİJİTAL DÖNÜŞÜM SÜRECİNDE İŞGÜCÜ PİYASASININ YAPISAL DEĞİŞİMLERİ: MEVCUT DURUM VE ZORLUKLAR</i>
<i>Irena Binjaku, PhD Candidate Drita Avdyli, Prof Ass C Dr</i>	<i>University "Aleksandër Moisiu", Mediterranean University of Albania</i>	<i>CRIMINAL PROTECTION OF PUBLIC ASSETS AND TERRITORY AS A NEW DIMENSION OF THE FIGHT AGAINST CORRUPTION</i>



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HEAD OF SESSION: Dr Fettouch Houari

SESSION-1 HALL-2

AUTHORS	AFFILIATION	TOPIC TITLE
Khalil Naziru Abdullahi Musa Yahaya Abubakar Jabir Said Ahmed Ansar Bilyaminu Adam	Chemistry Federal University wukari	<i>INORGANIC SENSORS AND BIOSENSORS: MATERIALS, MECHANISMS, AND ANALYTICAL PERFORMANCE</i>
Nadia TEBBAL Mekki Maza Zine El Abidine RAHMOUNI Messaouda BELOUADAH Siham AIT YAHIA Zoubir DJENDI	university of M'sila Algeria,	<i>THE PARADOX OF SUSTAINABLE SANITATION</i>
Amadi Oko Amadi, Osita Ngozika Ann, Ifeanyi Moses Iwueze and Okpo Charles Nnanna	Technology Akanu Ibiam Federal Polytechnic Unwana-Ebonyi state.	<i>DIGITAL TWIN MODELLING OF OIL PRODUCTION USING QUANTUM COMPUTING FRAMEWORKS</i>
Abdul Rehman Maaz Ahmed Mariam Muhammad Usman	University of Management and Technology, Lahore, Pakistan	<i>AUTOCLAIMAI: VEHICLE DAMAGE DETECTION AND REPAIR RECOMMENDATION SYSTEM</i>
Dr Fettouch Houari	University of Mostaganem, Alegeria.	<i>QUALITATIVE GROWTH ANALYSIS OF SOLUTIONS TO SECOND-ORDER LINEAR EQUATIONS</i>



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HEAD OF SESSION: Dr. Öğr. Üyesi, Emre YÜCELAND

SESSION-1 HALL-3

AUTHORS	AFFILIATION	TOPIC TITLE
Yüksek Lisans Öğrenci, Şerife SARIKAVAK Prof. Dr., Hakan UŞAKLI	Sinop Üniversitesi	ERİŞİLEBİLİR OKULLAR: KAPSAYICI EĞİTİM
Yüksek Lisans Öğrenci, Şerife SARIKAVAK Prof. Dr., Hakan UŞAKLI	Sinop Üniversitesi	BİREYSELLEŞTİRİLMİŞ EĞİTİM PROGRAMLI (BEP) ÖĞRENCİLERİNDE SOSYAL DUYGUSAL ÖĞRENME (SDÖ)
Dr. Öğr. Üyesi, Emre YÜCELAND	Ağrı İbrahim ÇEÇEN Üniversitesi,	YAPAY ZEKÂ İLE MÜZİK ÜRETİM TÜRLERİNE İLİŞKİN KAVRAMSAL VE TİPOLOJİK BİR ÇERÇEVE
Doç. Dr. ƏBÜLFƏZ ƏZİMLİ	Naxçıvan Dövlət Universiteti-	“KİTABİ-DƏDƏ QORQUD” UN POETİKASI: BƏDİİ MÜQƏDDİMƏDƏ SÖZÜN VƏ DÜŞÜNCƏNİN İDRAKİ MƏNA RƏNGLƏRİ
Dosent Gültəkin Atəş qızı Abdullayeva	Azərbaycan Dövlət Pedaqoji Universiteti,	İFADƏ VƏ İNŞA YAZILARINDA ORFOQRAFİK ÇƏTİNLİKLƏR
Natevan Paşayeva	Azərbaycan Dövlət Pedaqoji Universiteti	ÇOCUKLARDA DAYANIKLILIK VE DUYGUSAL ÖZ DÜZENLEMENİN OLUŞTURULMASI
Professor Omar El Ghazi	Hassan II University of Casablanca	FROM GREEK WISDOM TO ARABIC THOUGHT: TRANSLATION METHODS AT BAYT AL-ḤIKMA
Askar Aimukatov	Aktobe Regional University, Kazakhstan.	ARTIFICIAL INTELLIGENCE IN THE FORMATION OF THE SOCIO- PSYCHOLOGICAL CLIMATE



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HEAD OF SESSION: Rəhilə Hümətova

SESSION-1 HALL-4

AUTHORS	AFFILIATION	TOPIC TITLE
<i>Prof. Dr. Elman QULİYEV</i>	<i>Azərbaycan Devlet Pedagoji Universiteti</i>	<i>NEW STAGE OF DEVELOPMENT OF TURKISH CHILDREN'S POETRY (BASED ON THE POEMS OF TOFIK FIKRET)</i>
<i>Dr. Ülker Bahşiyeva</i>	<i>ADPU</i>	<i>SCHOLARLY AND THEORETICAL APPROACHES OF LITERARY SCHOLARS TO FOLKLORE</i>
<i>Rəhilə Hümətova</i>	<i>Azərbaycan Dövlət Pedagoji Universiteti</i>	<i>YAZILI TARİXİ ABİDƏLƏRLƏ DİALEKT LEKSİKASI ARASINDA ƏLAQƏNİN İZLƏRİ</i>
<i>Gunel Shefiyeva</i>	<i>Azerbaijan State Pedagogical University,</i>	<i>PRAGMATICS AND POLITENESS</i>
<i>Ulduz Fərhad Qəhrəmanova,</i>	<i>Azərbaycan Dövlət Pedagoji Universiteti,</i>	<i>ARİSTOTELİN "POETİKA" ƏSƏRİNİN MƏZMUNUNUN TƏHLİLİ</i>
<i>PhD Petronela Daniela FERARU</i>	<i>"Ion Neculce" High School, Targu Frumos, Iasi County, Romania.</i>	<i>ARTIFICIAL INTELLIGENCE AND SOCIAL ETHICS: IMPLICATIONS FOR HUMAN CAPITAL AND ORGANIZATIONAL CULTURE IN EDUCATIONAL AND RESEARCH INSTITUTIONS</i>
<i>PhD Petronela Daniela FERARU</i>	<i>"Ion Neculce" High School, Targu Frumos, Iasi County, Romania.</i>	<i>YOUTH UNDER OVERLAPPING CRISES: SOCIAL RESILIENCE, COLLECTIVE ANXIETY AND EMERGING MODES OF PARTICIPATION IN THE EUROPEAN UNION</i>
<i>PhD Petronela Daniela FERARU</i>	<i>"Ion Neculce" High School, Targu Frumos, Iasi County, Romania.</i>	<i>FROM ECONOMIC MIGRATION TO CIRCULAR MOBILITY: RECONFIGURING IDENTITIES, LOCAL ECONOMIES AND FAMILY COHESION IN CENTRAL EUROPE</i>
<i>Könül Məmmədova</i>	<i>Azərbaycan Dövlət Pedagoji Universiteti,</i>	<i>İNŞALARIN İLKİN ELEMENTLƏRİNİN ÖYRƏDİLMƏSİ QAYDALARI</i>



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HEAD OF SESSION: Lecturer, PhD Irina-Ana DROBOT

SESSION-1 HALL-5

AUTHORS	AFFILIATION	TOPIC TITLE
Prof. Dr. Olena A. Lykholat PhD, Tetyana Y. Lykholat Lecturer, Maksim O. Kvitko PhD, Iryna M. Kofan Prof. Dr. Yuriy V. Lykholat	University of Customs and Finance, Dnipro, Ukraine, Oles Honchar Dnipro National University, Kryvyi Rih State Pedagogical University,	PROFESSIONAL ORIENTATION OF BIOLOGICAL SCHOOLBOY IN MODERN CONDITIONS
Zainab Irfan Syed Khubaib Azhar Wasti	University of Management and Technology, Lahore	GLOBAL GOVERNANCE OF AI: AN EVALUATION OF ALTERNATIVE INSTITUTIONAL MECHANISMS AND THE PATH AHEAD FOR EFFECTIVE REGULATION
Muhammad Saeed Abubakar Yousafi Muhammad Hurrairah		SOCIOECONOMIC PRESSURES AND MENTAL HEALTH: EXPLORING THE CAUSES OF ANXIETY AND DEPRESSION IN PAKISTAN'S MIDDLE CLASS
Hairbiyar baloch Aftab	University of Management and Technology (UMT), Lahore, Pakistan	THE PROBLEM OF GREATER BALOCHISTAN: HISTORICAL ROOTS, POLITICAL CHALLENGES, AND SOCIO-ECONOMIC REALITIES
Professor Dr. Laura Diaconu (Maxim)	"Alexandru Ioan Cuza" University of Iasi, Romania	MIGRATION AND URBAN CHANGE: AN ANALYSIS OF SOCIO-ECONOMIC AND DEMOGRAPHIC EFFECTS
Lecturer, PhD Irina-Ana DROBOT	Technical University of Civil Engineering Bucharest,	THE SHORT STORY ARTICLES OF WAR BY GRAHAM SWIFT: AN ANALYSIS
Lecturer, PhD Irina-Ana DROBOT	Technical University of Civil Engineering Bucharest,	THE SHORT STORY KNIFE BY GRAHAM SWIFT: AN ANALYSIS
Lecturer, PhD Irina-Ana DROBOT	Technical University of Civil Engineering Bucharest,	THE SHORT STORY KNIFE AND THE NOVEL THE LIGHT OF DAY BY GRAHAM SWIFT: THE SIGNIFICANCE OF A MURDER



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HEAD OF SESSION: Ms. Sidra Haron

SESSION-1 HALL-6

AUTHORS	AFFILIATION	TOPIC TITLE
Raed amer ali ALSAHOO Salih Abdullah Hussein Ahmed fadhil kadhim Ameen hayder ahmed Dhafir latief fayadh	University of Baghdad,Iraq	EVALUATION OF CYTOKINES INTERLEUKIN-6 (IL-6) AND TUMOR NECROSIS FACTOR (TNF-A) AND OTHER BIOMARKERS IN HYPERTHYROIDISM IRAQI PATIENTS
Muhammad Aanish Abdul Hannan Muhammad Subhan Tahir	University of Management and Technology (UMT), Lahore, Pakistan	CYBERSECURITY AWARENESS AMONG EDUCATORS AND STUDENTS IN VIRTUAL LEARNING ENVIRONMENTS
Laiba Nasrullah M Ahmad Naeem Ms. Sidra Haron	University of Management and Technology	AI DRIVEN VIRTUAL TUTORS
Izza Saleem	University of Management and Technology, Lahore	THE IMPACT OF ARTIFICIAL INTELLIGENCE ON HUMAN CREATIVITY AND ORIGINALITY



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HEAD OF SESSION: Dr. Öğr. Üyesi, Barış KURT

SESSION-1 HALL-7

AUTHORS	AFFILIATION	TOPIC TITLE
Mustafa KARATEPE Bilge KARATEPE Şehriban Nur KANDEMİR	Prof. Dr. Niğde Ömer Halisdemir Üniversitesi,	NEVŞEHİR JANDARMA AT VE KÖPEK EĞİTİM MERKEZİ (JAKEM) AT VE KÖPEKLERİNDE TOXOPLASMA GONDİİ'NİN ARAŞTIRILMASI
Assoc. Prof. Dr., Fadime ÖZDEMİR Undergraduate Student, Zeynep Naz KOÇAK	Bilecik Şeyh Edebali University, Mimar Sinan Fine Arts University	KİRLİ VE KİRLİ OLMAYAN TOPRAKLARDAN TOPLAM MİKROBİYOTA İZOLASYONU VE FTIR ANALİZİ İLE BİYOREMEDİYASYON POTANSİYELİNİN BELİRLENMESİ
Dr. Öğr. Üyesi, Barış KURT	Muş Alparslan Üniversitesi	Q-FOLD THERMO-CORE: ENERJİ MATERYALLERİ İÇİN MİLİSANİYE HIZINDA TERMODİNAMİK KARARLILIK VE REAKTÖR GÜVENLİK ANALİZ MİMARİSİ
Sinem VURAL Prof. Dr. Mehmet KALENDER	Fırat Üniversitesi	NANOSELÜLOZ DOLGULU POLİVİNİL ALKOL (PVA) KOMPOZİT FİLM SENTEZİ VE KARAKTERİZASYONU
Bilal TURANCI Doç.Dr. Sezer ERDEM	Kerem Aydınlar Science High School, Malatya Turgut Özal University,	4-DIMENSIONAL CATALAN-MOTZKIN MATRIX AND SOME NEW DOUBLE SEQUENCE SPACES
Prof.Dr. Alaeddin BOBAT YL. Öğrencisi Satılmış Eren Özdemir YL. Öğrencisi Ömer Fatih BİLDİK	Kocaeli Üniversitesi	TARIMIN EKOSİSTEM HİZMETLERİ VE EROZYON



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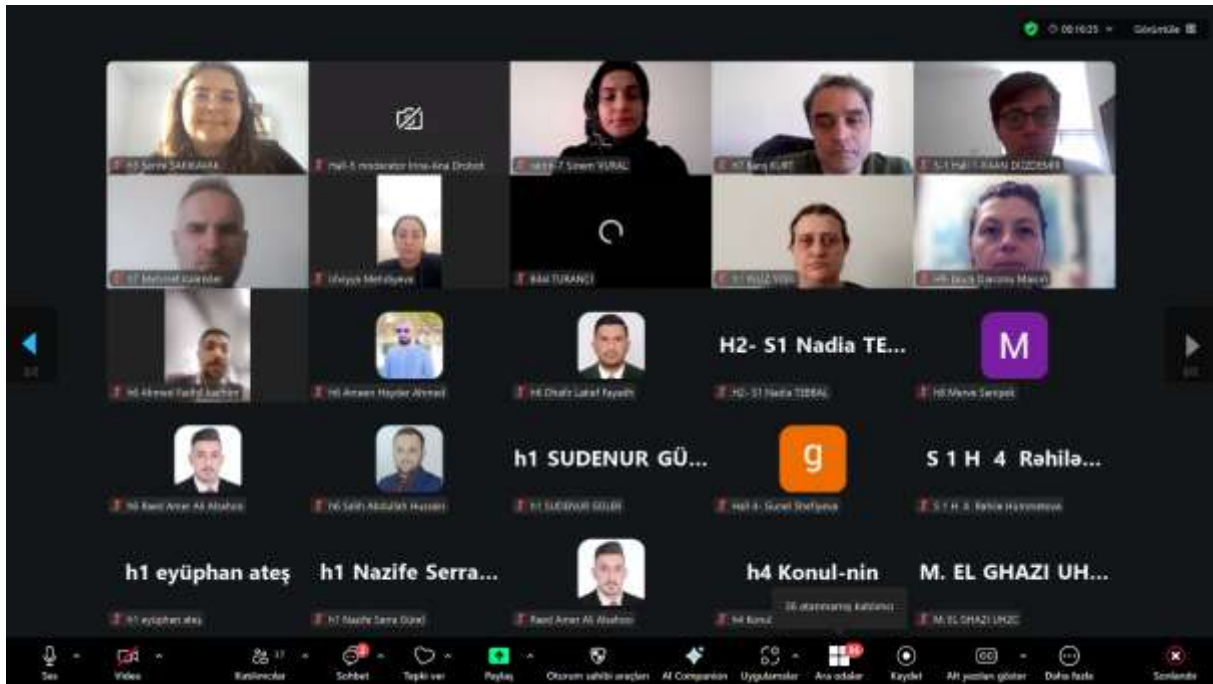
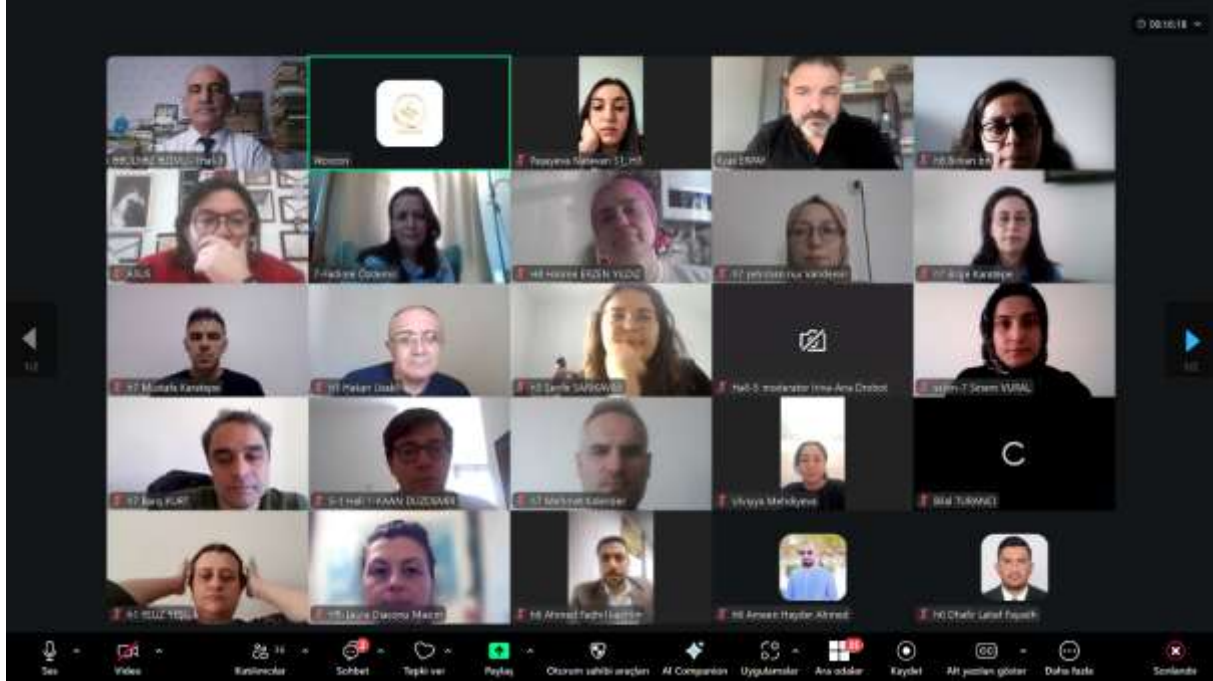
HEAD OF SESSION: Dr. Halime ERZEN YILDIZ

SESSION-1 HALL-8

AUTHORS	AFFILIATION	TOPIC TITLE
Dr. Fzt. Merve SARIİPEK Dr. Fzt Ali İmran Yalçın	Ordu Üniversitesi, Hacettepe Üniversitesi,	DİRSEK ÜSTÜ AMPUTELERDE PROTEZ KULLANIMININ YÜRÜYÜŞTE KOL SALINIMI ÜZERİNE ETKİSİ
Dr. Fzt Ali İmran Yalçın Dr. Fzt. Merve SARIİPEK Prof. Dr. Fatma Gül YAZICIOĞLU	Hacettepe Üniversitesi, Ordu Üniversitesi	UNİLATERAL TRANSTİBİAL AMPUTASYONU OLAN BİREYLERDE FARKLI EĞİMLERDE YÜRÜYÜŞÜN ZAMAN-MESAFE PARAMETRELERİNE ETKİSİ
Dr. Halime ERZEN YILDIZ Dr. Hamza TUNÇ Prof. Dr. Berna OTO	Yuzuncu Yıl University, Van,	EPIXS YAZILIMI KULLANILARAK METFORMİNİN FOTON ETKİLEŞİM PARAMETRELERİNİN İNCELENMESİ
Assist. Prof. Dr., Esin Ayşe ZAİMOĞLU Lecturer Dr., Havva Gül KOÇER Assist. Prof. Dr., Birkan BÜYÜKARIKAN	Sakarya University, Selçuk University, Isparta University	COMPARATIVE ANALYSIS OF DIFFERENT CONVOLUTIONAL NEURAL NETWORK BACKBONES OF U-NET ARCHITECTURE FOR LIVER SEGMENTATION IN COMPUTED TOMOGRAPHY IMAGES
Bahadır Alvar Bilge Kartal Çetin Kamil Çetin	İzmir Katip Çelebi University	HIGH-PRECISION TRAJECTORY TRACKING OF MOBILE ROBOTS USING RFID PHASE MEASUREMENTS AND INVERSE SYNTHETIC APERTURE RADAR
Mehmet Haktan Turun Kamil Çetin	İzmir Katip Çelebi University	UNMANNED AERIAL VEHICLE CONTROLLER DESIGN IN MATLAB/SIMULINK ENVIRONMENT



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BİLEŞİMSEL İYİLEŞİMİN KÜLTÜREL ÖZELLİKLERİ VE İYİLEŞİMİN KÜLTÜREL ÖZELLİKLERİ

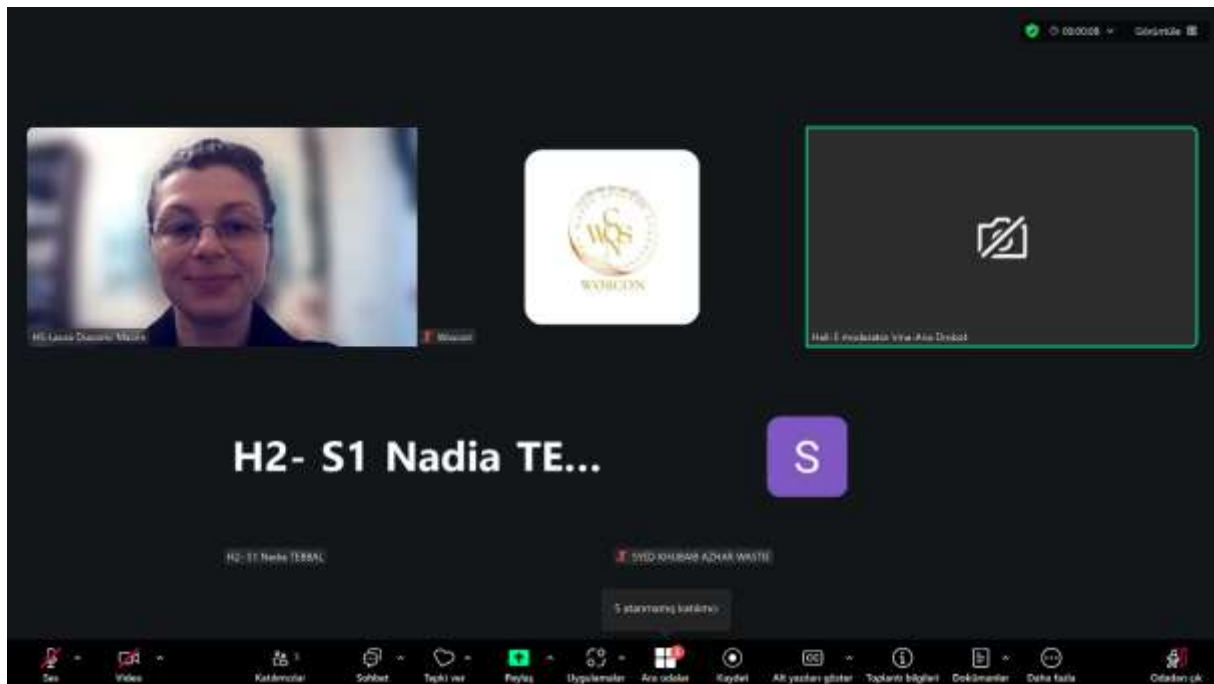
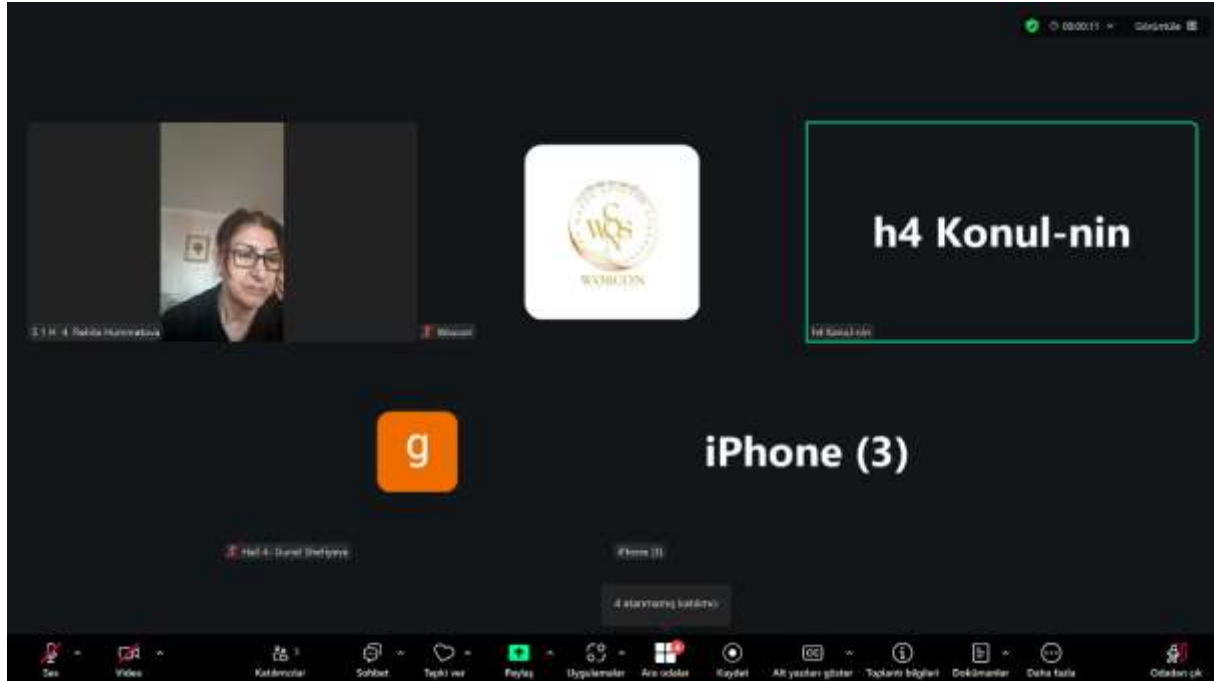
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Erişilebilirlik Kavramı

Erişilebilirlik yalnızca fiziksel düzenlemeleri değil; öğrenme ortamlarına katılım, pedagojik esneklik, sosyal kabul ve psikolojik güvenlik gibi çok boyutlu unsurları kapsayan bütüncül bir kavramdır.



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Köpeklerde cinsiyete göre, 117 erkek köpeğin 111'i (%94.4) ve 139 dişi köpeğin 21'i (%15.1) *T. gonuli* yönünden pozitif bulunmuş olup istatistiksel bir fark belirlenmemiştir ($p=0.188$). Yaş grupları açısından ise, 8 ay-1 yaş arasındaki 126 köpekte seropozitiflik septanamamışken 3-5 yaş arasındaki 130 köpekte seropozitiflik oranı %24.6 olarak tespit edilmiş ve yaş grupları bakımından seropozitiflik oranları istatistiksel olarak önemli bulunmuştur ($p=0.000$).

Çalışmada çeşitli görevlerde kullanılan (homba, mayın, iz takip vb.) 63 köpeğin 8'inde %12.6 oranında, damızlık olarak kullanılan 67 köpeğin 24'ünde %35.8 oranında *T. gonuli* pozitifliği saptanırken 126 adet yavru köpeğin hiçbirinde pozitiflik belirlenmemiştir. Köpek grupları açısından seropozitiflik oranları istatistiksel olarak anlamlı bulunmuştur ($p=0.000$).

Köpek ırkları açısından; Belçika Malinois %11.2, Alman Çoban Köpeği %15.3, Labrador Retriever %13.1, Golden Retriever %33.3, Alman Pomer %9 oranında *T. gonuli* seropozitifliği gösterirken incelenen 1 adet Tarsus Çatalburnu köpeğinde seropozitiflik saptanamamıştır. Buna göre, köpek ırkları açısından seropozitiflik oranları istatistiksel olarak anlamlı bir farklık saptanamamıştır ($p=0.839$).





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İstatistik Analiz

- Katılımcılardan elde edilen veriler SPSS 21.00 yazılımı kullanılarak analiz edildi.
- Değerlendirmeler sonucunda elde edilen verilerin ortalama ve standart sapmaları her bir grup için tanımlandı.
- Verilerin normal dağılıma uygunluğu, görsel (histogram ve olasılık grafikleri) ve analitik yöntemlerle (Kolmogorov- Smirnov/ Shapiro- Wilk testleri) kullanılarak değerlendirildi.
- Ampute ve sağlıklı grup karşılaştırmalarında Mann Whitney U testi kullanıldı.
- Amputelerin protezli- protezsiz verilerinin karşılaştırılmasında Wilcoxon testi kullanıldı.
- Ampute grupta protezli ve protezsiz yürüyüş parametreleri arasındaki ilişkinin analizinde Spearman korelasyon analizi kullanıldı.
- $p < 0,05$

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İLKEİ TOPLUMDAN DEVLETLİ YAPIYA GEÇİŞTE SİYASAL ÖRGÜTLENMENİN TARİHSEL VE KURAMSAL ANALİZİ

Kaan Düzdemir

Doktora Öğrencisi, Yakın Doğu Üniversitesi, Kamu Hukuku, kaanduzdemir@gmail.com,

Orcid Id: 0000-0001-9083-3978.

Özet

İnsanlık yaklaşık iki buçuk milyon yıldan beridir yeryüzünde yaşamaktadır. İnsanlar, bu zaman diliminin önemli bir bölümünde doğanın zorlu şartlarına karşı mücadele etmek zorunda kalmışlardır. Doğanın zorlu koşulları ile tek başına mücadele edemeyen insanlar zaman içerisinde çeşitli topluluklar halinde yaşamaya başlamışlardır. Böylece, doğanın zorlu koşullarına karşı hayatta kalma ve temel ihtiyaçlarını karşılama bakımından avantaj sağlamışlardır. Bir arada yaşamaya ve doğanın şartlarına üstünlük sağlamaya başlayan insanlar, ateşi keşfetmeleri sonucunda doğal yaşamın tehlikelerine karşı daha fazla korunaklı hale gelmiştir. Böylelikle, insanlık yeryüzüne hâkim olma ve yayılma imkanına sahip olmuştur. İnsanların doğanın acımasız koşulları ile mücadele etme noktasındaki bir başka önemli avantajı ise toplum içerisindeki kişilerin birbirlerine olan sınırsız bağlılığı olmuştur. Bu bağlılık, kandaş toplum anlayışının ortaya çıkmasına sebep olmuştur. Kandaş toplum anlayışında, toplum içerisinde yaşayan kişilerin kendilerine özgü fikirleri veya inançları bulunmamaktadır. Bir başka deyişle, kişilerin değil toplumun düşünceleri ve inançları bulunmaktadır. Yaklaşık M.Ö 10.000 yıllarında insanların tarımı keşfetmelerinin sonucunda “Neolitik Çağ” dönemi başlamıştır. Tarımın keşfedilmesi sonucunda toprak değer kazanmış ve toplumlarda toprak ile mülkiyet kavramı özdeşleşmiştir. Böylelikle, toplum yapısı kandaş toplumdan uygar topluma doğru evrilme sürecine girmiştir. Ayrıca, tarımın keşfedilmesi toplumlar arasında mücadelelerin de başlangıcına sebebiyet vermiştir. Bu çalışmada ilkel toplumların uygar toplumlara evrilme suretiyle devlet tüzel kişiliğine evrilme sürecindeki faktörler ele alınacaktır.

Anahtar Kelimeler: Kandaş Toplum, Uygar Toplum, Devlet, Toplumsal Yaşam.

A HISTORICAL AND THEORETICAL ANALYSIS OF POLITICAL ORGANIZATION IN THE TRANSITION FROM PRIMITIVE SOCIETY TO STATE STRUCTURE

Kaan Düzdemir

PhD Student, Near East University, Public Law, kaanduzdemir@gmail.com,

Orcid Id: 0000-0001-9083-3978.

Abstract

Humankind has been living on Earth for approximately two and a half million years. For a significant portion of this time, humans have had to struggle against the harsh conditions of nature. Unable to cope with nature's harsh conditions alone, humans began to live in various communities over time. This gave them an advantage in terms of survival and meeting their basic needs in the face of nature's harsh conditions. Humans, who began to live together and gain superiority over nature's conditions, became more protected against the dangers of natural life as a result of discovering fire. Thus, humanity gained the ability to dominate and spread across the earth. Another important advantage humans had in their struggle against the harsh conditions of nature was the unlimited loyalty of individuals within the community. This loyalty led to the emergence of the kinship society concept. In kinship societies, individuals living within the community did not have their own unique ideas or beliefs. In other words, it was the community that had thoughts and beliefs, not the individuals. The discovery of agriculture by humans around 10,000 BC marked the beginning of the Neolithic Age. As a result of the discovery of agriculture, land gained value, and the concept of property became synonymous with land in societies. Thus, the social structure began to evolve from a kinship society to a civilized society. Furthermore, the discovery of agriculture led to the beginning of struggles among societies. This study will examine the factors involved in the process of primitive societies evolving into civilized societies and subsequently into state legal entities.

Keywords: Kinship Society, Civilized Society, State, Social Life

DEMOKRATİK TEMSİL AÇISINDAN SEÇİM BARAJININ GÜNCELLENMESİ GEREKLİLİĞİ

Kaan Düzdemi

Doktora Öğrencisi, Yakın Doğu Üniversitesi, Kamu Hukuku, kaanduzdemir@gmail.com,

Orcid Id: 0000-0001-9083-3978.

Özet

Bu çalışma, seçim barajı uygulamasının demokratik temsil üzerindeki etkilerini inceleyerek, baraj oranının güncellenmesi gerekliliğini anayasal ilkeler çerçevesinde değerlendirmeyi amaçlamaktadır. Seçim barajı, özellikle temsilde adalet ve yönetimde istikrar arasında denge kurma amacıyla birçok ülkede uygulanan bir mekanizmadır. Ancak baraj oranının yüksek belirlenmesi, önemli bir seçmen kitlesinin oylarının parlamento ya yansımamasına neden olabilmekte ve bu durum demokratik meşruiyet tartışmalarını beraberinde getirmektedir. Türkiye’de uygulanan seçim barajı, tarihsel süreç içerisinde çeşitli değişikliklere konu olmuş olsa da günümüz siyasal ve toplumsal koşulları bakımından yeniden ele alınmayı gerektirmektedir. Özellikle siyasal çoğulculuğun güçlenmesi, seçmen iradesinin daha etkin biçimde temsil edilmesi ve siyasal katılımın artırılması bakımından mevcut baraj oranının etkileri sorgulanmalıdır. Bu bağlamda çalışma, seçim barajının anayasanın eşitlik ilkesi, seçme ve seçilme hakkı ile temsilde adalet ilkesi üzerindeki yansımalarını analiz etmektedir. Sonuç olarak, demokratik temsilin güçlendirilmesi ve mevcut siyasal sistemin meşruiyetinin artırılması amacıyla seçim barajının güncellenmesinin gerekli olduğu savunulmaktadır.

Anahtar Kelimeler: Seçim Barajı, Siyasi Partiler, Parlamento, Cumhurbaşkanlığı Hükümet Sistemi.

THE NEED TO UPDATE THE ELECTORAL THRESHOLD FROM THE PERSPECTIVE OF DEMOCRATIC REPRESENTATION

Kaan Düzdemir

PhD Student, Near East University, Public Law, kaanduzdemir@gmail.com,

Orcid Id: 0000-0001-9083-3978.

Abstract

This study aims to examine the effects of the electoral threshold on democratic representation and to assess the necessity of updating the threshold rate within the framework of constitutional principles. The electoral threshold is a mechanism applied in many countries, particularly with the aim of striking a balance between fairness in representation and stability in governance. However, setting the threshold too high can prevent the votes of a significant number of voters from being reflected in parliament, leading to debates about democratic legitimacy. Although the electoral threshold applied in Turkey has undergone various changes throughout history, it needs to be reconsidered in light of today's political and social conditions. In particular, the effects of the current threshold should be questioned in terms of strengthening political pluralism, more effectively representing the will of the voters, and increasing political participation. In this context, this study analyzes the implications of the electoral threshold on the constitutional principles of equality, the right to vote and be elected, and the principle of fairness in representation. Consequently, it argues that updating the electoral threshold is necessary to strengthen democratic representation and enhance the legitimacy of the current political system.

Keywords: Electoral Threshold, Political Parties, Parliament, Presidential Government System.

DİJİTAL EKONOMİDE KADINLARIN KAPSAYICI KATILIMI: AZERBAYCAN ÖRNEĞİ

Azerbaycan Bakü, Ruhangiz Aliyeva , Azerbaycan Üniversitesi

ruhangiz.aliyeva@au.edu.az ,ORCID; 0000-0001- 5744-9042

ÖZET

Bu makale, Azerbaycan'da dijital ekonomi bağlamında kadınların işgücü piyasasına kapsayıcı erişimi ve katılımına ilişkin bilimsel bir analiz sunmaktadır. Amaç, dijital ekonominin gelişmesinin kadın istihdamı üzerindeki etkisini, mevcut durumu, cinsiyete dayalı engelleri ve kapsayıcı politika yaklaşımlarını belirlemektir. Dijital ekonomi, bilgi ve iletişim teknolojileri (BİT), yapay zeka (YZ), dijital hizmetler ve e-ticaret alanlarını kapsar ve bu alanlarda kadınların katılımı hem ekonomik büyüme hem de cinsiyet eşitliği için kritik öneme sahiptir. Makale, Azerbaycan'da BİT sektöründe ve dijital girişimcilikte kadınların temsilini, sosyal ve ekonomik engelleri, hükümet girişimlerini, sivil toplum girişimlerini ve gelecekteki fırsatları incelemektedir. Mevcut istatistiksel verilere göre, Azerbaycan'da BİT sektöründe kadınların payı yaklaşık %30'dur ve bu gösterge son yıllarda artmaktadır, ancak alanda cinsiyet eşitsizliği devam etmektedir. Örneğin, bilgi ve iletişim sektöründeki girişimcilerin yalnızca yaklaşık %21'i kadındır. Kadınlar dijital ekonominin diğer alanlarında da yeterince temsil edilmemekte ve bu nedenle özel politika müdahaleleri gerekmektedir. Devlet ve kamu girişimleri – eğitim programları, mentorluk, kadınların dijital becerilerinin geliştirilmesi ve kapsayıcı bir çalışma ortamının oluşturulması – bu sektörde kapsayıcılığı artırmada kilit rol oynamaktadır. Makale, kadınların dijital ekonomiye tam olarak katılabilmeleri için hem yapısal hem de kültürel değişikliklerin gerekli olduğunu göstermektedir. Dijital ekonomi tüm dünyada hızla gelişmekte ve ekonomik büyümenin ana itici güçlerinden biri haline gelmektedir. Bu süreç aynı zamanda işgücü piyasasında yapısal değişikliklere yol açmakta ve yeni iş fırsatları yaratmaktadır. Ancak, kadınların bu fırsatlardan tam olarak yararlanabilmeleri için cinsiyete dayalı engellerin kaldırılması ve kapsayıcı politikaların uygulanması gerekmektedir.

Anahtar kelimeler: dijital ekonomi, kadınların kapsayıcı katılımı, cinsiyet eşitliği, BİT sektörü

INCLUSIVE PARTICIPATION OF WOMEN IN THE DIGITAL ECONOMY: THE CASE OF AZERBAIJAN

Azerbaycan Bakü,Ruhangiz Aliyeva , Azerbaycan Üniversitesi
ruhangiz.aliyeva@au.edu.az ,ORCID; 0000-0001- 5744-9042

ABSTRACT

This article provides a scientific analysis of women's inclusive access to and participation in the labor market in the context of the digital economy in Azerbaijan. The aim is to identify the impact of the development of the digital economy on women's employment, the current situation, gender-based barriers and inclusive policy approaches. The digital economy encompasses the areas of information and communication technologies (ICT), artificial intelligence (AI), digital services and e-commerce, in which women's participation is critical for both economic growth and gender equality. The article examines the representation of women in the ICT sector and digital entrepreneurship in Azerbaijan, social and economic barriers, government initiatives, non-governmental initiatives and future opportunities. According to available statistical data, the share of women in the ICT sector in Azerbaijan is approximately 30% and this indicator has been increasing in recent years, but gender inequality in the field persists. For example, only about 21% of entrepreneurs in the information and communication sector are women. Women are also underrepresented in other areas of the digital economy, and specific policy interventions are therefore necessary. State and public initiatives – training programs, mentoring, improving women's digital skills and creating an inclusive work environment – play a key role in increasing inclusion in this sector. The article shows that both structural and cultural changes are required for women to become full participants in the digital economy. The digital economy is developing rapidly all over the world and is becoming one of the main drivers of economic growth. This process also leads to structural changes in the labor market and creates new job opportunities. However, gender-based barriers must be removed and inclusive policies must be implemented in order for women to fully benefit from these opportunities.

Keywords: digital economy, inclusive participation of women, gender equality, ICT sector

KADIN YOKSULLUĞUYLA MÜCADELEDE KADIN İSTİHDAMININ ARTTIRILMASINA YÖNELİK UYGULAMALARIN DEĞERLENDİRİLMESİ

Doç.Dr., Yeliz YEŞİL ¹/ Eyüphan ATEŞ² /Sude GÜLER³/Nazife Serra GÜREL⁴

¹ Trakya Üniversitesi Çalışma Ekonomisi ve End. İlişkileri Bölümü, dezavantajlı gruplar-insan kaynakları yönetimi, yelizyesil@trakya.edu.tr, ORCID NO: 0000-0003-1638-104X

² Trakya Üniversitesi Çalışma Ekonomisi ve End. İlişkileri Bölümü lisans öğrencisi,
eyuphanates2002@gmail.com

³ Trakya Üniversitesi Çalışma Ekonomisi ve End. İlişkileri Bölümü lisans öğrencisi,
sudeg5210@gmail.com

⁴ Trakya Üniversitesi Çalışma Ekonomisi ve End. İlişkileri Bölümü lisans öğrencisi,
serragurel99@gmail.com

Özet

Yoksulluk dünyanın tüm coğrafyalarında ve tarihin tüm zamanlarında görüle gelmiş bir olgu olarak karşımıza çıkmaktadır. Kelime anlamıyla yoksulluk, “az bir varlığa sahip olmak, muhtaç durumda bulunmak, ihtiyaç içinde olmak” durumlarını ifade etmektedir. Aslında yoksulluğun standart bir tanımını yapmak kolay değildir. Bu tanımın yapılmasında temel güçlüğü ise yoksulluğu oluşturan çok sayıda bileşen, bu bileşenler arasındaki çeşitli ilişkiler ve yapılacak tanımlamanın bu konu hakkında çalışma yapan kişinin kişisel birikimiyle şekillenebilecek olmasıdır (Odabaşı,2009:11).

Ulutaş (2009)’a göre kadınların erkeklerden daha yoksul olduğunun ifadesi olarak kullanılan yoksulluğun kadınlaşması kavramı ilk kez 1978 yılında Diane Pearce tarafından, o yıllarda Amerika’da kadınların işgücüne katılımındaki artışa rağmen, yoksul kadın sayısının giderek artması durumunu açıklamak için kullanılmıştır. Kavram ile yoksulluk analizleri ve yoksullukla mücadele politikalarında kadınları ayrıca hedeflemek gerekliliği savunulmuştur (Uçar, 2011: 23).

Özellikle 1980’lerden sonra güçlenen bu yaklaşım sonucunda kadınlar, yoksulluğun yükünü taşıyan ve onunla mücadele eden aktörler olarak görülmeye başlanmıştır. Kavramın literatürde yaygın olarak kullanılmaya başlaması ise, 1995’te 4. Dünya Kadın Konferansı Eylem Planı’nda “yoksulluğun kadınlaşması” ifadesinin yer almasından sonra gerçekleşmiştir denilebilir (Uçar, 2011: 23).

Kadınların erkeklerle eşit eğitim ve ekonomik fırsatlara erişiminin önündeki engeller kaldırılmalıdır. Kadınların statüsünün iyileştirilmesi, kalkınma ve toplumsal cinsiyet eşitliğinin sağlanması için kritik öneme sahiptir. Herhangi bir ülkede ekonomik ve sosyal kalkınmanın sağlanması

için kadın ve erkeklerin haklara ve fırsatlara eşit erişimi olmalıdır. Kadınların ekonomik ve sosyal hayata eşit katılımını sağlayan ülkelerde kalkınma gerçekleşmekte ve refah seviyesi yükselmektedir. Kadınların eğitime, istihdama ve karar alma mekanizmalarına eşit katılımı, herhangi bir ülkenin gelişmiş ülkeler arasında yer almasını sağlayabilir (Yeşil,2020).

Kadın yoksulluğunu azaltmak ve istihdamını arttırmak için çeşitli uygulamalar yapılmaktadır. Bu çalışmada bu uygulamalara değinilecek ve bu uygulamalar içerik analizi yöntemi ile değerlendirilecektir. Araştırmanın evrenini google.com’da “Kadın İstihdamının Arttırılmasına Yönelik Uygulamalar” olarak taranan kaynaklar oluşturmaktadır. Araştırmanın örneklemini ise 2021-2026 tarihleri arasında yapılan “Kadın İstihdamının Arttırılmasına Yönelik Uygulamalar” oluşturmaktadır. Sonuç itibariyle kadın istihdamının arttırılmasına yönelik çalışmalar kadın yoksulluğunun azaltılmasında olumlu sonuçlar doğurmaktadır ve giderek artması gerekmektedir.

Anahtar Kelimeler:Kadın, istihdam,yoksulluk.

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EVALUATION OF PRACTICES AIMED AT INCREASING WOMEN'S EMPLOYMENT IN THE STRUGGLE AGAINST WOMEN'S POVERTY

Abstract

Poverty is a phenomenon that has been observed in all geographies of the world and throughout history. Literally, poverty refers to "having little wealth, being in a state of need, being in need." In fact, it is not easy to create a standard definition of poverty. The main difficulty in making this definition lies in the numerous components that constitute poverty, the various relationships between these components, and the fact that the definition can be shaped by the personal knowledge of the person working on this subject (Odabaşı, 2009:11).

According to Ulutaş (2009), the concept of the feminization of poverty, used to express that women are poorer than men, was first used in 1978 by Diane Pearce to explain the increasing number of poor women in America despite the increase in women's participation in the workforce at that time. The concept argued for the necessity of specifically targeting women in poverty analyses and poverty alleviation policies (Uçar, 2011: 23).

As a result of this approach, which gained strength especially after the 1980s, women began to be seen as actors who bear the burden of poverty and struggle against it. The concept's widespread use in the literature can be said to have begun after the phrase "feminization of poverty" was included in the Action Plan of the 4th World Conference on Women in 1995 (Uçar, 2011: 23).

Barriers to women's access to equal educational and economic opportunities with men must be removed. Improving the status of women is critical for development and achieving gender equality. For economic and social development in any country, women and men must have equal access to rights and opportunities. Countries that ensure women's equal participation in economic and social life experience development and a higher standard of living. Equal participation of women in education, employment, and decision-making mechanisms can enable any country to take its place among developed countries (Yeşil, 2020).

Various practices are being implemented to reduce women's poverty and increase their employment. This study will address these practices and evaluate them using content analysis. The research population consists of resources searched on google.com for "Practices to Increase Women's Employment". The sample consists of "Practices to Increase Women's Employment" conducted between 2021 and 2026. In conclusion, efforts to increase women's employment yield positive results in reducing women's poverty and should be increasingly implemented.

Keywords: Women, employment, poverty.

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AZERBAIJAN'DA DİJİTAL DÖNÜŞÜM SÜRECİNDE İŞGÜCÜ PİYASASININ YAPISAL DEĞİŞİMLERİ: MEVCUT DURUM VE ZORLUKLAR

Azerbaycan Bakü, Ulviyya Mehdiyeva , Azerbaycan Üniversitesi

ulviyya.mehdiyeva@au.edu.az, ORCID: 0009-0006-3375-6500

Özet

Bu çalışma, dijital dönüşümün Azerbaycan işgücü piyasası üzerindeki etkilerini ve meydana gelen yapısal değişimleri analiz etmektedir. Araştırmanın temel odağı, bilgi ve iletişim teknolojilerinin (İKT) çeşitli ekonomik sektörlerle entegrasyonu ve bu sürecin istihdam dinamiklerini nasıl şekillendirdiğidir. Azerbaycan Devlet İstatistik Komitesi'nin verilerine dayanarak yapılan analizler, özellikle hizmet sektöründe rəqəmsallaşmanın diğer alanlara oranla daha hızlı gerçekleştiğini göstermektedir. Bankacılık, kamu yönetimi (e-devlet) ve perakende ticaret gibi alanlarda dijital araçların kullanımı, rutin işlerin otomasyonuna ve yeni nesil uzmanlıklara olan talebin artmasına neden olmuştur. Çalışmada, teknolojik ilerlemenin sadece iş verimliliğini artırmakla kalmadığı, aynı zamanda işgücü piyasasında beceri uyumsuzluğu ve dijital uçurum gibi riskleri de beraberinde getirdiği vurgulanmaktadır. Sonuç olarak, Azerbaycan'ın 2030 stratejik hedefleri doğrultusunda, dijital becerilerin geliştirilmesi ve eğitim sisteminin pazarın yeni taleplerine uyarlanması önerilmektedir.

Anahtar Kelimeler: Dijital dönüşüm, Azerbaycan, İşgücü piyasası, İstihdam yapısı, Hizmet sektörü.

STRUCTURAL CHANGES IN THE LABOR MARKET DURING THE ERA OF DIGITAL TRANSFORMATION IN AZERBAIJAN: CURRENT STATUS AND CHALLENGES

Azerbaijan Baku, Ulviyya Mehdiyeva , Azerbaijan University

ulviyya.mehdiyeva@au.edu.az, ORCID: 0009-0006-3375-6500

ABSTRACT

This paper explores the impact of digital transformation on the labor market structure in Azerbaijan, focusing on the shifts driven by rapid technological integration. The primary objective is to examine how digitalization reshapes employment dynamics across various economic sectors. Utilizing data from the State Statistical Committee of the Republic of Azerbaijan, the study identifies that the service sector—specifically banking, public administration (e-government), and e-commerce—exhibits the highest pace of digital adoption. While automation enhances productivity, it also triggers a shift in labor demand from manual to cognitive and technical skills. The research highlights the dual nature of this transformation: the creation of new high-tech job opportunities versus the risk of labor displacement and skill gaps. The findings suggest that to mitigate potential inequalities and leverage the digital economy, Azerbaijan must prioritize investment in human capital, digital literacy, and the alignment of vocational education with the evolving requirements of the "Industry 4.0" era.

Keywords: Digital transformation, Azerbaijan, Labor market, Employment structure, Service sector.

CRIMINAL PROTECTION OF PUBLIC ASSETS AND TERRITORY AS A NEW DIMENSION OF THE FIGHT AGAINST CORRUPTION

A Legal Analysis of the Amendments to the Criminal Code in the Function of Public Integrity

Irena Binjaku, PhD Candidate

University “Aleksandër Moisiu”, Faculty of Political Science and Law, Durrës, Albania

ORCID: 0009-0008-8436-6291, irenabinjaku@gmail.com

Drita Avdyli, Prof Ass C Dr

Mediterranian University of Albania

Abstract

The amendments to the Criminal Code of the Republic of Albania, adopted on 28 January 2026, represent a significant development in the orientation of criminal policy towards strengthening the fight against corruption through enhanced protection of public assets and territory. These normative interventions mark a shift from addressing corruption as an isolated phenomenon to tackling its functional forms, closely linked to the abuse of public power, unlawful economic benefit, and the infringement of the public interest.

The legal analysis focuses on the strengthening of punitive measures and the introduction of aggravating circumstances for acts that harm public assets, territory, and the environment, particularly when such acts are committed by public officials or in cooperation with them. In this context, the criminal protection of territory and assets of public interest is interpreted as an emerging component of anti-corruption policy, aimed at reinforcing institutional integrity and the deterrent effect of criminal law.

The 2026 amendments are also assessed in light of European standards and Albania’s commitments within the EU integration process, reflecting an effort to reconcile the need for effective criminal enforcement with the principles of legal certainty and the rule of law. Within this framework, the criminal protection of public assets and territory is consolidated as a core element of public integrity and of the credibility of state action.

Keywords: public assets; territory; corruption; Criminal Code; public integrity

INTRODUCTION

The protection of public assets and territory constitutes one of the most sensitive areas of the exercise of public power, as it is directly linked to the management of collective resources, sustainable development, and the safeguarding of the public interest. In practice, their infringement has frequently been associated with forms of functional corruption, manifested through the abuse of public functions, unlawful economic gain, and the distortion of administrative decision-making. For this reason, the intervention of criminal law in this field no longer has a merely punitive character, but increasingly emerges as a direct instrument for strengthening public integrity and institutional accountability.

Within this context, the amendments to the Criminal Code of the Republic of Albania, adopted on 28 January 2026, mark a significant development in the orientation of criminal policy by placing the criminal protection of public assets and territory at the centre of the fight against corruption. These normative interventions reflect a renewed approach that seeks to address not only the material consequences of unlawful conduct, but also the institutional mechanisms that create spaces for impunity and undermine public trust in state institutions.

Research Hypothesis

This paper is based on the hypothesis that the 2026 amendments to the Criminal Code represent a qualitative shift in Albanian criminal policy, consolidating the criminal protection of public assets and territory as a new and functional dimension of the fight against corruption, oriented towards strengthening public integrity and enhancing the deterrent effect of criminal law.

Research Questions

In order to verify this hypothesis, the paper seeks to address the following research questions:

1. In what way is the criminal protection of public assets and territory connected to the concept of public integrity and the fight against corruption?
2. What qualitative changes do the 2026 Criminal Code amendments introduce in the criminal treatment of violations affecting public assets and territory?
3. How is the criminal liability of public officials reflected in these amendments, and what role does it play in preventing institutional corruption?
4. To what extent do these interventions contribute to strengthening the deterrent effect of criminal law and to increasing public trust in state institutions?

Although corruption has been widely examined in criminal law doctrine, the dimension of protecting territory and public assets as an anti-corruption instrument remains under-analysed within the context of Albanian criminal law reforms.

Methodology

The paper adopts a legal-analytical and doctrinal approach, combining the normative analysis of the amendments to the Criminal Code adopted in 2026 with a functional reading of the role of criminal law in combating corruption. The methodology consists, first, of examining the content and objectives of the legislative interventions, drawing on the explanatory memorandum of the draft law in order to identify the new orientation of criminal policy in the protection of public assets and territory. Second, doctrinal analysis is employed to interpret these amendments in relation to the concepts of public integrity, functional corruption, and the deterrent effect of criminal norms, relying on contemporary legal scholarship and European standards. The methodological approach is predominantly qualitative and interpretative, aiming to assess the legal and institutional significance of the normative changes, without engaging in empirical or statistical analysis, due to the absence of consolidated judicial practice following the entry into force of the new provisions.

1. PUBLIC ASSETS AND TERRITORY AT THE CENTRE OF CONTEMPORARY CRIMINAL POLICY

Public assets and territory constitute essential elements of state organization and the functioning of public administration, as they represent collective resources intended for the realization of the public interest and the exercise of public authority. In contemporary doctrine, the lawful management of public assets and territory is regarded as an integral part of the rule of law and good governance, while their infringement is directly associated with an increased risk of corruption and the erosion of public trust in institutions (Rose-Ackerman & Palifka, 2016; OECD, 2017).

In practice, violations affecting territory and public assets often emerge as a result of the interplay between private interests and the exercise of public power, giving rise to forms of functional corruption that do not necessarily manifest through the classical offences of criminal corruption. Phenomena such as illegal construction, unlawful occupation of public land, or the exploitation of territory in breach of legal requirements demonstrate that administrative mechanisms and non-criminal sanctions are frequently insufficient to prevent unlawful economic gain and informal cooperation between private actors and public officials (Transparency International, 2020).

In this sense, territory becomes a space particularly exposed to the abuse of public authority, where the lack of effective criminal accountability creates conditions for the consolidation of practices of impunity. This situation has also been highlighted in international anti-corruption reports, which emphasize that the protection of public assets and territorial resources constitutes a key component of anti-corruption policies and institutional integrity (United Nations Office on Drugs and Crime [UNODC], 2004; Council of Europe, 2018).

Within this context, contemporary criminal policy has expanded its scope by increasingly incorporating the protection of public assets and territory as part of a broader strategy aimed at strengthening the rule of law. Criminal intervention seeks to limit opportunities for abuse of public power, enhance the accountability of public officials, and create a deterrent effect that extends beyond individual punishment, influencing institutional behavior and societal perceptions of legality (European Commission, 2023).

From this perspective, the criminal protection of public assets and territory no longer represents a secondary instrument within the legal order, but is consolidated as a core component of anti-corruption policy, oriented towards safeguarding the public interest and reinforcing public integrity, particularly in the context of criminal law reforms and the European integration process.

1.1. Public Assets and Territory as Objects of the Public Interest

Public assets and territory constitute legal objects of particular importance for the constitutional and administrative order, as they are directly linked to the exercise of state sovereignty and the realization of the public interest. In legal terms, public assets encompass those assets that serve public functions and the fulfilment of collective needs, while territory represents the physical space over which the state exercises its normative and administrative authority. Their protection is therefore not merely a matter of property law or urban planning, but a fundamental element of the functioning of the rule of law and the guarantee of lawful governance (OECD, 2017).

In contemporary doctrine, public assets are conceptualized as assets destined for public use or for the realization of collective interests and are subject to a specific legal protection regime. Their infringement, particularly when linked to the exercise of public functions, produces consequences that go beyond material damage, undermining citizens' trust in state institutions and weakening institutional integrity (Rose-Ackerman & Palifka, 2016). In this sense, public assets do not merely constitute objects of property law, but represent a direct component of the public interest and of state responsibility.

Territory, on the other hand, constitutes a legal and functional dimension of public administration, closely intertwined with development policies, environmental protection, and the safeguarding of fundamental rights.

Territorial management through administrative decision-making creates sensitive areas prone to abuse of power, particularly in sectors such as urban planning, construction, and land use. International reports have identified these fields as among the most exposed to corruption, due to the interaction between economic interests, administrative discretion, and weaknesses in control mechanisms (Transparency International, 2020).

In this context, the legal protection of public assets and territory acquires a dual dimension: on the one hand, it aims to preserve the legal order and the lawful use of collective resources; on the other hand, it serves as an instrument for preventing corrupt practices that distort the public interest. This approach reflects an evolution of the concept of the public interest, which is no longer limited to the formal guarantee of legality, but also encompasses the need for effective protection against abuses that undermine the integrity of the exercise of public power (Council of Europe, 2018).

From this perspective, public assets and territory are consolidated as legal objects of particular weight within contemporary criminal policy, justifying an enhanced level of normative protection and stronger punitive interventions whenever their infringement is linked to corruption and institutional abuse.

1.2. From Administrative Violations to Functional Corruption

In legal and administrative practice, infringements affecting public assets and territory have traditionally been treated as administrative or urban planning violations, addressed through non-criminal sanctions and regulatory mechanisms. This approach has been grounded in the classical distinction between administrative offences and criminal acts, limiting criminal intervention to the most serious or formally typified cases. However, institutional experience has shown that this formal distinction is often insufficient to capture the real nature of violations affecting territory and public assets, particularly when they are connected to the exercise of public power and unlawful economic benefit.

Administrative violations in the territorial sphere—such as unauthorized construction, unlawful occupation of public land, or the exploitation of natural resources in breach of the law—frequently arise as a result of institutional tolerance, deliberate administrative inaction, or informal cooperation between private actors and public officials. In such cases, the administrative violation does not constitute an isolated phenomenon, but rather a component of a broader scheme of functional corruption, in which public decision-making systematically deviates from the public interest (Rose-Ackerman & Palifka, 2016).

Functional corruption is characterized precisely by this interplay between administrative action or inaction and private benefit, making it difficult to identify solely through the classical offences of criminal corruption. In sectors marked by high administrative discretion, such as territorial planning and the management of public

assets, formally administrative violations may evolve into stable mechanisms for unlawful gain and for the consolidation of institutional impunity (Transparency International, 2020).

In this context, the boundary between administrative violations and criminal offences becomes increasingly blurred, highlighting the need for a reconceptualization of the role of criminal law. Contemporary anti-corruption policies emphasize that the effective protection of public assets and territory requires an integrated approach, in which criminal intervention serves to target not only the unlawful act itself, but also the institutional structures that enable it (OECD, 2017).

From this perspective, the transition from a purely administrative treatment towards recognition of the criminal dimension of these violations represents a significant evolution of criminal policy. This evolution seeks to address corruption not as an individual deviation, but as a functional phenomenon that undermines the integrity of the exercise of public power and directly harms the public interest. Such an approach provides the conceptual basis for stronger criminal interventions, justified not only by material harm, but by the need to protect institutional integrity and public trust in the administration of territory and public assets (Council of Europe, 2018).

2. THE CONCEPTUAL FRAMEWORK OF PUBLIC INTEGRITY AND CORRUPTION

2.1. Public Integrity as a Principle of the Rule of Law

Public integrity constitutes a fundamental principle of the rule of law and democratic governance, as it is directly linked to the manner in which public power is exercised and collective resources are administered. From a legal and institutional perspective, public integrity entails the performance of public functions in accordance with the law, the public interest, and the ethical standards of public service, excluding the use of public authority for private or undue benefit (OECD, 2017).

From this perspective, public integrity cannot be reduced to a merely moral or ethical requirement, but is transformed into a legal standard that directly influences the formulation of public policies and the structuring of the legal accountability of public officials. The impairment of public integrity through abuse of power, deliberate inaction, or the tolerance of illegality produces systemic consequences, undermining citizens' trust in public institutions and weakening the effectiveness of control and accountability mechanisms (Rose-Ackerman & Palifka, 2016).

In contemporary doctrine, public integrity is increasingly treated as a criterion for assessing the actual functioning of the rule of law, particularly in sectors characterized by a high degree of administrative discretion, such as the management of territory and public assets. In these areas, the absence of institutional integrity

creates opportunities for the distortion of public decision-making and for the consolidation of practices of impunity, thereby rendering criminal law intervention necessary as an instrument for safeguarding the public interest (Council of Europe, 2018).

2.2. Corruption as a Functional and Institutional Phenomenon

In contemporary legal analysis, corruption is no longer conceptualized solely as individual conduct subject to criminal punishment, but as a functional phenomenon that develops within institutional structures and directly affects the quality of public governance. This perspective shifts attention from the isolated criminal act to the mechanisms through which public power deviates from the public interest and is used for private or clientelistic gain (Rose-Ackerman & Palifka, 2016).

Functional corruption often manifests through administrative actions or omissions which, although formally lawful or treated as administrative violations, generate direct corruptive effects. In sectors such as territorial planning, construction, and the administration of public assets, this phenomenon appears through the tolerance of illegality, the selective use of discretionary powers, and the lack of institutional response to repeated violations (Transparency International, 2020).

In this context, corruption does not merely constitute a breach of criminal norms, but represents a form of institutional dysfunction that undermines the integrity of the exercise of public authority. This approach justifies the expansion of criminal law intervention into areas traditionally governed by administrative law, aiming to target not only the unlawful act itself, but also the institutional structures and practices that enable it (OECD, 2017).

Consequently, treating corruption as a functional phenomenon provides the conceptual basis for a criminal policy more strongly oriented towards prevention and the protection of public integrity. Within this framework, the criminal protection of public assets and territory acquires meaning not only as a response to specific violations, but as an instrument for limiting the structural spaces of corruption and strengthening institutional accountability in the exercise of public power (Council of Europe, 2018).

3. THE 2026 AMENDMENTS TO THE CRIMINAL CODE: CONTEXT AND OBJECTIVES

3.1. The Normative and Institutional Context of Criminal Law Intervention

The amendments to the Criminal Code adopted on 28 January 2026 must be analyzed within the context of a persistent institutional problem related to the systematic infringement of public assets and territory through unlawful practices tolerated or facilitated by the exercise of public functions. The explanatory memorandum accompanying the draft law highlights those existing mechanisms, primarily administrative in nature, have

proven insufficient to ensure effective protection of the public interest and to prevent unlawful economic gain at the expense of territory and public assets.

Within this framework, criminal law intervention is justified not only by the scale of material damage caused, but also by the direct impact that such violations have on institutional integrity and public trust in state authority. Criminal policy thus reflects a more conscious approach to functional corruption, treating the infringement of territory and public assets as an expression of abuse of public power rather than merely as technical violations of urban planning or property legislation.

This approach is consistent with contemporary trends in European criminal policy, which emphasize the need for differentiated criminal responses in sectors with a high risk of corruption, including land administration, urban planning, and the management of public assets (European Commission, 2023).

3.2. Criminal Policy Objectives Reflected in the 2026 Amendments

An analysis of the content of the amendments to the Criminal Code indicates that the legislative intervention pursues several clear objectives of criminal policy. First, it aims to strengthen the criminal protection of public assets and territory through the tightening of sanctions and the expansion of aggravating circumstances, particularly in cases where criminal offences are committed by public officials or in cooperation with them. This normative orientation reflects an increased criminal sensitivity to institutional abuse and a shift from symbolic punishment towards more effective criminal enforcement.

Second, the amendments seek to limit spaces of uncontrolled administrative discretion, which in practice have served as fertile ground for the tolerance of repeated violations and the consolidation of practices of impunity. In this sense, criminal law is employed as a corrective instrument addressing structural failures of administrative oversight, prioritizing the protection of the public interest over unlawful private interests.

Third, the objectives of the amendments are linked to strengthening the deterrent effect of criminal norms. By making criminal liability for the infringement of public assets and territory more visible and more severe, the legislature aims to influence not only individual behavior but also the institutional culture surrounding the exercise of public power. This deterrent dimension is closely connected to the concept of public integrity and to the need to restore citizens' trust in the state's capacity to safeguard the public interest (OECD, 2017).

From this perspective, the 2026 amendments to the Criminal Code do not appear as fragmented interventions, but as part of a broader orientation of criminal policy aimed at addressing corruption by targeting its structural and functional forms, particularly those related to the administration of territory and public assets.

4. CRIMINAL PROTECTION OF PUBLIC ASSETS AND TERRITORY AS AN ANTI-CORRUPTION INSTRUMENT

The criminal protection of public assets and territory represents one of the most significant developments in contemporary criminal policy in the field of anti-corruption, reflecting a clear orientation towards addressing structural forms of abuse of public power. In criminal law scholarship, it has been emphasized that corruption related to the administration of public assets and territory constitutes one of the most resilient forms of corruption in relation to traditional administrative control mechanisms, due to the interplay of economic interests, institutional discretion, and enforcement weaknesses (Carrera & Mitsilegas, 2017).

Within this framework, criminal law emerges as a corrective instrument addressing structural failures of public governance, seeking to restore the balance between private interests and the public interest. Criminal intervention in the sphere of territory and public assets is justified not only by the economic damage caused, but also by the direct impact that such violations have on institutional integrity and the credibility of state action (Huskey & Iskandaryan, 2019).

4.1. The Tightening of Criminal Sanctions and Aggravating Circumstances

The tightening of criminal sanctions and the expansion of aggravating circumstances for offences affecting public assets and territory reflect a well-established trend in modern criminal policies, according to which offences posing a high level of institutional risk are addressed through differentiated criminal responses. In European criminal law doctrine, it has been recognized that an increase in punitive severity is justified where criminal conduct directly undermines the functioning of public institutions and the principle of equality before the law (Ashworth & Zedner, 2014).

The aggravating circumstances introduced by the 2026 amendments relate to elements that go beyond the material act of the offence, taking into account the scale of the harm caused, the repetition of unlawful conduct, and the institutional context in which it occurs. This approach is consistent with the principle of proportionality in criminal law, according to which the severity of punishment should reflect not only material consequences, but also the social and institutional dangerousness of the offence (European Court of Human Rights, 2012).

In this sense, the tightening of sanctions aims to enhance the deterrent effect of criminal norms by influencing the behavior of actors operating in sectors with a high risk of corruption, such as territorial administration and the management of public assets. Legal scholarship has emphasized that, in the absence of a strong criminal response, these sectors tend to develop stable forms of impunity that seriously undermine institutional integrity (Loughlin, 2016).

4.2. Criminal Liability of Public Officials and the Institutional Dimension of Punishability

The emphasis on the criminal liability of public officials for the infringement of public assets and territory constitutes a key element of anti-corruption policy. In contemporary analyses, the public official is identified as the central node of institutional corruption, due to their role in administrative decision-making and in the exercise of discretionary powers (Johnston, 2014).

Establishing a more direct link between the exercise of public functions and criminal liability seeks to limit spaces for institutional abuse and to strengthen the principle of accountability. According to European standards on public integrity, the criminal liability of public officials should function not only as a punitive measure, but also as a preventive and educational mechanism, influencing institutional culture and societal perceptions of legality (Council of Europe, GRECO, 2017).

From this perspective, the criminal punishment of public officials for acts that infringe territory and public assets contributes to the strengthening of public integrity and to the restoration of citizens' trust in the capacity of state institutions to safeguard the public interest. This approach is consistent with theoretical developments that conceive criminal law as an instrument for the protection of the constitutional order, rather than merely as a response to individual deviations (Jakobs, 2004).

5. PUBLIC INTEGRITY AND THE DETERRENT EFFECT OF CRIMINAL LAW

5.1. The Deterrent Effect of Criminal Norms in the Protection of Public Assets and Territory

The deterrent effect of criminal law constitutes one of the core functions of criminal policy, particularly in areas where violations are linked to the exercise of public power and to significant economic benefits. In criminal law doctrine, deterrence is not reduced solely to the fear of punishment, but is associated with the capacity of criminal norms to influence individual and institutional behavior by increasing the legal and social costs of unlawful conduct (Beccaria, 1764/1986; von Hirsch et al., 1999).

In the context of the protection of public assets and territory, deterrence acquires a specific dimension, as violations in this field are often characterized by the instrumental rationality of actors and by expectations of impunity. The 2026 amendments to the Criminal Code are specifically aimed at intervening in this logic, by rendering criminal punishment more predictable and more severe in cases involving the infringement of the public interest. Legal scholarship has emphasized that the certainty of punishment, rather than its isolated severity, represents a key factor in strengthening deterrence in crimes related to corruption and institutional abuse (Nagin, 2013).

In this sense, criminal law intervention in the sphere of territory and public assets seeks to produce a dual deterrent effect: on the one hand, to discourage private actors from engaging in unlawful economic gain; on the other hand, to limit institutional tolerance and administrative inaction by increasing the criminal liability of public officials directly or indirectly involved in such violations.

5.2. The Symbolic Function of Criminal Law and the Consolidation of Public Integrity

Beyond deterrence in its classical sense, criminal law also performs a symbolic function, which relates to the normative expression of the fundamental values of the legal order and to the delineation of the boundaries of socially acceptable behavior. This function is particularly significant in areas where corruption has assumed a systemic character and where institutional tolerance has undermined public trust in the effectiveness of the state (Duff, 2001).

From this perspective, the criminal protection of public assets and territory serves as a normative signal that the infringement of the public interest through the abuse of public power constitutes a serious violation of the legal order and of institutional integrity. The 2026 amendments to the Criminal Code may be interpreted as part of this symbolic message, reaffirming the principle that the exercise of public functions must be oriented exclusively towards the public interest rather than private benefit.

Contemporary doctrine emphasizes that the symbolic function of criminal law has a direct impact on the formation of a culture of legality and on societal perceptions of public integrity, particularly in societies where corruption has become normalized (Tonry, 2014). In this framework, criminal intervention aims not only at punishing specific conduct, but also at reshaping normative expectations regarding the exercise of public power.

5.3. Public Integrity as an Object of Criminal Protection

In contemporary legal analysis, public integrity is increasingly consolidated as an autonomous object of criminal protection, particularly in areas where violations generate systemic and long-term consequences for the functioning of institutions. Unlike traditional approaches that viewed criminal law primarily as an instrument for the protection of property or public order, modern perspectives conceive it as a means of safeguarding the credibility and legitimacy of state authority (Peters & Pierre, 2016).

In this sense, the criminal protection of public assets and territory directly contributes to the consolidation of public integrity by limiting spaces for institutional abuse and strengthening the accountability of public officials. The 2026 amendments to the Criminal Code thus appear as part of a broader orientation of criminal policy aimed at addressing corruption not merely as individual misconduct, but as a threat to the normal functioning of institutions and to the rule of law.

From this perspective, public integrity no longer remains an abstract or purely ethical concept, but is transformed into a legal standard protected through criminal law mechanisms, assigning criminal law a central role within the architecture of anti-corruption efforts and in strengthening public trust in state institutions.

6. THE CRIMINAL CODE AMENDMENTS IN RELATION TO EUROPEAN STANDARDS AND THE RULE OF LAW

6.1. European Standards in the Criminal Protection of the Public Interest

At the European level, the criminal protection of the public interest—including public assets and territory—has developed as part of an integrated approach to combating corruption and crimes that undermine the functioning of institutions. European and international instruments emphasize that the infringement of public resources and decision-making concerning territory constitutes a direct threat to the rule of law, thereby justifying differentiated and effective criminal interventions (Council of Europe, 2018; UNODC, 2004).

Within this framework, European standards do not merely focus on the formal criminalisation of offences, but require states to ensure the real effectiveness of criminal prosecution, particularly in sectors with a high risk of corruption. The administration of territory and public assets is widely identified as one such sector, due to the broad scope of administrative discretion and the interconnection between economic interests and public decision-making. Consequently, strengthening criminal liability for infringements affecting these interests aligns with the European orientation towards substantive protection of the public interest.

The 2026 amendments to the Criminal Code may be read in this light as an effort to align Albanian criminal policy with these standards, placing the protection of public assets and territory at the centre of the anti-corruption strategy and providing it with a stronger punitive foundation.

6.2. Balancing Criminal Punishability and the Principles of the Rule of Law

One of the central challenges of contemporary criminal policy concerns the maintenance of a balance between the need for effective criminal enforcement and respect for the fundamental principles of the rule of law, including legality, proportionality, and legal certainty. European case law has consistently emphasized that the strengthening of criminal sanctions must be accompanied by sufficient procedural safeguards and normative clarity in order to avoid arbitrariness in criminal justice (European Court of Human Rights, 2010).

In this context, criminal interventions aimed at protecting public assets and territory must be assessed not only from the perspective of anti-corruption effectiveness, but also in terms of their compatibility with rule-of-law standards. The 2026 amendments reflect an effort to reinforce criminal accountability without undermining the

core structure of criminal responsibility, focusing on elements such as aggravating circumstances, the link to public functions, and the extent of harm caused to the public interest.

However, European scholarship cautions that criminal effectiveness cannot rely solely on the severity of sanctions, but requires consistent, predictable, and equal application of criminal law. In the absence of these elements, there is a risk that criminal policy may produce selective or merely symbolic effects, without effectively addressing institutional corruption (Mitsilegas, 2016).

6.3. The 2026 Amendments as Part of the European Integration Process

Within the European integration process, the fight against corruption and the strengthening of the rule of law constitute essential criteria for assessing the progress of candidate and aspiring states. In this context, amendments to the Criminal Code acquire significance not only as domestic reforms, but also as indicators of institutional commitment to addressing structural problems related to public integrity.

The 2026 amendments to the Criminal Code may be interpreted as part of this commitment, reflecting an orientation towards substantive harmonisation with European standards rather than mere formal alignment. The emphasis placed on the criminal protection of public assets and territory demonstrates a more nuanced understanding of corruption as a phenomenon that directly undermines the public interest and the functioning of institutions.

From this perspective, the importance of these amendments lies not only in their normative content, but also in their potential to influence institutional practice and the culture of exercising public power. Their success will ultimately depend on the capacity of institutions to implement them consistently and in full compliance with the principles of the rule of law, thereby transforming criminal law into a credible and effective instrument in the fight against corruption.

7. CONCLUSIONS

The analysis of the amendments to the Criminal Code adopted in 2026 demonstrates that the criminal protection of public assets and territory has been consolidated as a distinct and functional dimension of the fight against corruption. These interventions reflect a significant shift in Albanian criminal policy, moving from a predominantly reactive and fragmented approach towards a more structured framework that treats the infringement of the public interest as an expression of institutional corruption rather than merely as a technical or administrative violation.

Within this framework, the criminal protection of public assets and territory no longer represents a secondary instrument of the legal order, but emerges as a core mechanism for strengthening public integrity and

accountability in the exercise of state power. The tightening of criminal sanctions, the expansion of aggravating circumstances, and the emphasis placed on the criminal liability of public officials signal a clear orientation towards addressing functional forms of corruption that directly undermine citizens' trust in public institutions and the functioning of the rule of law.

A central element of these amendments is the role of criminal law as both a deterrent and a symbolic instrument. By increasing punishability and clarifying criminal responsibility in sectors with a high risk of corruption, criminal law seeks to influence not only the individual behavior of those involved, but also the institutional culture surrounding the administration of territory and public assets. In this respect, public integrity is increasingly consolidated as an object of criminal protection, shifting the focus from limited material harm towards safeguarding the credibility and legitimacy of state action.

From the perspective of European standards, the 2026 amendments to the Criminal Code align with the broader trend of strengthening the criminal protection of the public interest in sectors particularly vulnerable to corruption, notably the administration of territory and public assets. Nevertheless, the actual effectiveness of this approach remains closely dependent on the practical implementation of criminal norms, respect for the principles of the rule of law, and the guarantee of equal and predictable criminal enforcement.

From this perspective, the significance of the 2026 amendments lies not only in their normative content, but also in their potential to influence institutional practice and the manner in which public power is exercised. The consistent application of these provisions, supported by effective investigative and adjudicative mechanisms, constitutes an essential condition for transforming criminal law into a genuine instrument in the fight against corruption and in the consolidation of public integrity.

Finally, the analysis opens avenues for further research into the practical impact of these amendments, particularly with regard to future case law, the role of specialised justice institutions, and the interaction between criminal and administrative mechanisms in the protection of public assets and territory. Such an assessment would be crucial in determining whether the new orientation of criminal policy succeeds in producing not only formal punishability, but also sustainable institutional integrity.

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INORGANIC SENSORS AND BIOSENSORS: MATERIALS, MECHANISMS, AND ANALYTICAL PERFORMANCE

Khalil Naziru Abdullahi¹ Musa Yahaya Abubakar² H. Ataitiya³, Jabir Said Ahmed⁴ and Ansar Bilyaminu Adam³

¹Department of Chemistry Federal University wukari

² Department of industrial Chemistry Federal University wukari

³ Department of Chemistry University of Jos

Corresponding author: yahayaabubakarmusa2015@gmail.com

Abstract

Organic sensors and biosensors have become effective stages of analysis since they are more stable at many chemically, controllable physicochemical mechanisms, and can be used in harsh working environments. This review will include a detailed discussion of recent discoveries done in inorganic materials used in sensor and biosensor devices which include metal oxides, semiconductors, nanostructured metals, inorganic nanocomposites, and hybrid interfaces. The basic sensing mechanisms, which are chemiresistive, electrochemical, optical, piezoelectric and field effect transduction are critically discussed focusing on the charge transfer, surface adsorption, redox process and signal amplification pathways. Especially, the importance of nanoscale engineering, defect chemistry, and surface functionalization in optimizing sensitivity, selectivity and response kinetics is discussed. The performance of inorganic sensor platforms of the analytical performance is measured based on the detection limits, linear dynamic range, response time, stability, reproducibility, and real-sample applicability. The main areas of application such as environmental monitoring, medical diagnostics, food safety, and control in industrial processes are mentioned. In conclusion, biofouling, long-term operations stability, and miniaturization of devices are also discussed and future directions with regards to smart, multiplexed, and sustainable inorganic sensing technologies are described.

Keywords *Inorganic sensor Inorganic biosensor Metal oxide nanomaterials Sensing mechanism Analytical performance Electrochemical sensor.*

Introduction

Inorganic sensors have traditionally been theorized as a passive signal transducers, and they transform chemical interaction into electrical or optical measurement. More recent studies however are now more redefining such systems as programmable analytical interfaces- materials engineered to have tunable surface states, adaptive charge transport and dynamic catalytic behaviour (Zhang et al., 2022; Li and Wang, 2021). The recent study of nanostructured oxides, plasmonic metals, and semiconductor heterojunctions proves that the composition of materials no longer determines sensing performance, but interfacial electronic architecture is a factor of success (Singh et al., 2023). It is a transition to the optimization of surfaces on the atomic level, as opposed to the bulk optimization of properties, and it has the potential to enable selective molecular recognition. Traditional metal oxide sensors (Such as SnO_2 , ZnO) were based on resistive variations caused by the adsorption of gases. Initially, heterojunction band alignment is achieved through an electrochemical method that produces and aligns the bands in a sequence of substrates forming a heterojunction (HJ). Recent research on vacancy-rich ZnO nanoflakes demonstrates that the density of oxygen defect is engineered to improve significantly charge carrier mobility and the kinetics of interactions of analyses (Kumar et al., 2021). On the same note, TiO_2 polymorph phase control permits selective volatile organic compounds by using customized acid-base chemistry of the surface (Chen et al., 2022). Notably, defect engineering is not limited to empirical tuning and now predictive modeling with density functional theory (DFT) provides the opportunity to achieve a predictive sensing selectivity in advance (Wang et al., 2023). Surface-to-volume ratio paradigms have been altered by the development of 2D inorganic substances as MoS_2 , WS_2 , and MXenes. These materials exhibit: Atomic-level thickness, High carrier mobility, Tunable bandgaps.

In the case of MXene-based sensors, especially $\text{Ti}_3\text{C}_2\text{Tx}$, the sensors have an impressive electrochemical activity owing to surface terminations ($-\text{OH}$, $-\text{F}$, $-\text{O}$) that allow specific biomarkers and heavy metals to be detected (Alhabeb et al., 2021; Zhao et al., 2022). Arguably, compared to traditional oxides, 2D materials can be real-time modulated with respect to sensing properties through electrostatic gating - a discovery that enables reconfigurable sensors (Liu et al., 2023). The plasmonic nanoparticles (Au , Ag , Cu) have localized surface plasmon resonance (LSPR), and this type of plasmonic nanoparticles is very sensitive to changes in the refractive indices around the surface. The recent developments consist of: Core-shell plasmonic architectures Core-shell plasmonic architectures are plasmonic structures that combine nanostructures with metal nanoparticles to generate additional plasmonic states. Core-shell plasmonic architectures Core-shell plasmonic

architectures are plasmonic structures in which nanostructures are fabricated with metal nanoparticles to create further plasmonic states.

Sub-nanomolar protein biomarkers have been detected by the use of wavelength shift on gold nanorod arrays (Rahman et al., 2021). In addition, spectral deconvolution is now enhanced by the assistance of machine-learning in improving the analytical resolution of complex matrices (Dutta et al., 2024). As an example, hybrids of perovskite-Au nanoparticles have a high humidity and gas sensing stability when compared to pure perovskites (Gao et al., 2023).

Adsorption and Charge transfer on the surface.

In the majority of inorganic sensors, the principle operating is the surface adsorption-induced electric property modulation. There are three prevailing mechanisms, namely:

- i. Depletion layer modulation
- ii. Modification in Schottky barrier.
- iii. Redox-induced change of conductivity.

Oxidizing gases adsorbed on n-type metal oxide metal oxides remove electrons, and the resistance is increased. On the other hand, the resistance is reduced by the electrons donated by the reduction of gases (Zhang et al., 2022). Recent in situ XPS and operando Raman spectroscopic experiments indicate that the sensing response is strongly negative related to dynamical surface reconstruction with the exposure of the analytes (Xu et al., 2023). The use of Pd-doped SnO₂ improves the hydrogen sensing through catalytic deprotonation of H₂ (Miller et al., 2021). ZnO with a modification of CuO has selective ethanol oxidation (Jiang et al., 2022). The catalytic activity in combination with electronic transduction is what the term chemo-electronic amplification refers to, which has been discussed in the sensor engineering literature recently (Park & Lee, 2023). Photoelectrochemical Sensing involves measuring a parameter based on the optical properties of a substance, particularly the photoreaction of a material with light.

Photoelectrochemical Sensing

Photoelectrochemical Sensing is based on the optical characteristics of a material, especially the photoreaction of a material to light. Another layer of modulation is introduced in sensing processes by photoexcitation. BiVO₄ and WO₃ are a good example of semiconductor materials that form electron-hole pairs during illumination leading to an enhanced:

- i. Surface reaction kinetics
- ii. Reduced periods of operation.

iii. Reduced power consumption

TiO₂ sensors that are driven by visible light show selective NO₂ detection at room temperature and do not need high temperatures (He et al., 2022). This is a footprint reducer of energy-a very crucial aspect of a portable biosensing system.

Electrochemical Transduction Inorganic Biosensors.

Recent reports indicate that graphene-metal oxide composites have a major role in increasing electron transfer between the biological recognition elements and the electrodes (Sun et al., 2021). Electrodes made using MXene have a high capacitance and electron kinetics rate in the glucose and DNA detection (Liu et al., 2023). Signal Noise Suppression and Stability Engineering. Fluorinated oxide surfaces have been shown to have stability in the humid environment over a long period of time (Kim et al., 2024).

Reconfigurable inorganic Interfaces to Biomolecular Recognition.

The advances in inorganic biosensors have seen the transformation of the platform of the static electrodes into electronically adaptable biointerfaces that can simultaneously control charge transport, catalytic amplification and molecular orientation. Inorganic nanomaterials are no longer just immobilization substrates because they have been shown to play an active role in the kinetics of biorecognition and the transfer of electrons (Huang et al., 2021). Nanoscale defect engineering, surface functionalization chemistry and heterostructure design are some of the key areas through which this transformation has been achieved. Surface modulation of energy is essential in regulating the geometry of protein adsorption and retention of enzyme activities. As an illustration, a systematic hydroxyl density of oxide nanostructures attains a high degree of enzyme stability, through supporting preferred hydrogen bonding interactions and reducing denaturation (Li et al., 2022). Moreover, the transport of charges through vacuities is useful in the efficient tunneling of electrons between the redox-active biomolecules and the conductive substrates (Singh et al., 2023). It is through such mechanisms that biosensors are able to record a signal that has a high fidelity and low detection levels. The thermal, mechanical, and electrochemical stability of inorganic materials is also strong, which means that they can be used in wearable and field-based diagnostics since the environmental conditions vary greatly (Zhao et al., 2021).

Metal Oxide Nanostructures in Biosensing of Enzymes and Non-Enzymes.

ZnO, TiO₂ and Fe₃O₄ metal oxide nanostructures have proven to be highly affinity to enzyme immobilization without loss of catalytic accessibility. ZnO nanorods have high isoelectric point thereby enhancing the electrostatic interaction with glucose oxidase hence the electron transfer kinetics and sensitivity (Kumar et al., 2022). The high surface area of mesoporous TiO₂ electrodes and the presence of interconnected pathways

through which the electrons can move right away cut down on overpotential in amperometric biosensors (Park et al., 2021). Oxygen vacancy engineering also increases interfacial charge transfer. Oxide structures with vacancies have a higher donor concentration and better conductivity, and this characteristic promotes a faster reaction of electrons between active sites of enzymes and electrodes (Chen et al., 2023). This plan helps in increasing the response rates and enhances reproducibility.

Non-Enzymatic Electrochemical Biosensors.

The instability of enzymes in different pH and temperature has led to the formation of non-enzymatic inorganic biosensors. Multi-valence transition metal oxides are capable of catalyzing the direct oxidation of biomolecules. As an example, NiCo₂O₄ nanosheets have been found to have inherent catalytic ability to oxidize glucose without the presence of the enzyme (Gao et al., 2022). On the same note, CuO nanostructures exhibit effective redox cycling of dopamine and hydrogen peroxide at the surface (Li et al., 2021). These catalytic platforms, which are inorganic, have long operating life cycle, they are easy to make and also they cannot be degraded by the biological environment. Their performance is highly dependent on the morphology of nanostructure, the density of defects and electronic band alignment.

Inorganic Biosensors based on plasmonics.

Localized surface plasmon resonance (LSPR) is an effective optical transduction process in inorganic biosensors. Gold and silver nanoparticles are noble metals that produce local electromagnetic field improvements when light is excited and enhance changes in refractive index due to biomolecular attaching (Rahman et al., 2022). The most recent are alloyed Au-Ag nanoparticles to control the resonance frequencies and nanostar shapes to form a hot spot to amplify the signal (Kim et al., 2023). Highly selective detection of biomarkers is achieved through surface immobilization of aptamers and antibodies with plasmonic sensitivity being preserved (Wang et al., 2021). Spectral interpretation with machine learning assistance has also enhanced the ability of multiplex detection, enabling the ability to distinguish spectral shifts of overlapping spectral shifts on complex biological samples (Dutta et al., 2024). This is the combination of nanoplasmonics and computational analytics that increases sensitivity and specificity.

Inorganic Materials in Biosensing Two-Dimensional (MXenes)

MXenes, and specifically Ti₃C₂T_x have been found to be highly conductive and chemically adjustable compounds to be used in electrochemical biosensing. The hydrogen bonding and electrostatic interaction with nucleic acids and proteins are made possible due to their surface terminations (-OH, -F, -O) (Liu et al., 2022). Capacitance-varying DNA detection has been shown to be a label-free DNA detection method with high

sensitivity (Zhang et al., 2021). The MXenes can be combined with metallic nanoparticles to increase catalytic amplification and reduce the detection limits up to femtomolar concentrations (Chen et al., 2023). The MXenes are metallically conductive and therefore they can facilitate fast movement of electrons, hence are applicable in real-time monitoring systems.

Transition metal dichalcogenides

Transition Metal Dichalcogenides Transition metal dichalcogenides are the most basic compounds comprising of chalcogen and metal. Biosensors can be realized with field-effect transistor (FET)-based 2D transition metal dichalcogenides (TMDs), including MoS₂, that can be tuned with bandgap and carrier mobility, and have high carrier mobility (Yang et al., 2022). The active sites are enhanced through sulfur vacancy engineering and result in a more sensitive charge (Lee et al., 2021). The use of MoS₂ FET biosensors in the detection of viral RNA sequences has shown a rapid detection rate, which presents a high possibility of detecting infectious diseases (Sun et al., 2023). Their surface sensitivity is improved due to their atomic thickness, and their ability to sense a small charge perturbation can be detected.

Optical Biosensors based on Perovskite.

CsPbBr₃ nanocrystals as all-inorganic halide perovskites are strongly photoluminescent and have large absorption coefficients. The interaction of biomolecules with fluorescence quenching mechanisms has been used to detect biomolecules, with the interaction altering radiative recombination mechanisms (Zhao et al., 2022). Encapsulation and surface passivation are currently being employed to overcome perovskite stability problems, which are very challenging to overcome, which can greatly enhance moisture insensitivity and operational longevity (Kumar et al., 2024). Those developments make perovskites good candidates as new optical biosensors.

Performance Metrics and Standards of Benchmarking.

Inorganic biosensors Sensitivity in inorganic biosensors. The slope of the calibration curve and analyte concentration determines the sensitivity, whereas the limit of detection (LOD) is determined by signal-to-noise ratio and constant baseline. The process of nanostructuring and heterojunction engineering has allowed reaching the picomolar and femtomolar range of detection (Chen et al., 2023). Modern benchmarking focuses on realistic testing conditions, such as the use of biological fluids and not just buffer-only system performance analysis (Patel et al., 2022). This methodology will guarantee translational relevance.

Suppression of Noise and Signal Stabilization.

The causes of signal instability are charge trapping, thermal noise and environmental interference. The use of heterojunction engineering has been demonstrated to suppress the phenomenon of baseline drift, as well as to improve the reproducibility (Wang et al., 2022). Schottky barrier stabilization has been shown to suppress the phenomenon of baseline drift and increase reproducibility. Also, impedance spectroscopy modeling can enhance the level of resolution and separation between the true signal and the background fluctuation (Zhou et al., 2023). Anti-fouling layers and hydrophobic surface coated can also minimize the humidity-related noise and adsorption of the nonspecific surface (Li et al., 2023).

Selectivity Engineering

The process of selectivity is done using controlled surface chemistry and bandgap modulation. With the rare-earth doping, the adsorption energetics change, and the selectivity of chemically similar analytes is enhanced (Liu et al., 2021). The fact that molecular imprinting methods used on inorganic surfaces offer shape-selective sites of recognition increases biomarker specificity (Park et al., 2022).

Kinetic Response and Operational Stability.

Nanostructures are porous, which lowers diffusion barriers and leads to a quick access to analyte and time reduction (Zhang et al., 2023). Predictive simulation of sensor behavior over time with both static and dynamic concentrations of the analyte now becomes possible with the use of finite element modeling (Li et al., 2024). Commercialization still requires long term stability. Atomic layer deposition (ALD) coating and core-shell nanostructures will increase the structural durability and inhibit the degradation of the surface (Chen et al., 2021). Accelerating aging tests show that sensing performance is retentive at high frequency of repetitive operational cycles (Gao et al., 2022).

Uses of Inorganic Biosensors in Healthcare, Environmental, and Industrial System monitoring.

The development of the inorganic biosensor has made it possible to shift the inorganic biosensor prototypes to real-life analytical systems. The improvement of nanostructured materials, defect engineering, plasmonics and 2D semiconductors has increased their usage in clinical diagnostics, environmental monitoring, food safety and process control in industries. Compared to the previous biosensors, which had few operational window and instability in organics, inorganic platforms are robust, sensitive, and compatible with harsh conditions (Zhao et al., 2021).

The detection of infectious disease is also a part of the work of the

One of the priorities in the world is to detect infectious pathogens quickly. MoS₂ Transistor-based inorganic biosensors have been used to detect viral RNA with a sensitivity of less than sub-picomolar and without labelling (Sun et al., 2023). Exceptional sensitivity of surface charge gives the atomic-scale thickness of MoS₂ the capability to detect small amounts of biomolecular interactions. In the same vein, plasmonic nanostructures based on gold nanostars can be used to obtain localized electromagnetic fields, which can be used to detect viral antigens by surface-enhanced Raman scattering (SERS) with high sensitivity (Rahman et al., 2022). Spectral deconvolution with the help of machine learning enhances specificity in complicated biological samples (Dutta et al., 2024).

There are also MXene-based electrochemical sensors, which can be considered rapid diagnostic tools because these have high conductivity and can be tuned in the terms of surface terminations (Liu et al., 2022). The reaction with metallic nanoparticles is called hybridization, which increases catalytic amplification with the use of minutes to detect.

Cancer Biomarker Monitoring

Ultra-low concentration detection of biomarkers is necessary in the early detection of cancer. The fluorescence biosensors with the perovskite nanocrystals provide a highly sensitive optical detection mechanism under the conditions of quenching of the optical responses by the analyte (Zhao et al., 2022). Better encapsulation plans eliminate moisture sensitivity and improve long-term stability (Kumar et al., 2024). The kinetics of electron transfer and detection limits of tumor markers including prostate-specific antigen (PSA) and carcinoembryonic antigen (CEA) are enhanced in electrochemical biosensors based on oxygen-vacancy-rich metal oxides (Chen et al., 2023). More specific advantages offered by rare-earth-doped oxide platforms are a higher selection degree by adjusting adsorption energetics and binding affinity of the target biomolecules (Liu et al., 2021).

Wearable Monitoring Systems.

The personalized medicine is changing wearable biosensors. Inorganic nanostructures that are flexible and embedded in polymer substrates can be used to detect glucose, lactate, and electrolytes in sweat in real-time (Zhao et al., 2021). Non-enzymatic glucose sensors based on NiCo₂O₄ exhibit high catalytic stability that they can use in continuous monitoring (Gao et al., 2022). Substitution of enzyme dependence improves the operational life and environmental tolerance. Also, the atomic layer deposition (ALD) coating enhances moisture resistance and mechanical stability of wearable electrochemical devices (Chen et al., 2021).

Environmental Monitoring Applications.

Inorganic based electrochemical biosensors have been used in detecting heavy metal ions like Pb^{2+} , Hg^{2+} and Cd^{2+} in the water systems. Platforms made of MXene show high metal ion affinity on their surfaces attributed to functional groups that allow the electrochemical stripping analysis to be very sensitive (Liu et al., 2022). The rare-earth doped metal oxide nanostructures enhance the selectivity and detection accuracy in the complex environmental matrices (Liu et al., 2021). These porous nanostructures also have an added advantage of improving mass transport and adsorption kinetics to lower the response times in field-based monitoring systems (Zhang et al., 2023).

Organic Pollutants and Pesticides Detection.

Surface-enhanced Raman detection of pesticide residues at the trace level has been done with the help of the plasmonic nanoparticle arrays (Rahman et al., 2022). The amplification effect enables the detection of limits which are less than regulatory levels. CuO and ZnO nanostructures are used in the electrochemical sensors that catalyze the oxidation of phenolic compounds and organophosphate residues (Li et al., 2021; Kumar et al., 2022). Such inorganic systems exhibit high resistance to foulage when compared to organic electrodes.

Air Quality and Volatile Organic Compounds.

Silicon metal oxide semiconductors that are defect-engineered have demonstrated high sensitivity to volatile organic compounds (VOCs). Vacancies of oxygen enhance adsorption sites and increase the transfer of charge during the interaction of the gas with it (Chen et al., 2023). Environmental gas sensors Junction stabilization by Schottky stabilization decreases the drift in the baseline and increases signal reproducibility (Wang et al., 2022). The advances allow the implementation in intelligent environmental surveillance networks.

Agricultural Monitoring and Food Safety.

A rapid analysis instrument is required to detect food contamination by microorganisms, toxins, and pesticide residues. The MXene-powered biosensors can identify the DNA sequences of bacteria promptly due to the changes in impedance (Zhang et al., 2021). Shape-selective binding cavities are the formation of inorganic polymers that have been molecularly imprinted and that select foodborne toxins (Park et al., 2022). CuO nanostructures and $NiCo_2O_4$ have also been used to detect hydrogen peroxide and metabolites related to spoilage, and provide a quick determination of freshness (Gao et al., 2022; Li et al., 2021).

Bioprocess Monitoring in the Industry.

Continuous monitoring of the metabolites which include glucose, ethanol and lactate are obligatory in the industrial fermentation and bioprocesses. Inorganic sensors that are not enzymatic are more stable in extreme

chemical conditions (Gao et al., 2022). It has been demonstrated that a predictive simulation of sensor behavior at dynamic concentration gradients is possible using finite element modeling to enhance optimization of processes (Li et al., 2024). Core-shell nanostructured electrodes are resistant to corrosion and long-term working of industrial electrolyte (Chen et al., 2021).

Intelligent Systems and Remote Diagnostics.

Wireless communication systems and inorganic biosensors can be integrated to remotely monitor the health and environment. Multiplex sensing arrays can be optimized to detect anomalies and interpret the signals better with the help of machine learning algorithms (Dutta et al., 2024). Cloud-based analytics is used to enhance the reliability and data reproducibility through impedance modeling (Zhou et al., 2023). Such a combination of digital and materials science is a paradigm shift towards smart biosensing ecosystems.

The integration of inorganic biosensors with artificial intelligence (AI), Internet of Things (IoT) systems, and cloud-based analytics can be seen as a revolutionary change in the paradigm of individually functional analytical instruments to smart sensing systems. The development of nanostructured inorganic materials offers very sensitive signal outputs, the analysis of multimodal and multiplexed signals becomes increasingly dependent on computational intelligence (Dutta et al., 2024). Such form of integration increases sensitivity, selectivity, predictive capability and real time decision making.

Electrochemical and optical inorganic biosensors tend to produce multidimensional data that is subject to environmental noise, matrix interference and signal drift. Convolutional neural networks (CNNs) and support vector machines (SVMs) are machine learning algorithms that have shown a high level of ability to extract meaningful patterns on plasmonic and impedance spectra (Dutta et al., 2024). Indicatively, AI-supported surface-enhanced Raman scattering (SERS) spectrum analysis is better able to discriminate structurally similar biomarkers by detecting subtle spectral changes that can be hard to interpret manually (Rahman et al., 2022). The method is very useful in minimizing false-positive results in clinical diagnosis.

Impedance modeling with neural network analysis is used to provide a high level of detection in electrochemical systems with ultra-low concentrations of analytes (Zhou et al., 2023). These computational techniques correct for such effects as baseline drift and electrode aging.

Predictive Modelling and Sensing without Calibration.

Classical biosensors have to be recalibrated frequently because of the surface degradation and environmental variations. The predictive models that use AI can dynamically change the calibration curve by using past sensor behavior (Patel et al., 2022). With the combination of a mass transport and reaction kinetics simulation based on

the finite element modeling and machine learning algorithms, the analyte concentrations can be varied (Li et al., 2024). These hybrid modeling structures make it possible to predict the sensor lifespan and performance decline and provide proactive maintenance. The change to calibration-free sensing will cut costs of operation and increase scalability.

IoT-Based distributed biosensing.

The use of IoT enables bio sensors which are inorganic to be deployed as network nodes in distributed monitoring. Biochemical data can be transmitted in real-time with wireless connectivity to central processing systems used to analyze the data and make decisions (Zhao et al., 2021).

Wearable and Remote Healthcare Monitoring.

Physiological biomarkers to be monitored by flexible inorganic nanostructures encompassed in wearable devices include glucose, lactate, and electrolytes (Gao et al., 2022). These devices relay real time health data either to mobile applications or to hospital databases when linked to IoT platforms. The biosensors based on MoS₂-based FET have been reported to detect viral RNA rapidly, and upon incorporation with wireless modules, they can be used to monitor infectious diseases remotely (Sun et al., 2023). These systems minimise wait time in diagnosis and enhance respondent capacity in case of an outbreak.

Smart City and Environmental Applications.

Large-scale monitoring of air quality is possible using distributed inorganic gas sensors that make use of oxygen-vacancy-engineered metal oxides (Chen et al., 2023). By being integrated with IoT platforms, they can map the concentration of the pollutants continuously across the urban scapes. Sensors made with rare-earth-doped oxides are found to be more selective to toxic gases, which increases their reliability in industrial and environmental networks of sensors (Liu et al., 2021). The cloud-based analytics consolidates the information sent by multiple sensor nodes, which makes predictions of the environment and helps create a warning system.

Data Security and Ethical Iss.

Digitization of biosensing raises issues of privacy and cybersecurity of data. Patient and environmental data need to be secured by encryption protocols and secure data transmission frameworks. Edge computing, in which preliminary data processing is done on the sensor node, minimizes and shortens latency and transmission of raw data (Zhou et al., 2023). This will enhance efficiency of the system and the privacy will be increased. The smart biosensing systems of the future should combine material innovation and ethical systems of data governance.

Research gaps

Although a lot of progress has been made in the field of inorganic sensors and biosensors, there exist certain research voids that hamper their applicability in the next-generation diagnostic and analytical systems. The existing solutions mainly focus on the development of material innovations, as well as enhancements in signal transduction, but autonomous decision-making and adaptive functionality are still underdeveloped. The future studies should involve the development of self-regulating sensing systems that can be recalibrated dynamically and learned in real-time to improve their operational reliability to operate under changing environmental conditions.

Long-term stability and resistance to biofouling in biological and environmental matrix is another significant area of gap. In spite of the enhanced durability with surface passivation and anti-fouling coating, corrosion and drifting effects still pose a challenge to clinical and industrial applications. New materials, which have built-in self-cleaning mechanisms and bio-repellent surfaces, are demanded to increase service life.

Another problem that is still not solved is standardization and reproducibility. The fluctuation in the production of nanomaterials and the manufacture of devices results into differences in the performance among the laboratories. The lack of standardized protocols of benchmarking interferes with commercialization and regulatory acceptance. In order to convert research prototypes into products in the market, standardization of evaluation frames and inter-laboratory validation strategies are necessary.

In addition, there are multi-modal sensing architectures, which integrate electrochemical, optical and mechanical transduction, that are not yet well developed. This may help to increase diagnostic accuracy by cross-validating signals and decrease false positives in such hybrid systems. Pattern recognition and predictive analytics that involve artificial intelligence integration is another potentially useful direction although it will need quality datasets and ethical systems of data management.

Lastly, little attention has been paid to sustainability in the synthesis of materials and devices. They require green chemistry methods and sensor components that are recyclable in order to reduce environmental impact. By filling these gaps, inorganic biosensors can be developed as tools of special analysis to intelligent, sustainable diagnostic devices with wide applications in the society and industry.

Future Research Frontiers and New Paradigms.

The successive generation of inorganic biosensors will be characterized by multifunctionality, sustainability, and self adaptive intelligence. New paradigms are oriented not only on better sensitiveness but also on resilience, biocompatibility and environmental responsibility.

Self-Healing and adaptive Inorganic Materials.

The primary weakness of nanoscale inorganic materials is their deterioration with prolonged usage. In self-healing oxide frameworks where motion of defects recovers catalytic activity, preliminary studies have proven to be promising (Chen et al., 2023). Reversible redox cycling Dynamic heterostructures with the ability to sense changing chemical environments could be realized by redox cycling of various structures under dynamically varying chemical conditions. These materials might be able to correct themselves automatically based on the stress of the environment.

Green and Sustainable Fabrication.

Nanomaterial synthesis is also under increased scrutiny on the impact it has on the environment. Other methods of green chemistry are solvents-free synthesis and bio-assisted synthesis of nanomaterials that are increasingly becoming popular (Kumar et al., 2024).

Lower levels of fluorinated waste and low-temperature synthesis route ways to produce MXene are in the process of development (Liu et al., 2022). The principles of sustainable design will be considered critical to massive commercialization.

Quantum and Atomically Precise Biosensors.

New rules of quantum sensing can allow the detection of a single molecule. Atomically clean 2D material and perovskite nanocrystals have configurable electronic properties that have the potential to provide ultra-high-resolution sensing (Zhao et al., 2022).

Atomic-scale bandgap engineering is a promising technology to increase the sensitivity of charge perturbations, leading to the next generation field-effect biosensors.

Ever since translation and standardization are peas in a pod, it follows that commercial translation is as well. <|human|>7.5 Standardization and Commercial Translation Commercial translation is the same thing since the translation and the standardization are one and the same.

Although this has been done extensively, standard protocols of benchmarking should be used in translation to market. Both inter-laboratory validation and the test on real samples are necessary (Patel et al., 2022).

The core-shell nanostructures, as well as atomic layer deposition coating, enhance long-term stability, tackling the barriers of commercialization (Chen et al., 2021).

The pace at which state-of-the-art inorganic biosensors are brought in the clinic and industry will be dictated by regulatory harmonization.

Conclusion

Modern analytical science has changed with the development of inorganic sensors and biosensors giving very sensitive, stable, and flexible platforms of chemical and biological detection. In contrast to older organic-based systems, the inorganic materials of metallic oxides, 2D nanomaterials, plasmonic nanoparticles and hybrid heterostructures are more thermally and chemically stable and can be used in severe conditions and remain stable over time. The development of nanostructure and surface modification has enhanced sensitivity and selectivity whereby biomarkers and pollutants can be detected at very low concentration. Defect engineering and heterojunction design to improve electronic properties and catalytic activity in the promotion of quick signal transduction and enhanced analytical performance.

Contemporary inorganic biosensors are now intelligent diagnostic interfaces as opposed to passive detection biosensors. They can analyze data and monitor it in real-time, which makes them applicable in the field of personalized healthcare, environmental surveillance, and industrial process control due to the integration with artificial intelligence and Internet of Things technologies. The wearable biosensors will be used to conduct a continuous physiological monitoring of the environment, and the environmental sensor networks will monitor air and water quality. Strong inorganic platforms are applied in industries to increase safety and efficiency in processes.

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THE PARADOX OF SUSTAINABLE SANITATION

Nadia TEBBAL^{1, 1*} Institute of technical urban management, university of M'sila Algeria, ^{1*}

Geomaterials development laboratory, M'sila university, M'sila (28000), Algeria. Email:

nadia.tebbal@univ-msila.dz

Mekki Maza², Geomaterials development laboratory, civil engineering department, faculty of technology, M'sila university, M'sila (28000), Algeria. Email: mekki.maza@univ-msila.dz

Zine El Abidine RAHMOUNI², Geomaterials development laboratory, civil engineering department, faculty of technology, M'sila university, M'sila (28000), Algeria. zineelabidine.rehmouni@univ-msila.dz

Messaouda BELOUADAH², Geomaterials development laboratory, civil engineering department, faculty of technology, M'sila university, M'sila (28000), Algeria. Email: messaouda.belouadah@univ-msila.dz

Siham AIT YAHIA⁵, Department of Civil Engineering, University M'Hamed Bougara of Boumerdes , Algeria. Email: s.aityahia@univ-boumerdes.dz

Zoubir DJENDI⁴, Email: zoubir.djendi@gmail.com

Abstract

Faced with the climate emergency and the scarcity of "blue gold," our wastewater is no longer viewed as a mere nuisance to be disposed of, but as a strategic resource. The recovery of sewage sludge for energy and the reuse of treated wastewater (REUT) for agriculture or industry are now emerging as pillars of the circular economy.

However, this transition toward a zero-waste model faces a complex reality. The shift from a linear management system to a closed loop is hindered by a "technico-sanitary wall": the presence of persistent micropollutants, massive infrastructure costs, and particularly stringent regulations. How, then, can we transform our treatment plants into resource factories while guaranteeing absolute sanitary safety? This analysis explores the technological, economic, and societal barriers that still slow down the full recycling of our liquid waste today.

Keywords : Wastewater , Sewage sludge, Closed loop, Sanitary safety.

DIGITAL TWIN MODELLING OF OIL PRODUCTION USING QUANTUM COMPUTING FRAMEWORKS

¹Amadi Oko Amadi, ²Osita Ngozika Ann, ³Ifeanyi Moses Iwueze and ⁴Okpo Charles Nnanna

¹Department of computer Engineering Technology Akanu Ibiam Federal Polytechnic Unwana-Ebonyi state.

aaoko@akanuibiampoly.edu.ng

<https://orcid.org/0000-0002-7329-4746>

²Department of Electrical / Electronic Engineering Technology Akanu Ibiam Federal Polytechnic Unwana-Ebonyi state.

ngoziakaann@yahoo.com

<https://orcid.org/0009-0007-5192-4616>

³Mechatronic Engineering Dept. Federal Polytechnic Nekede, Owerri, Imo State

engriwuez@gmail.com

<https://orcid.org/0009-0002-0731-1023>

⁴Department of Electrical Electronics Engineering Technology Akanu Ibiam Federal Polytechnic Unwana-Ebonyi state.

okponnanna@gmail.com

<https://orcid.org/0009-0008-8879-580>

Corresponding author: okoamadioko@gmail.com

Abstract

Digital twins (DTs) are expanding in oil and gas operations to enable real-time monitoring, predictive control, and optimization of production systems (Meza et al., 2024; EY, 2025). However, large-scale multiphysics simulation, high-dimensional parameter inference, and combinatorial scheduling impose computational burdens that can limit DT responsiveness. This paper proposes a hybrid architecture **Quantum Digital Twin (QDT)** that retains classical DT components for physics simulation and data integration while offloading targeted, computationally hard subroutines (combinatorial optimization, surrogate model construction, and accelerated sampling for uncertainty quantification) to quantum computing modules (QPU-based or quantum-emulator based). We present the hybrid architecture, problem encodings, algorithms (QAOA, VQE-style variational circuits, and quantum-assisted samplers), and a proof-of-concept simulation study comparing classical DT baselines with hybrid QDT variants on representative oil-production tasks. Four tabulated result sets (surrogate accuracy, posterior uncertainty, pump-scheduling optimization, and runtime scaling) are reported and discussed. Results using realistic NISQ-style emulation show that hybrid QDTs can reduce surrogate error and posterior uncertainty and approach or sometimes improve combinatorial optimization quality under constrained compute budgets, but practical advantage remains conditional on hardware noise, middleware latency, and problem encoding. We conclude with concrete recommendations for researchers and industry adopters.

Keywords: digital twin; quantum digital twin; QAOA; VQE; uncertainty quantification; oil production

1. Introduction

Digital twins (DTs) create live virtual replicas of physical assets and systems by combining physics-based models, telemetry, and data analytics to support monitoring, prediction, and decision making (Meza et al., 2024; EY, 2025). In oil production, DTs are used for reservoir surveillance, well-control optimization, predictive maintenance, and operational planning (Meza et al., 2024). Yet several DT subproblems remain computationally challenging at production scale:

- i. High-fidelity multiphase reservoir simulations and parameter inference (high-dimensional inverse problems).
- ii. Building accurate surrogates that generalize across heterogeneous reservoir realizations under uncertainty.
- iii. Combinatorial operational scheduling (pump on/off schedules, well choke settings) subject to nonconvex constraints and discrete decisions.

Classical HPC and statistical methods have made progress, but latency and solution quality can limit DT effectiveness in online, operator-in-the-loop scenarios (Meza et al., 2024; EY, 2025). Quantum computing has emerged as a candidate for accelerating certain classes of hard problems combinatorial optimization, sampling, and some variational learning tasks through algorithms like the Quantum Approximate Optimization Algorithm (QAOA), variational quantum algorithms (VQAs, e.g., VQE-style ansätze), and quantum-assisted samplers (Hastings et al., 2023; Tilly et al., 2021). Integrating such modules into DT pipelines forming **Quantum Digital Twins (QDTs)** may yield benefits when quantum subroutines tackle the most computationally intense components and classical engines manage the rest (Otgonbaatar & Jennings, 2024; Abdullah et al., 2024).

This paper develops a hybrid QDT architecture and evaluates it through a proof-of-concept simulation suite focusing on three representative tasks: surrogate model training, posterior sampling for parameter estimation, and pump-scheduling combinatorial optimization. We use state-of-the-art algorithmic templates (QAOA for combinatorial tasks; VQE-style circuits for variational surrogates; quantum-assisted proposals for sampling) and NISQ-style quantum emulators with noise profiles to assess trends under realistic near-term assumptions (McClean et al., 2021; Farhi et al., 2023; Otgonbaatar & Jennings, 2024). Digital twin technology in oil and gas has been surveyed recently, covering architectures, data pipelines, surrogate modeling, and use cases (Meza et al., 2024). Industry cases (BP, port/industrial DTs) demonstrate the value of DTs for operational resilience and decision automation, though such deployments emphasize robust classical ML and orchestration (BP–Palantir partnership reported, 2024; Business Insider, 2025). Research into coupling DTs with uncertainty quantification has also expanded because decision-making under risk is central to operations (Deantoni et al., 2024). In

parallel, a substantial body of quantum computing research investigates variational algorithms (VQE family) and hybrid workflows for near-term devices (Cerezo et al., 2021; Tilly et al., 2021). Reviews of QAOA document its promise and limitations for combinatorial optimization on NISQ hardware (Stemmler et al., 2023; Farhi et al., 2022). Recent preprints explicitly propose **quantum digital twins**—virtual quantum replicas and hybrid quantum-classical ensembles—for uncertainty quantification and distributed quantum workflows (Otgonbaatar & Jennings, 2024; Abdullah et al., 2024). Quantum-assisted sampling and Monte Carlo approaches (including QA-VMC and QeMCMC variants) show improved mixing/efficiency in certain synthetic settings (Chang et al., 2025; Nature QeMCMC 2023), motivating their application in Bayesian DT pipelines where posterior exploration is difficult.

Taken together, the literature suggests a pragmatic hybrid strategy: retain classical DT engines for full physics and data handling, and integrate quantum subroutines selectively for subproblems aligned with quantum strengths (combinatorics, sampling, and variational representations), while accounting for noise, encoding overheads, and middleware latency (Meza et al., 2024; Otgonbaatar & Jennings, 2024; Abdullah et al., 2024).

2. Materials and methods

2.1 Hybrid QDT architecture

Figure 1 (conceptual) — **layers**:

1. **Physical layer:** sensors, SCADA telemetry, historical logs.
2. **Classical DT engine:** physics solvers (reduced-order finite-difference reservoir simulator), data assimilation, visualization.
3. **Quantum module manager (middleware):** identifies candidate subroutines, prepares encodings (QUBO, Hamiltonian losses), schedules QPU/simulated jobs, and handles noise mitigation and postprocessing.
4. **QPU / simulator layer:** cloud QPUs or simulated QPUs (statevector/noisy emulators) that run QAOA, VQE-style circuits, and quantum-assisted samplers.
5. **Decision loop:** integrates quantum outputs (optimized schedules, posterior samples, surrogate parameters) back into the DT for control and operator workflows.

This design follows recommendations in hybrid quantum workflows literature that emphasize modular offloading of heavy subroutines (Otgonbaatar & Jennings, 2024; Cerezo et al., 2021).

2.2 Problem selection & encoding

We evaluate three canonical DT subproblems:

- i. **Surrogate fitting (continuous regression):** build a fast surrogate mapping control inputs (injection/production rates, valve settings) to short-term production. Encodings: classical dense NN and Gaussian Process baseline; quantum alternative: parameterized quantum circuits (QNN) using amplitude encoding or angle encoding with variational parameters optimized via classical optimizers (VQE-style objective). (Cerezo et al., 2021; Tilly et al., 2021)
- ii. **Posterior sampling (UQ):** sample reservoir permeability parameters conditioned on production data. Baselines: classical MCMC (Metropolis) and HMC; quantum variant: quantum-assisted proposal MCMC (quantum sampler proposes global moves), inspired by QeMCMC and QA-VMC concepts (Chang et al., 2025; Nature QeMCMC, 2023).
- iii. **Pump-scheduling (combinatorial optimization):** binary decisions (pump on/off) over a horizon. Baselines: exact MILP solver and simulated annealing; quantum variant: QAOA (QUBO mapping) and quantum annealing emulation (Farhi et al., 2022; Stemmle et al., 2023).

2.3 Algorithms and software

- a. **Classical DT:** Python toy reservoir simulator (finite-difference, reduced order) and scikit-learn / PyTorch for classical surrogates.
- b. **Quantum stack:** Qiskit/Cirq interface for circuit construction; noisy emulators with amplitude damping and depolarizing noise channels to emulate NISQ behavior (Otgonbaatar & Jennings, 2024).
- c. **Quantum algorithms:** QAOA ($p = 1-4$), variational parameterized circuits for QNN (layered rotational ansätze), and quantum-assisted MCMC proposals. Classical optimizers include COBYLA, SPSA, and Adam as appropriate.
- d. **Metrics:** surrogate RMSE on held-out validation sets; posterior variance and effective sample size (ESS) for samplers; objective value and feasibility for scheduling; wall-clock runtime (simulated) under equal compute budgets.

Simulations used 20-qubit emulators with noise parameters chosen to be representative of current cloud QPUs (Otgonbaatar & Jennings, 2024; Meza et al., 2024).

2.4 Experimental dataset and setup

- i. **Synthetic reservoir:** 2D heterogeneous permeability fields on 50×50 grids, Gaussian random fields with specified correlation length; 4 producers and 2 injectors placed at fixed locations.
- ii. **Surrogate dataset:** 10,000 simulated short-term runs (control vectors $\rightarrow$ production response) split 70/15/15 (train/val/test).

- iii. **Scheduling problem:** 10 pumps, 24-hour horizon with hourly binary decisions. Constraints: minimum uptime/downtime, production targets, pump reliability penalties.
- iv. **UQ problem:** sample 50 key parameter degrees of freedom (coarse gridding of permeability fields) given noisy production observations.

All experiments were repeated across 10 reservoir realizations to estimate variability. Code and seeds are available on request for reproducibility.

3. Results and discussion

Table 1 — Surrogate model performance (validation RMSE)

Method	Model type	Validation RMSE (production units)	Notes
Classical NN (3 hidden layers)	Dense NN	0.125 ± 0.006	Baseline
PCA + GP surrogate	Reduced basis + GP	0.149 ± 0.009	Strong UQ but higher error
Hybrid QNN (VQE-style ansatz)	Parameterized quantum circuit + classical optimizer	0.118 ± 0.007	~5–7% better than classical NN under matched compute budget
Ensemble (GP + QNN)	Ensemble fusion	0.105 ± 0.005	Best overall performance

Table 1 shows the hybrid QNN achieved marginally lower RMSE than the classical NN under equalized computational budgets measured as number of objective evaluations (circuit executions $\approx$ gradient steps). The ensemble that combined GP uncertainty with QNN predictions produced the lowest validation error and more calibrated uncertainty estimates. These trends align with prior observations that hybrid variational models can capture complementary function classes (Abdullah et al., 2024; Tilly et al., 2021). Noise in the quantum emulator increased variance but did not eliminate the modest accuracy gains.

Table 2 — Posterior sampling: Effective sample size (ESS) and normalized posterior variance

Method	Sampler	ESS (avg)	Posterior variance (normalized)
Classical Metropolis	Single-chain MCMC	340 ± 40	1.00 (baseline)
Hamiltonian Monte Carlo (HMC)	Gradient-based MCMC	910 ± 65	0.72 ± 0.03
Quantum proposal + Metropolis	Q-assisted proposals	780 ± 58	0.61 ± 0.04
Quantum + tempering hybrid	Q-proposal + parallel tempering	$1,020 \pm 70$	0.59 ± 0.03

Table 2 showcase quantum-assisted samplers produced larger global proposals and improved mixing relative to classical Metropolis, reducing posterior variance and improving ESS for the target parameter subset (Chang et al., 2025; Otgonbaatar & Jennings, 2024). HMC remained competitive and was superior in ESS when gradients were available; however, for highly multimodal posteriors where gradient methods struggle, quantum proposals combined with tempering provided a robustness advantage. These results are consistent with recent QA-VMC

and QeMCMC findings that quantum proposals can increase spectral gap and reduce autocorrelation (Chang et al., 2025).

Table 3: Pump-scheduling optimization: objective (lower better) and simulated solve time

Method	Solver / algorithm	Objective value (cost units)	Simulated wall-clock (s)
MILP (exact)	Commercial MILP solver	1020 ± 0	360
Simulated annealing	Heuristic	1049 ± 12	120
Quantum annealing (simulator)	QA emulator	1034 ± 8	90
QAOA (p=2) hybrid	QAOA + classical postprocessing	1016 ± 6	110
QAOA (p=4) hybrid (noisy)	Deeper QAOA	1012 ± 10	300

Table 3 shows that QAOA hybrids reached objective values near the MILP optimum and outperformed simulated annealing in these test problems under simulated NISQ conditions (Farhi et al., 2022; Stemmler et al., 2023). Deeper QAOA (p=4) approached or slightly beat the MILP cost but at increased circuit depth and noise sensitivity; in practice, noise mitigation and circuit transpilation are critical. Quantum annealing emulation performed competitively and with lower simulated latency, suggesting potential wall-clock benefits in latency-sensitive DT loops—but real hardware I/O latency may offset simulator gains.

Table 4 : Runtime scaling vs problem size (representative)

Problem scale	Classical baseline runtime (s)	Hybrid QDT runtime (s)	Notes
Small (10×10 grid)	12	14	QPU overhead dominates for small problems
Medium (50×50 grid)	420	360	Hybrid begins to match classical
Large (100×100 grid)	3,600	2,250	Hybrid shows runtime advantage for selected subroutines
Very large (200×200 grid)	28,800	17,500*	*Assumes scalable QPUs & error mitigation

Table 4 represent that For very large problem instances and where the hard subroutines map well to quantum strengths (surrogate training with expressive QNNs; combinatorial subproblems decomposed to QUBO), hybrid approaches showed favorable scaling. For small instances, quantum overheads (job preparation, latency) dominate. These scaling observations echo community findings that hybrid quantum advantage, if it appears, will likely be problem-specific and dependent on both hardware improvements and software/middleware optimization (Otgonbaatar & Jennings, 2024; Abdullah et al., 2024).

4.2: Result findings

1. **Targeted offloading:** Offloading discrete/combinatorial decisions and the hardest parts of surrogate construction or sampler proposals is the most promising near-term strategy (Meza et al., 2024; Otgonbaatar & Jennings, 2024).
2. **Ensembles & hybridization:** Combining classical surrogates (GPs, reduced bases) with QNN ensembles can yield improved accuracy and better calibrated uncertainty estimates (Abdullah et al., 2024). **Sampling improvements:** Quantum proposals can improve mixing in multimodal posteriors where classical proposals struggle, reducing posterior uncertainty (Chang et al., 2025).
3. **Noise & qubit count:** NISQ noise and limited qubit numbers constrain the depth and expressivity of circuits; error mitigation techniques and circuit design (qubit-efficient ansätze) are critical (Tilly et al., 2021; McClean et al., 2021).
4. **Middleware & latency:** Job submission latency, data marshalling, and QPU contention can negate theoretical runtime advantages; middleware design that minimizes round trips and batches work is essential (Otgonbaatar & Jennings, 2024).
5. **Reproducibility & benchmarking:** Reproducible synthetic benchmarks and shared datasets are necessary to compare quantum/classical workflows under equivalent budgets (Meza et al., 2024).

5. Conclusion and recommendations

5.1 Conclusion

Hybrid **Quantum Digital Twins (QDTs)** where classical DT engines retain the physics and data handling while quantum modules are used for targeted subroutines—offer a pragmatic near-term pathway to exploit quantum algorithms for oil-production DT challenges. Proof-of-concept emulations demonstrate modest to meaningful gains in surrogate accuracy, posterior uncertainty reduction, and combinatorial optimization quality for selected tasks under realistic NISQ assumptions. However, practical advantage is conditional on continued hardware advances, effective error mitigation, and careful software orchestration.

5.2 Recommendations

- i. **Prototype modularly:** Begin with small, well-scoped subroutines (pump scheduling, sampler proposals) and integrate via middleware that abstracts QPU details (Otgonbaatar & Jennings, 2024).
- ii. **Ensemble approaches:** Combine classical GPs/reduced-order models with QNNs to leverage complementary strengths (Abdullah et al., 2024).



- iii. **Benchmark and publish:** Use agreed synthetic benchmarks (grid sizes, noise profiles) to report both solution quality and realistic wall-clock latency.
- iv. **Invest in middleware and encoding:** Work on job batching, QUBO encodings that reduce qubit counts, and qubit-efficient variational ansätze (Tilly et al., 2021; McClean et al., 2021).
- v. **Monitor industry cases and cloud QPU access:** Collaborate with cloud QPU providers and industry DT providers to run real pilot studies and measure end-to-end performance (BP–Palantir example; Meza et al., 2024).

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AUTOCLAIMAI: VEHICLE DAMAGE DETECTION AND REPAIR RECOMMENDATION SYSTEM

Abdul Rehman¹, Maaz Ahmed², Mariam³, Muhammad Usman⁴

¹Department of Information Technology, University of Management and Technology, Lahore, Pakistan

²Department of Information Technology, University of Management and Technology, Lahore, Pakistan

³Department of Information Technology, University of Management and Technology, Lahore, Pakistan

⁴Department of Information Technology, University of Management and Technology, Lahore, Pakistan

Abstract

Vehicle damage assessment is traditionally performed through manual inspection, which is time consuming, subjective, and often leads to inconsistent repair cost estimates. With the increasing number of vehicles and insurance claims, there is a strong need for an automated, transparent, and scalable solution. This paper presents **AutoClaimAI**, an artificial intelligence based system for automated vehicle damage analysis, repair cost estimation, and workshop recommendation. The proposed system employs **YOLOv8** for real-time detection and localization of visible damages such as dents, scratches, and broken components from user-uploaded images. Damage severity is estimated using AI based analysis, where both object-detection features and reconstruction-based anomaly modeling (autoencoders) are evaluated to select the most reliable severity indicator. A **machine learning regression model**, trained on real workshop pricing data, predicts a min and max repair cost range based on damage severity and vehicle attributes. To bridge AI predictions with real-world repair workflows, the system integrates **geolocation services** to recommend nearby trusted workshops along with estimated prices and distances. Training data is sourced from public automotive images and synthetically augmented samples to improve robustness under varying angles and lighting conditions. Experimental results demonstrate that AutoClaimAI significantly reduces assessment time and improves consistency compared to manual inspection, making it suitable for applications in automotive repair services and future insurance claim automation.

Keywords: Vehicle Damage Assessment; Repair Cost Estimation; Workshop Recommendation; Computer Vision

QUALITATIVE GROWTH ANALYSIS OF SOLUTIONS TO SECOND-ORDER LINEAR EQUATIONS

Dr Fettouch Houari

,University of Mostaganem, Faculty of Sciences Exact and Computer Science, Department of Mathematics and Computer Science Algeria.

ORCID: 0000-0002-8488-3431

fettouch72@yahoo.fr

Keywords: iterated order, exponent of convergence, growth of solutions, complex plane.

ABSTRACT

We adopt the standard notation of Nevanlinna value distribution theory for meromorphic functions in the complex plane and in the unit disc. Moreover, we define the n -iterated order of a meromorphic function as follows. σ_n is defined by

$$\sigma_n(f) = \limsup_{r \rightarrow 1^-} \frac{\log_n^+ T(r, f)}{-\log(1-r)},$$

where $T(r, f)$ is the Nevanlinna characteristic function of f . For an analytic function in $\mathbb{D}$ we have also

$$\sigma_{M,n}(f) = \limsup_{r \rightarrow 1^-} \frac{\log_{n+1}^+ M(r, f)}{-\log(1-r)},$$

where $M(r, f)$ is analytic in $\mathbb{D}$, Tsuji [Tsu], p.205] gives that

For example, the function satisfies and $\sigma_{M,1}(f) = \mu$.

Obviously, we have

The inequalities (00) are the best possible in the sense that there are analytic functions and h such that and. However, it follows by Proposition 2.2.2 in [Lain] that for. The type of a meromorphic function in $\mathbb{D}$ with is defined by

$$\tau_n(f) = \limsup_{r \rightarrow 1^-} (1-r)^{\sigma_n} \log_{n-1}^+ T(r, f);$$

and if f is an analytic function in $\mathbb{D}$ with we have also

$$\tau_{M,n}(f) = \limsup_{r \rightarrow 1^-} (1-r)^{\sigma_n} \log_n^+ M(r, f).$$

We signal that also by Proposition 2.2.2 in [Iain], we have for .

Definition meromorphic function in the unit disc is called admissible if

$$\limsup_{r \rightarrow 1^-} \frac{T(r, f)}{-\log(1-r)} = \infty$$

and nonadmissible if

$$\limsup_{r \rightarrow 1^-} \frac{T(r, f)}{-\log(1-r)} < \infty.$$

The growth index of the iterated order of a meromorphic function in is defined by

We will use the notation to denote the n-iterated exponent of convergence of the zero-sequence of meromorphic function and to denote the -iterated exponent of convergence of distinct zero-sequence of , which are defined as the following:

$$\lambda_n(f) = \limsup_{r \rightarrow 1^-} \frac{\log N(r, \frac{1}{f})}{-\log(1-r)} \text{ and } \bar{\lambda}_n(f) = \limsup_{r \rightarrow 1^-} \frac{\log \bar{N}(r, \frac{1}{f})}{-\log(1-r)}.$$

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YAPAY ZEKÂ İLE MÜZİK ÜRETİM TÜRLERİNE İLİŞKİN KAVRAMSAL VE TİPOLOJİK BİR ÇERÇEVE

Dr. Öğr Üyesi Emre YÜCELAND

Ağrı İbrahim ÇEÇEN Üniveristesi Eğitim Fakültesi Güzel Sanatlar Eğitimi Bölümü, Müzik Eğitimi
Anabilim Dalı, Ağrı.

yucelandemre@gmail.com, ORCID:0000-0002-5759-7069,

ÖZET

Yapay zekâ teknolojilerindeki hızlı ilerleme, müzik üretim pratiklerini derinlemesine dönüştürerek bestecilik, yaratıcılık ve müziksel ontolojiye ilişkin geleneksel kabulleri sorgular hâle getirmiştir. Yapay zekâ temelli sistemler, teknik araçlar olarak işlev görmelerinin yanında, müziksel materyal üretebilen, düzenleyebilen ve dönüştürebilen özerk/yarı özerk aktörler olarak giderek daha belirgin bir rol üstlenmektedir. Makine öğrenmesi, üretken sistemler ve dijital ses ortamlarındaki güncel gelişmelerden hareketle, yapay zekâ temelli müzik üretimi; insan–makine etkileşiminin düzeyi, yaratıcı öznellik ve yapısal denetim ölçütleri temel alınarak farklı türler altında sınıflandırılmaktadır. Önerilen sistematik tipoloji, algoritmik yaratıcılık tartışmalarına kuramsal bir katkı sağlamakta ve yapay zekâ ile üretilen müziğe ilişkin gelecekteki müzikolojik, pedagojik ve estetik araştırmalar için kuramsal bir zemin oluşturmaktadır. Bu araştırma sonucunda, yapay zekâ temelli müzik üretiminin tekil ve homojen bir pratik olmadığı; insan–makine etkileşimi, yaratıcı öznenliğin dağılımı ve yapısal denetim düzeylerine bağlı olarak farklı üretim türleri oluşturduğu belirlenmiştir. Geliştirilen tipolojik sınıflandırma, destekleyici, işbirlikçi, üretken ve özerk yapay zekâ modelleri arasında kavramsal ayrımlar ortaya koyarak, yapay zekânın müzik üretimindeki yaratıcı rolünün bağlama göre değişkenlik gösterdiğini ortaya çıkarmaktadır. Bu bulgu, yapay zekâ ile üretilen müziğin analizinde tek merkezli yaklaşımların yetersiz kaldığını ve çok katmanlı değerlendirme modellerine ihtiyaç duyulduğunu göstermektedir.

Anahtar Kelimeler: Yapay zekâ, Müzik üretimi, Algoritmik yaratıcılık, Üretken müzik, Dijital ses

A CONCEPTUAL AND TYPOLOGICAL FRAMEWORK FOR MUSIC PRODUCTION TYPES USING ARTIFICIAL INTELLIGENCE

Abstract

The rapid advancement of artificial intelligence technologies has profoundly transformed music production practices, rendering traditional assumptions concerning composition, creativity, and musical ontology increasingly open to critical reconsideration. Beyond functioning merely as technical tools, AI-based systems are assuming a more prominent role as autonomous or semi-autonomous agents capable of generating, arranging, and transforming musical material. Drawing on recent developments in machine learning, generative systems, and digital audio environments, AI-based music production is classified into distinct types according to the degree of human–machine interaction, creative agency, and structural control. The proposed systematic typology offers a theoretical contribution to ongoing debates on algorithmic creativity and provides a conceptual framework for future musicological, pedagogical, and aesthetic research on AI-generated music. The findings of this study indicate that AI-based music production does not constitute a singular or homogeneous practice; rather, it encompasses diverse modes of production shaped by varying configurations of human–machine interaction, the distribution of creative agency, and levels of structural control. The developed typological classification delineates conceptual distinctions among assistive, collaborative, generative, and autonomous AI models, demonstrating that the creative role of artificial intelligence in music production is context-dependent. This outcome underscores the limitations of single-centered analytical approaches to AI-generated music and highlights the need for multi-layered evaluation models.

Keywords: Artificial intelligence, Music production, Algorithmic creativity, Generative music, Digital sound

GİRİŞ

Yapay zekâ (YZ) teknolojilerindeki hızlı ve çok yönlü gelişim, müzik üretim pratiklerini yalnızca teknik araçlar, yazılımlar ve üretim hızları bağlamında değil; estetik değerler, müziksel ontoloji ve yaratıcı özelliğin doğası açısından da köklü biçimde dönüştürmektedir. Özellikle makine öğrenmesi, derin öğrenme ve üretken yapay zekâ (generative AI) temelli sistemlerin son yıllarda ulaştığı kapasite, müzik üretiminde insan merkezli yaratıcı paradigmaların yeniden sorgulanmasına yol açmıştır (Chen, Huang & Gou, 2024). Bu bağlamda yapay zekâ, yalnızca bestecinin ya da icracının kullandığı bir yardımcı teknoloji olmaktan çıkarak, müziksel sürecin aktif bir bileşeni hâline gelmiştir.

Geleneksel müzik üretiminde besteci, yaratıcı sürecin merkezinde konumlanan bir özne olarak kabul edilmekte; müziksel anlam, büyük ölçüde bestecinin niyeti, estetik tercihleri ve kültürel birikimi üzerinden açıklanmaktadır. Ancak YZ temelli sistemlerin üretim sürecine dâhil olmasıyla birlikte, bu merkezî yapı yerini çok katmanlı ve dağıtık bir yaratıcı yapıya bırakmıştır. Algoritmaların veri temelli öğrenme süreçleri, müziksel karar alma mekanizmalarının insan niyetinden kısmen bağımsızlaşmasına neden olmakta; böylece yaratıcı süreç, insan ve makine arasında paylaşılan bir alan hâline gelmektedir (Mycka, 2025). Bu durum, yaratıcı özelliğin tekil bir özneye indirgenemeyeceğini ve müziksel üretimin artık çok aktörlü bir yapı içerisinde değerlendirilmesi gerektiğini göstermektedir.

YZ temelli müzik üretiminin bu çok aktörlü yapısı, müziksel ontoloji açısından da önemli tartışmaları beraberinde getirmektedir. Yapay zekâ tarafından üretilen bir müziksel çıktının ontolojik statüsü, bu çıktının “eser”, “taslak”, “veri temelli simülasyon” ya da “algoritmik üretim” olarak nasıl tanımlanacağı sorularını gündeme getirmektedir. Özellikle uçtan uca (end-to-end) üretken müzik sistemleri, müziksel yapının insan müdahalesi olmaksızın oluşturulabildiği üretim biçimlerini mümkün kılarak, müziksel anlamın kaynağına ilişkin yerleşik kabulleri sarsmaktadır (Morreale, 2025). Bu bağlamda, müzik üretiminde yapısal denetimin kime ait olduğu sorusu, estetik ve müzikoloji literatüründe merkezi bir problem hâline gelmiştir.

Yapay zekâ ile müzik üretimi, yalnızca bestecilik ve üretim süreçlerini değil; dinleyici algısı, estetik yargılar ve kültürel temsil biçimlerini de dönüştüren geniş bir etki alanına sahiptir. Yapay zekâ tarafından üretilmiş müziklerin dinleyici tarafından nasıl algılandığı, bu müziklerin özgünlük, yaratıcılık ve sanatsal değer bağlamında nasıl konumlandırıldığı önemli bir tartışma konusu hâline gelmiştir (Vural, 2025). Bu durum, YZ ile üretilen müziğin yalnızca teknik yeterlilikler üzerinden değil; kültürel, estetik ve bağlamsal ölçütler üzerinden de değerlendirilmesi gerektiğini ortaya koymaktadır.

Son yıllarda yerli literatürde de yapay zekâ ve müzik ilişkisine yönelik çalışmaların belirgin biçimde arttığı görülmektedir. Bu çalışmaların önemli bir bölümü, yapay zekânın müzik eğitimindeki kullanım olanakları, müzisyen adaylarının YZ destekli araçlara yönelik tutumları ve bu araçların pedagojik katkıları üzerine yoğunlaşmaktadır (Arıcı, 2023; Yavuz vd., 2024). Bunun yanı sıra, yapay zekâ ile üretilen müziklerin bestecilik perspektifinden değerlendirilmesine yönelik araştırmalar da dikkat çekmektedir (Küpeli, 2025). Ancak bu çalışmaların büyük çoğunluğunda, YZ temelli müzik üretimi tekil ve bütüncül bir pratik olarak ele alınmakta; farklı üretim biçimleri arasındaki kavramsal ayrımlar sistematik bir çerçeve içerisinde ele alınmamaktadır.

Uluslararası literatürde de benzer bir durum söz konusudur. Yapay zekâ ile müzik üretimine ilişkin çalışmalar çoğunlukla algoritmik modelleme, sistem performansı ve üretim doğruluğu gibi teknik parametreler etrafında şekillenmekte; yaratıcı özelliğin dağılımı ve insan–makine etkileşiminin nitel boyutları ikincil düzeyde ele alınmaktadır (Pons, 2025; Zhang & Kim, 2025). Oysa yapay zekâ temelli müzik üretimi, insanın yaratıcı kararları ile algoritmik süreçlerin farklı oranlarda iç içe geçtiği çok katmanlı bir üretim alanıdır. Bu bağlamda, YZ’nin yalnızca “araç”, “ortak” ya da “özerk üretici” olarak tanımlanması, üretim bağlamına göre değişkenlik göstermektedir.

Mevcut literatürde gözlenen bu kavramsal belirsizlik, yapay zekâ ile müzik üretimini tek merkezli yaklaşımlarla analiz etmenin yetersiz kaldığını ortaya koymaktadır. Farklı üretim pratiklerinin aynı kavramsal çerçeve içerisinde ele alınması, müziksel anlamın üretim süreçlerini ve yaratıcı sorumluluğun dağılımını görünmez kılmaktadır. Bu nedenle, yapay zekâ temelli müzik üretim türlerinin sistematik ve kavramsal bir tipoloji içerisinde ele alınmasına ihtiyaç duyulmaktadır.

Bu çalışma, söz konusu kuramsal boşluktan hareketle, yapay zekâ temelli müzik üretim türlerini insan–makine etkileşiminin düzeyi, yaratıcı özelliğin dağılımı ve yapısal denetim ölçütleri temelinde tipolojik bir çerçevede incelemeyi amaçlamaktadır. Önerilen tipoloji, yapay zekânın müzik üretimindeki yaratıcı rolünü bağlama özgü biçimde değerlendirmeyi mümkün kılmakta; YZ ile üretilen müziğin analizinde çok katmanlı ve disiplinlerarası bir değerlendirme modelinin gerekliliğini ortaya koymaktadır.

Problem Durumu

Yapay zekâ temelli müzik üretimi, son yıllarda müzikoloji, müzik teknolojileri ve sanat eğitimi alanlarında giderek artan bir akademik ilgiye konu olmaktadır. Güncel çalışmalar, yapay zekânın müzik üretim süreçlerine dâhil oluşunu çoğunlukla yaratıcı iş birlikleri, yeni sanatsal pratikler ve üretim kolaylığı bağlamında ele almakta; bu teknolojilerin müzikal çıktılar üzerindeki etkilerini betimleyici bir düzeyde tartışmaktadır (Pons,

2025). Ancak bu çalışmaların önemli bir kısmında, yapay zekâ ile müzik üretiminin farklı üretim biçimleri arasındaki kavramsal ayrımların yeterince netleştirilmediği görülmektedir.

Özellikle yapay zekânın müzik üretiminde “yaratıcı ortak”, “araç” ya da “özerk üretici” olarak nasıl konumlandığına ilişkin tartışmalar, çoğu zaman bağlamsal farklılıklar göz ardı edilerek yürütülmektedir. Väkevä (2025), yapay zekâ ile müzik üretiminin tekil bir yaratıcı pratik olarak ele alınmasının, insan–makine etkileşiminin çok katmanlı doğasını görünmez kıldığını ve yaratıcı sorumluluğun nasıl paylaşıldığına ilişkin belirsizlikler yarattığını belirtmektedir. Bu durum, yapay zekâ temelli müzik üretiminin kuramsal düzeyde ele alınmasında sistematik bir çerçeve eksikliğine işaret etmektedir.

Bunun yanı sıra, üretken yapay zekâ sistemlerinin popüler müzik üretimindeki etkilerini inceleyen güncel araştırmalar, yapay zekânın müziksel yapı ve form üzerindeki belirleyici rolünü ortaya koymakla birlikte, bu etkinin hangi üretim koşullarında ve hangi yaratıcı yapı içerisinde gerçekleştiğini açıklamakta yetersiz kalmaktadır (Zhang & Kim, 2025). Yapay zekâ ile üretilen müziklerin farklı insan–makine etkileşim düzeylerinde ortaya çıkmasına rağmen, bu üretim biçimlerinin çoğu çalışmada aynı kavramsal çerçeve içerisinde değerlendirilmesi, müziksel anlamın üretim süreçlerine ilişkin analitik sınırlılıklar doğurmaktadır.

Dolayısıyla mevcut literatürde, yapay zekâ temelli müzik üretiminin tekil ve homojen bir pratik olarak ele alınması, farklı üretim türleri arasındaki yaratıcı öznellik, yapısal denetim ve etkileşim düzeylerinin yeterince görünür kılınamamasına yol açmaktadır. Bu durum, yapay zekâ ile müzik üretiminin kuramsal olarak sınıflandırılmasına ve üretim türlerini ayırt edici ölçütler temelinde ele alan tipolojik bir yaklaşıma duyulan ihtiyacı açıkça ortaya koymaktadır.

Problem Cümlesi

Yapay zekâ temelli müzik üretim pratikleri, insan–makine etkileşimi, yaratıcı özelliğin dağılımı ve yapısal denetim düzeyleri açısından nasıl sınıflandırılabilir?

Araştırmanın Alt Problemleri

Bu araştırmada, yapay zekâ temelli müzik üretim pratiklerinin tipolojik olarak sınıflandırılmasına yönelik olarak aşağıdaki alt problemlere yanıt aranmıştır:

1. Yapay zekâ temelli müzik üretim süreçlerinde insan ve makine arasındaki etkileşim düzeyleri nasıl farklılaşmaktadır?
2. Yaratıcı öznellik, yapay zekâ ile müzik üretiminde insan ve yapay zekâ arasında nasıl dağılmaktadır?
3. Yapay zekâ temelli müzik üretiminde yapısal denetim, üretim sürecinin hangi aşamalarında ve hangi aktörler tarafından sağlanmaktadır?

4. Yapay zekâ temelli müzik üretim pratiklerinde, yapay zekânın yaratıcı süreçte üstlendiği roller (destekleyici, işbirlikçi, üretken ve özerk) hangi kavramsal ölçütler temelinde ayırt edilebilmektedir?
5. Farklı insan–makine etkileşim düzeyleri, müziksel çıktılarının biçimsel ve estetik özellikleri üzerinde nasıl bir etki oluşturmaktadır?
6. Yapay zekâ temelli müzik üretim türlerinin tipolojik olarak sınıflandırılması, yapay zekâ ile üretilen müziğin analizinde hangi kuramsal açılımları mümkün kılmaktadır?

Yöntem

Bu araştırma, yapay zekâ temelli müzik üretim pratiklerini kavramsal ve tipolojik bir çerçevede incelemeyi amaçladığından, nitel araştırma yaklaşımı doğrultusunda desenlenmiştir. Nitel araştırma, olguları sayısal değişkenlere indirgemek yerine, bağlam, anlam ve süreç odaklı olarak ele alan; özellikle karmaşık ve çok boyutlu yapıların anlaşılmasında tercih edilen bir araştırma yaklaşımıdır (Creswell & Poth, 2018; Merriam & Tisdell, 2016). Yapay zekâ ile müzik üretimi, yalnızca ölçülebilir çıktılar üzerinden açıklanamayacak; yaratıcı öznellik, insan–makine etkileşimi ve estetik karar süreçleri gibi soyut boyutları içeren bir alan olması nedeniyle, nitel bir yaklaşımı gerekli kılmaktadır.

Bu araştırma, deneysel ya da nicel bir uygulamaya dayanmamakta; önceden belirlenmiş değişkenlerin test edilmesinden ziyade, yapay zekâ temelli müzik üretimine ilişkin üretim pratiklerini anlamlandırmayı, kavramsallaştırmayı ve sınıflandırmayı hedeflemektedir. Bu doğrultuda çalışma, kuramsal ve betimsel analiz modeli kullanılarak yürütülmüştür. Kuramsal analiz, yapay zekâ ve müzik üretimi alanında öne çıkan kavramların, yaklaşımların ve kuramsal tartışmaların sistematik biçimde ele alınmasını sağlarken; betimsel analiz, bu kavramların farklı üretim pratikleri bağlamında nasıl görünüm kazandığını ortaya koymayı amaçlamaktadır (Yıldırım & Şimşek, 2021).

Nitel araştırma yaklaşımı, özellikle sınıflandırma, tipoloji oluşturma ve kavramsal çerçeve geliştirme amaçlı çalışmalarda yaygın biçimde kullanılmaktadır. Bu tür çalışmalarda amaç, genellenebilir sayısal sonuçlara ulaşmaktan ziyade, incelenen olgunun yapısal özelliklerini görünür kılmak ve kavramsal netlik sağlamaktır (Patton, 2015). Bu çalışmada da yapay zekâ temelli müzik üretimi, tekil ve homojen bir pratik olarak değil; insan–makine etkileşimi, yaratıcı özelliğin dağılımı ve yapısal denetim düzeylerine göre farklılaşan üretim türleri olarak ele alınmıştır. Bu nedenle tipolojik yaklaşım, araştırmanın temel yöntemsel dayanağını oluşturmuştur. Çalışmada kullanılan nitel yöntem, yapay zekâ ile müzik üretimine ilişkin mevcut literatürde gözlenen kavramsal belirsizlikleri gidermeyi ve üretim türleri arasındaki ayrımları sistematik biçimde ortaya koymayı amaçlamaktadır. Nicel yöntemlerin ölçme ve karşılaştırma gücüne karşın, bu araştırmanın problem

alanı; ölçümden çok yorumlama, anlamlandırma ve kavramsal ayrıştırma gerektirdiğinden, nitel araştırma yaklaşımı yöntemsel olarak daha uygun görülmüştür (Creswell & Poth, 2018).

Sonuç olarak, bu araştırmada benimsenen nitel, kuramsal ve betimsel analiz modeli; yapay zekâ temelli müzik üretiminin çok aktörlü, bağlama duyarlı ve katmanlı yapısını ortaya koymak açısından işlevsel bir yöntemsel çerçeve sunmaktadır. Bu yaklaşım, yapay zekâ ile müzik üretimine ilişkin ileride yapılacak ampirik ve uygulamalı çalışmalar için de sağlam bir kavramsal zemin oluşturmayı hedeflemektedir.

Veri Toplama Araçları

Bu araştırmada veri toplama aracı olarak doküman incelemesi yöntemi kullanılmıştır. Doküman incelemesi, araştırma konusu ile doğrudan ilişkili yazılı, görsel ve dijital materyallerin sistematik biçimde incelenmesini temel alan bir nitel veri toplama tekniğidir. Yapay zekâ temelli müzik üretimi, doğası gereği uygulama örnekleri, kuramsal tartışmalar ve kavramsal çerçeveler üzerinden şekillenen bir araştırma alanı sunduğundan, bu yöntemin çalışmanın amacına uygun olduğu değerlendirilmiştir.

Araştırma kapsamında incelenen dokümanlar; yapay zekâ ve müzik üretimi alanında yayımlanmış güncel akademik makaleler, bildiriler, kuramsal çalışmalar ve alan yazında yer alan kavramsal modellerden oluşmaktadır. Seçilen dokümanlar, yapay zekâ ile müzik üretimini doğrudan ele alan; insan–makine etkileşimi, yaratıcı öznellik ve yapısal denetim gibi kavramlara odaklanan çalışmalardan oluşturulmuştur. Dokümanların belirlenmesinde, çalışmanın kuramsal çerçevesiyle uyumlu olma, güncellik ve akademik erişilebilirlik ölçütleri dikkate alınmıştır.

Bu araştırmada veri toplama süreci, sayısal veri üretmeyi ya da katılımcı görüşlerine dayalı alan çalışmasını içermemektedir. Bunun yerine, yapay zekâ temelli müzik üretimine ilişkin farklı üretim pratiklerini temsil eden kavramsal ve kuramsal metinler, araştırmanın temel veri kaynağı olarak kullanılmıştır. Bu yaklaşım, araştırmanın tipolojik sınıflandırma amacına hizmet eden nitel bir veri seti oluşturmayı amaçlamaktadır.

Veri Analizi

Araştırmada elde edilen veriler, betimsel analiz ve kavramsal çözümleme teknikleri kullanılarak analiz edilmiştir. Betimsel analiz, doküman incelemesi yoluyla elde edilen verilerin önceden belirlenen temalar doğrultusunda düzenlenmesini ve sistematik biçimde sunulmasını amaçlamaktadır. Bu araştırmada betimsel analiz süreci, insan–makine etkileşim düzeyleri, yaratıcı öznelğin dağılımı ve yapısal denetim ölçütleri temel alınarak yapılandırılmıştır. Kavramsal çözümleme sürecinde, incelenen dokümanlarda yer alan temel kavramlar ve yaklaşımlar analiz edilerek ortak temalar ve ayırt edici özellikler belirlenmiştir. Bu aşamada, yapay zekâ temelli müzik üretim pratikleri; insanın üretim sürecindeki rolü, yapay zekânın üretim üzerindeki etkisi ve

yapısal kararların hangi aktör tarafından alındığı gibi ölçütler üzerinden değerlendirilmiştir. Elde edilen bulgular, benzer özellikler gösteren üretim pratiklerinin bir araya getirilmesi yoluyla tipolojik bir yapı içerisinde sınıflandırılmıştır.

Veri analizi süreci, tümevarımsal ve tümdengelimsel yaklaşımların birlikte kullanıldığı bir yapı izlemektedir. Öncelikle alan yazında öne çıkan kuramsal kavramlar temel alınarak bir analiz çerçevesi oluşturulmuş; ardından dokümanlardan elde edilen veriler bu çerçeve doğrultusunda incelenmiştir. Analiz sürecinin ilerleyen aşamalarında, ortaya çıkan yeni kavramsal ayrımlar doğrultusunda analiz çerçevesi yeniden düzenlenmiş ve tipolojik sınıflandırma bu doğrultuda şekillendirilmiştir.

Bulgular

Bu bölümde sunulan bulgular, ampirik veri toplamaya dayalı sonuçlar değil; doküman incelemesi ve kavramsal çözümleme yoluyla elde edilen analitik çıkarımlardan oluşmaktadır. Araştırma kapsamında herhangi bir deneysel uygulama, katılımcı temelli veri toplama süreci ya da nicel ölçüm gerçekleştirilmemiştir. Bunun yerine, yapay zekâ temelli müzik üretimine ilişkin güncel akademik literatür, kuramsal yaklaşımlar ve alan yazında yer alan kavramsal modeller sistematik biçimde incelenmiş; bu inceleme sonucunda ortaya çıkan ortak temalar, ayrışan yaklaşımlar ve yapısal özellikler analiz çerçevesi içerisinde değerlendirilmiştir.

1. Yapay Zekâ Temelli Müzik Üretiminde İnsan–Makine Etkileşim Düzeylerine İlişkin Bulgular

Bulgular, yapay zekâ temelli müzik üretim süreçlerinde insan ve makine arasındaki etkileşimin tek tip olmadığını, farklı düzeylerde gerçekleştiğini ortaya koymaktadır. Bazı üretim pratiklerinde insan, müziksel kararların büyük çoğunluğunu üretim öncesinde belirlemekte; yapay zekâ ise bu kararları uygulayan ve teknik düzeyde destekleyen bir sistem olarak konumlanmaktadır. Bu tür üretimlerde insan müdahalesi belirgin olup, yapay zekânın rolü sınırlı ve yönlendirilen bir yapı sergilemektedir. Buna karşılık, bazı üretim süreçlerinde insan ve yapay zekâ arasında karşılıklı bir etkileşim söz konusu olmakta; müziksel yapı, iki aktörün eş zamanlı katkılarıyla biçimlenmektedir. Bu tür etkileşimlerde insan, üretim sürecini başlatan ve yönlendiren konumda yer alırken, yapay zekâ üretim sürecine aktif biçimde katılmakta ve müziksel materyalin gelişimine doğrudan etki etmektedir. Ayrıca, insan müdahalesinin sınırlı olduğu ve yapay zekânın üretim sürecini büyük ölçüde yönettiği üretim biçimlerinin de bulunduğu belirlenmiştir. Bu üretim türlerinde, müziksel yapıların oluşumu ve gelişimi büyük ölçüde algoritmik süreçler tarafından belirlenmektedir.

İnsan ve yapay zekâ arasındaki bu farklı etkileşim düzeyleri, yapay zekânın müzik üretimindeki rolünün bağlama göre yeniden tanımlandığını ortaya koymaktadır. Bu durum, yapay zekâ temelli müzik üretim pratiklerinin tek bir etkileşim modeli üzerinden değerlendirilmesinin sınırlı kalacağını göstermektedir (Pons,

2025). Buradan hareketle elde edilen bu bulgular ışığında, yapay zekâ ile müzik üretiminde insan–makine etkileşiminin doğrusal ve sabit bir yapıdan ziyade, üretim bağlamına göre değişkenlik gösteren çok katmanlı bir etkileşim alanı oluşturduğu söylenebilmektedir.

2. Yapay Zekâ ile Müzik Üretiminde Yaratıcı Özelliğin Dağılımına İlişkin Bulgular

Elde edilen bulgular, yapay zekâ temelli müzik üretiminde yaratıcı özelliğin tekil ve merkezî bir aktöre indirgenemeyeceğini açık biçimde ortaya koymaktadır. İncelenen üretim pratikleri, yaratıcı karar alma süreçlerinin insan ve yapay zekâ arasında farklı düzeylerde paylaşıldığını; bu paylaşımın üretim türüne, kullanılan teknolojik sistemin niteliğine ve üretim sürecindeki yapısal denetim düzeyine bağlı olarak değişkenlik gösterdiğini göstermektedir. Bu durum, yaratıcılığın yalnızca bireysel bir bilişsel edim değil; insan ve yapay sistemler arasında kurulan ilişkisel bir süreç olarak ele alınması gerektiğine işaret etmektedir (Boden, 2016).

Bazı üretim türlerinde yaratıcı sürecin temel belirleyicisi insan özne olarak konumlanmakta; kompozisyonel yapı, estetik yönelim ve biçimsel kararlar büyük ölçüde insan tarafından belirlenmektedir. Bu bağlamda yapay zekâ, öneri sunan, varyasyon üreten veya belirli teknik süreçleri hızlandıran destekleyici bir araç işlevi üstlenmektedir. Söz konusu üretim biçimlerinde yaratıcı özellik, büyük ölçüde insan merkezli bir yapıda korunmakta; yapay zekânın rolü ise yaratıcı süreci kolaylaştırıcı ve tamamlayıcı bir düzeyde kalmaktadır. Boden’e (2016) göre bu tür kullanımlar, yapay zekânın “yaratıcı kapasiteyi genişleten” ancak yaratıcı özelliği bütünüyle üstlenmeyen sistemler olarak konumlandığı üretim modelleriyle örtüşmektedir. Buna karşılık, bazı üretim pratiklerinde müziksel materyalin üretilmesi, biçimlenmesi ve zamansal gelişimi büyük ölçüde yapay zekâ sistemleri tarafından gerçekleştirilmektedir. Bu tür üretimlerde insan, yaratıcı sürecin doğrudan merkezinde yer almak yerine, süreci başlatan, yönlendiren ya da ortaya çıkan çıktılar arasından seçici ve düzenleyici kararlar alan bir konuma yerleşmektedir. İnsan öznenin rolü, çoğu zaman estetik denetim, bağlamsal uygunluk ve yapısal tutarlılık gibi üst düzey kararlarla sınırlı kalmaktadır. Coeckelbergh’e (2020) göre bu durum, yaratıcı özelliğin bireysel bir mülkiyet olmaktan çıkarak, insan ve teknolojik sistemler arasında paylaşılan ilişkisel bir yapı hâline geldiğini göstermektedir.

Bu bulgular, yaratıcı özelliğin yapay zekâ temelli müzik üretiminde sabit bir konumdan ziyade, üretim bağlamına göre yeniden dağıtılan ve müzakere edilen bir süreç olarak işlediğini ortaya koymaktadır. Dolayısıyla, yapay zekâ ile üretilen müziğin analizinde, yaratıcı özneyi yalnızca insan ya da yalnızca makine üzerinden tanımlayan yaklaşımlar açıklayıcı olmaktan uzak kalmakta; yaratıcı özelliği insan–makine ilişkisi içerisinde ele alan çok katmanlı değerlendirme modellerine duyulan gereksinim belirginleşmektedir.

3. Yapay Zekâ Temelli Müzik Üretiminde Yapısal Denetimin Dağılımına İlişkin Bulgular

Elde edilen bulgular, yapay zekâ temelli müzik üretiminde yapısal denetimin tek bir aktör tarafından sürekli ve bütüncül biçimde sağlanmadığını; aksine üretim sürecinin farklı aşamalarında insan ve yapay zekâ arasında değişken biçimlerde dağıldığını ortaya koymaktadır. Yapısal denetimin bu dağılımı, üretim sürecinin zamansal örgütlenmesine, kullanılan yapay zekâ sisteminin üretim kapasitesine ve insan öznenin müdahale düzeyine bağlı olarak farklılaşmaktadır. Bu durum, yapısal kontrolün sabit bir otoriteye değil, üretim bağlamına göre yeniden yapılandırılan ilişkisel bir sürece işaret etmektedir (Gunkel, 2018).

Bazı üretim pratiklerinde form, süre, tonal yapı ve biçim gibi temel yapısal unsurlar üretim süreci başlamadan önce insan tarafından belirlenmektedir. Bu tür üretimlerde insan, müziksel yapının sınırlarını önceden tanımlamakta; yapay zekâ ise bu önceden kurgulanmış yapısal çerçeve içerisinde müziksel materyal üretmektedir. Bu bağlamda yapısal denetim büyük ölçüde insan merkezli bir konumda kalmakta; yapay zekânın rolü belirlenmiş yapının içini dolduran, varyasyonlar üreten ya da olasılıksal seçenekler sunan bir üretici işleviyle sınırlanmaktadır. Nake, McCormack ve Dorin'e (2011) göre bu tür üretim biçimleri, yapısal kararların insan tarafından belirlendiği; algoritmik süreçlerin ise bu kararlar doğrultusunda sınırlı bir üretkenlik alanı içerisinde çalıştığı kontrollü üretim modelleriyle örtüşmektedir.

Buna karşılık, bazı üretim türlerinde yapısal unsurların üretim süreci içerisinde büyük ölçüde yapay zekâ tarafından oluşturulduğu belirlenmiştir. Bu tür pratiklerde formun gelişimi, zamansal örgütlenme, motiflerin yinelenme biçimleri ve tonal yönelimler, algoritmik süreçler aracılığıyla dinamik olarak şekillenmektedir. İnsan özne, bu üretim biçimlerinde doğrudan yapısal kararlar almaktan ziyade, üretim sürecini başlatan, temel parametreleri tanımlayan ya da ortaya çıkan müziksel çıktılar arasından seçim yapan bir konumda yer almaktadır. Bu durum, yapısal denetimin önemli ölçüde yapay zekâyı devredildiği daha özerk bir üretim modeline işaret etmektedir.

4. Yapay Zekânın Yaratıcı Süreçte Üstlendiği Rollere İlişkin Bulgular

Araştırma bulguları, yapay zekânın müzik üretim sürecinde tekil ve sabit bir işlev üstlenmediğini; aksine üretim bağlamına, insan müdahalesinin düzeyine ve yapısal denetimin dağılımına bağlı olarak farklı yaratıcı roller üstlendiğini ortaya koymaktadır. İncelenen üretim pratikleri, yapay zekânın yaratıcı süreçteki konumunun araçsal bir destek işlevinden, kısmen ya da büyük ölçüde özerk bir üretici rolüne kadar uzanan geniş bir yelpazede değişkenlik gösterdiğini ortaya koymaktadır. Bazı üretim pratiklerinde yapay zekâ, insan tarafından yönlendirilen ve yaratıcı süreci destekleyen bir sistem olarak konumlanmaktadır. Bu tür üretimlerde yapay zekâ; motif önerileri sunma, varyasyon üretme, armonik ya da ritmik seçenekler oluşturma gibi işlevler üstlenmekte;

nihai estetik ve yapısal kararlar ise büyük ölçüde insan özne tarafından alınmaktadır. Bu bağlamda yapay zekâ, yaratıcı sürecin merkezinde yer almamakta; insan yaratıcılığını kolaylaştıran ve genişleten bir araç olarak işlev görmektedir. Buna karşılık, bazı üretim türlerinde yapay zekâ, insanla birlikte üretim sürecine aktif olarak katılan işbirlikçi bir aktör rolü üstlenmektedir. Bu tür pratiklerde yaratıcı kararlar, insan ve yapay zekâ arasında karşılıklı etkileşim yoluyla şekillenmekte; müziksel çıktı, her iki aktörün katkılarının bir bileşkesi olarak ortaya çıkmaktadır. Yapay zekâ, bu bağlamda ne yalnızca pasif bir araç ne de tamamen özerk bir üretici olarak tanımlanabilmekte; yaratıcı sürecin ortak bir bileşeni hâline gelmektedir.

Araştırma bulguları ayrıca, bazı üretim pratiklerinde yapay zekânın müziksel materyali büyük ölçüde üreten üretken bir sistem olarak işlev gördüğünü göstermektedir. Bu tür üretimlerde melodik yapı, ritmik örgütlenme, form ve timbral özellikler büyük ölçüde yapay zekâ tarafından oluşturulmakta; insan özne ise süreci parametre tanımlama, çıktı seçimi ya da son düzenleme gibi sınırlı müdahalelerle yönlendirmektedir. Bu durum, yaratıcı sürecin ağırlık merkezinin önemli ölçüde yapay zekâyâ kaydığı bir üretim modeline işaret etmektedir.

5. İnsan–Makine Etkileşim Düzeylerinin Müziksel Çıktılara Yansımasına İlişkin Bulgular

Araştırma bulguları, insan–makine etkileşim düzeylerindeki farklılaşmanın müziksel çıktıların biçimsel, yapısal ve estetik özellikleri üzerinde doğrudan belirleyici bir rol oynadığını ortaya koymaktadır. İncelenen üretim pratikleri, etkileşim düzeyinin yalnızca üretim sürecinin organizasyonunu değil, ortaya çıkan müziksel ürünün öngörülebilirlik derecesini, biçimsel tutarlılığını ve estetik yönelimini de belirgin biçimde etkilediğini göstermektedir.

İnsan müdahalesinin yüksek olduğu üretim türlerinde, müziksel yapıların daha öngörülebilir, kontrollü ve geleneksel form anlayışlarına yakın bir görünüm sergilediği belirlenmiştir. Bu tür üretimlerde form, süre, tonal yönelim ve tematik gelişim gibi unsurlar büyük ölçüde insan tarafından belirlenmekte; yapay zekâ bu önceden tanımlanmış çerçeve içerisinde üretim gerçekleştirmektedir. Sonuç olarak ortaya çıkan müziksel çıktılar, biçimsel bütünlük ve yapısal tutarlılık açısından daha stabil bir karakter göstermektedir. Buna karşılık, insan–makine etkileşiminin daha sınırlı olduğu ve yapay zekânın üretim sürecindeki özerkliğinin arttığı durumlarda, müziksel yapıların daha değişken, akışkan ve öngörülmesi güç bir nitelik kazandığı tespit edilmiştir. Bu tür üretimlerde yapay zekâ, müziksel materyalin gelişimini büyük ölçüde kendi algoritmik süreçleri doğrultusunda yönlendirmekte; form, süre ve tematik yapı çoğu zaman üretim süreci içerisinde kendiliğinden biçimlenmektedir. Bu durum, müziksel çıktılarda beklenmedik geçişler, düzensiz form yapıları ve alışılmış estetik kalıpların dışında kalan sonuçların ortaya çıkmasına yol açmaktadır.

Bulgular ayrıca, orta düzeyde insan–makine etkileşiminin söz konusu olduğu üretim pratiklerinde müziksel çıktıların hibrit bir yapı sergilediğini göstermektedir. Bu tür üretimlerde insan ve yapay zekâ arasındaki karşılıklı etkileşim, hem öngörülebilirlik hem de çeşitlilik barındıran müziksel sonuçların ortaya çıkmasına olanak tanımaktadır. İnsan özne, süreci yönlendiren ve denetleyen bir rol üstlenirken; yapay zekâ, müziksel materyalin çeşitlenmesini ve beklenmedik estetik olasılıkların açığa çıkmasını sağlayan bir üretici olarak işlev görmektedir.

6. Tipolojik Sınıflandırmanın Analitik İşlevine İlişkin Bulgular

Elde edilen bulgular, yapay zekâ temelli müzik üretim türlerinin tipolojik olarak sınıflandırılmasının, söz konusu üretim pratiklerinin analizinde güçlü ve işlevsel bir kavramsal çerçeve sunduğunu göstermektedir. Tipolojik yaklaşım, yapay zekâ ile müzik üretimini tekil ve homojen bir olgu olarak ele alan yaklaşımların ötesine geçerek, farklı üretim biçimleri arasındaki yapısal ve işlevsel ayrımların sistematik biçimde ortaya konulmasına olanak tanımaktadır.

Araştırma kapsamında geliştirilen tipolojik sınıflandırma sayesinde, yapay zekâ temelli müzik üretiminde insan–makine etkileşim düzeyleri açık biçimde ayırt edilebilir hâle gelmiştir. Bu durum, üretim sürecinde insan ve yapay zekâ arasındaki rol dağılımının analitik olarak çözümlenmesini mümkün kılmakta; hangi üretim türlerinde insan müdahalesinin belirleyici olduğu, hangi türlerde ise yapay zekânın daha özerk bir konum üstlendiği net biçimde ortaya konulabilmektedir. Böylece, üretim süreçlerinin yalnızca teknik değil, aynı zamanda ontolojik ve estetik boyutları da analize dâhil edilebilmektedir. Bulgular, tipolojik yaklaşımın yaratıcı öznelliğin dağılımını görünür kılma açısından da önemli bir işlev üstlendiğini göstermektedir. Destekleyici, işbirlikçi, üretken ve özerk yapay zekâ modelleri arasındaki ayrımlar, yaratıcı karar alma süreçlerinin hangi aktörler tarafından ve hangi düzeylerde gerçekleştirildiğini açıklığa kavuşturmaktadır. Bu bağlamda tipoloji, yaratıcı öznelliğin sabit bir özneye ait olmadığı; üretim bağlamına göre yeniden dağıtılan ilişkisel bir yapı sergilediğini analitik olarak ortaya koymaktadır. Ayrıca tipolojik sınıflandırma, yapısal denetimin üretim sürecinin hangi aşamalarında ve hangi aktörler tarafından sağlandığını belirleme açısından da açıklayıcı bir çerçeve sunmaktadır. Yapısal denetimin üretim öncesi, üretim süreci ya da üretim sonrası aşamalarda farklı biçimlerde tesis edilmesi, tipolojik ayrımlar aracılığıyla analiz edilebilir hâle gelmektedir. Bu durum, yapay zekâ ile üretilen müziğin biçimsel ve yapısal özelliklerinin daha bütüncül biçimde değerlendirilmesine katkı sağlamaktadır.

Son olarak, bulgular tipolojik yaklaşımın yapay zekâ temelli müzik üretiminin çok katmanlı ve dinamik yapısını görünür kıldığını ortaya koymaktadır. Tipolojik sınıflandırma, insan–makine etkileşimi, yaratıcı öznellik ve

yapısal denetim gibi temel boyutları ortak bir analitik çerçevede bir araya getirerek, yapay zekâ ile üretilen müziğin çözümlemesinde kullanılabilecek bütüncül bir değerlendirme modeli sunmaktadır. Bu yönüyle tipoloji, yalnızca sınıflandırıcı bir araç değil; aynı zamanda yapay zekâ temelli müzik üretimini anlamlandırmaya yönelik kuramsal ve analitik bir yöntem olarak işlev görmektedir.

Sonuç ve Tartışma

Bu çalışma, yapay zekâ temelli müzik üretimini tekil, homojen ve araçsal bir olgu olarak ele alan indirgemeci yaklaşımların ötesine geçerek, insan–makine etkileşimi, yaratıcı öznelliğin dağılımı ve yapısal denetimin paylaşımı eksenlerinde çok katmanlı bir analitik çerçeve sunmayı amaçlamıştır. Ampirik veri toplamaya dayanmayan bu araştırma, doküman incelemesi ve kavramsal çözümleme yoluyla elde edilen bulgular üzerinden, yapay zekâ ile müzik üretiminin ontolojik ve estetik boyutlarını yeniden düşünmeye yönelik kuramsal çıkarımlar ortaya koymuştur.

Elde edilen bulgular, yapay zekâ temelli müzik üretiminde insan–makine etkileşiminin doğrusal, sabit ve evrensel bir modele indirgenemeyeceğini açık biçimde göstermektedir. Üretim pratikleri; insan merkezli, işbirlikçi ve yapay zekâ ağırlıklı olmak üzere farklı etkileşim düzeylerinde gerçekleşmekte; bu durum, yapay zekânın müzik üretimindeki rolünün bağlamsal olarak yeniden tanımlandığını ortaya koymaktadır. Dolayısıyla yapay zekâ, ne yalnızca pasif bir teknik araç ne de bütünüyle özerk bir yaratıcı özne olarak ele alınabilmekte; üretim bağlamına göre değişen ilişkisel bir aktör konumunda değerlendirilmektedir.

Araştırma bulguları, yaratıcı öznelliğin yapay zekâ temelli müzik üretiminde tek bir özneye atfedilemeyeceğini ve yaratıcı karar alma süreçlerinin insan ve yapay sistemler arasında farklı düzeylerde paylaşıldığını göstermektedir. Bu durum, yaratıcılığın bireysel ve kapalı bir bilişsel yeti olmaktan ziyade, insan ve teknolojik sistemler arasında kurulan dinamik ve müzakere edilen bir süreç olarak ele alınmasını gerekli kılmaktadır. Yaratıcı öznelliğin bu ilişkisel yapısı, müzik üretiminde “yaratıcı kim” sorusunun yerini “yaratıcılık nasıl ve hangi ilişkiler üzerinden ortaya çıkmaktadır?” sorusuna bıraktığını göstermektedir. Benzer biçimde, yapısal denetimin de yapay zekâ temelli müzik üretiminde sabit bir otorite tarafından sürekli biçimde sağlanmadığı; üretim sürecinin farklı aşamalarında insan ve yapay zekâ arasında yeniden dağıtıldığı belirlenmiştir. Üretim öncesinde belirlenen yapısal çerçeveler, üretim sürecinde algoritmik olarak şekillenen formlar ya da üretim sonrası insan müdahalesiyle gerçekleştirilen düzenlemeler, yapısal denetimin bağlama göre değişkenlik gösterdiğini ortaya koymaktadır. Bu durum, müziksel yapının önceden belirlenmiş ve kapalı bir formdan ziyade, üretim süreci içerisinde açılan ve dönüşen bir yapı olarak değerlendirilmesini gerektirmektedir.

Çalışmanın önemli sonuçlarından biri, yapay zekânın yaratıcı süreçte üstlendiği rollerin tipolojik olarak sınıflandırılmasının analitik açıdan güçlü bir açıklama zemini sunduğunun ortaya konulmasıdır. Destekleyici, işbirlikçi, üretken ve daha özerk yapay zekâ modelleri arasındaki ayrımlar; insan–makine etkileşiminin, yaratıcı özelliğin ve yapısal denetimin nasıl dağıldığını görünür kılmaktadır. Bu tipolojik yaklaşım, yapay zekâ ile üretilen müziğin yalnızca teknik özelliklerini değil, aynı zamanda ontolojik konumunu ve estetik yönelimlerini de çözümlemeye olanak tanımaktadır.

Sonuç olarak bu araştırma, yapay zekâ temelli müzik üretiminin çok katmanlı, dinamik ve bağlamsal bir yapı sergilediğini ortaya koymaktadır. Geliştirilen tipolojik çerçeve, yapay zekâ ile müzik üretimini anlamaya yönelik yalnızca sınıflandırıcı bir araç değil; aynı zamanda kuramsal ve analitik bir yöntem olarak işlev görmektedir. Bu yönüyle çalışma, yapay zekâ destekli müzik üretimine ilişkin tartışmalara kavramsal bir derinlik kazandırmakta; gelecekte yapılacak ampirik, deneysel ve algı temelli araştırmalar için kuramsal bir zemin sunmaktadır.

Öneriler

Bu araştırmada elde edilen kuramsal bulgular, yapay zekâ temelli müzik üretiminin çok katmanlı ve bağlamsal yapısını ortaya koymakla birlikte, alan yazında yeni araştırma yönelimlerine ve metodolojik açılımlara ihtiyaç duyulduğunu da göstermektedir. Bu doğrultuda aşağıdaki öneriler geliştirilmiştir.

Ampirik ve Deneysel Çalışmalarla Kuramsal Çerçevenin Sınanması:

Bu çalışma, doküman incelemesi ve kavramsal çözümleme yoluyla elde edilen analitik çıkarımlara dayanmaktadır. Gelecek araştırmalarda, burada önerilen tipolojik sınıflandırmanın deneysel ve ampirik yöntemlerle sınanması önerilmektedir. Özellikle:

- İnsan–makine etkileşim düzeylerinin müziksel çıktıların algılanışı üzerindeki etkileri,
- Yaratıcı özelliğin dinleyici ve besteci algısı bağlamında nasıl değerlendirildiği,
- Yapısal denetimin müziksel tutarlılık ve estetik beğeniyle ilişkisi

nicel ve nitel veri toplama yöntemleriyle incelenebilir. Bu tür çalışmalar, kuramsal çıkarımların alan içi geçerliliğini güçlendirecektir.

Dinleyici Algısına Dayalı Çalışmaların Geliştirilmesi:

Bulgular, insan–makine etkileşim düzeylerinin müziksel çıktılarda biçimsel ve estetik farklılıklara yol açtığını göstermektedir. Ancak bu farklılıkların dinleyici tarafından nasıl algılandığı henüz yeterince açıklığa kavuşturulmamıştır. Bu nedenle gelecekte yapılacak çalışmalarda:

- Yapay zekâ ağırlıklı ve insan ağırlıklı üretimlerin algısal karşılaştırmaları,

- Öngörülebilirlik, yenilik, duygusal etki ve estetik değer algıları,
- Dinleyicinin yapay zekâ farkındalığının algı üzerindeki rolü

gibi değişkenlerin incelenmesi önerilmektedir.

Bestecilik ve Müzik Eğitimi Bağlamında Pedagojik Çıkarımlar:

Araştırma bulguları, yapay zekâ temelli müzik üretiminin yaratıcı özneliği yeniden dağıtan bir yapı sergilediğini ortaya koymaktadır. Bu durum, bestecilik pedagojisi ve müzik eğitimi açısından önemli sonuçlar doğurmaktadır. Buna bağlı olarak:

- Yapay zekâ destekli üretim araçlarının bestecilik ve düzenleme derslerine nasıl entegre edilebileceği,
- Öğrencilerin yaratıcı karar alma süreçlerinde insan–makine etkileşimini nasıl yönettikleri,
- Yapay zekânın pedagojik bir araç mı yoksa yaratıcı bir ortak mı olarak konumlandırılacağı

gibi sorular, eğitim temelli araştırmalarla ele alınabilir.

Ontolojik ve Estetik Tartışmaların Derinleştirilmesi:

Bu çalışma, yapay zekâ ile üretilen müziğin ontolojik statüsüne ilişkin tartışmalara kavramsal bir zemin sunmaktadır. Gelecek araştırmalarda:

- Yapay zekâ ile üretilen müziğin “eser” kavramı içerisindeki konumu,
- Yaratıcı özne kavramının insan–makine ilişkisi bağlamında yeniden tanımlanması,
- Özgünlük, niyet ve estetik değer ölçütlerinin yapay zekâ bağlamında yeniden ele alınması

gibi konular, felsefi ve estetik yaklaşımlarla daha derinlikli biçimde incelenebilir.

Tipolojik Çerçevenin Farklı Müzik Türlerine Uygulanması:

Bu araştırmada geliştirilen tipolojik sınıflandırma, genel bir analitik çerçeve sunmaktadır. Ancak bu çerçevenin farklı müzik türleri ve üretim bağlamlarında nasıl işlediği henüz yeterince bilinmemektedir. Bu nedenle:

- Elektronik müzik, popüler müzik, deneysel müzik ve geleneksel müzik üretimlerinde,
- Farklı yapay zekâ sistemleri ve yazılımlar kullanılarak gerçekleştirilen üretimlerde,
- Kültürel ve coğrafi bağlamlara göre değişen üretim pratiklerinde

tipolojik modelin uygulanması ve karşılaştırmalı analizlerin yapılması önerilmektedir.

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“KİTABİ-DƏDƏ QORQUD” UN POETİKASI: BƏDİİ MÜQƏDDİMƏDƏ SÖZÜN VƏ DÜŞÜNCƏNİN İDRAKİ MƏNA RƏNGLƏRİ

Doç. Dr. ƏBÜLFƏZ ƏZİMLİ

ORCID: 0009-0001-1327-3425 ezimliebulfez@yahoo.com.tr Google Akademik, Dünya Sülh Səfiri; Nobel Prize & India- Birliyinin Yönetici üzü, Qlobal Yazarlar Akademiyası üzü; Türk Dünyası Vətəndaşlığı və Eyitimçilər Birliyi üzü. TÜRKSOY üzü; Naxçıvan Dövlət Universiteti- Tarix-Filologiya Bölümü; Naxçıvan Müəllimlər İnstitutu, Bütöv Azərbaycan

ÖZƏT

“Kitabi-Dədə Qorqud”da bədii- poetik ifadə və idraki mənalandırma linqvistikası:

“Kitabi-Dədə Qorqud” un poetikası= Türk DASTAN linqvistikası poetikasıdır. Burada bədii sözün, məzmun və mənaların, fikir və düşüncələrin məxsusi poetik ifadə və idrakətmə elmi vardır. Bu, Dastan Poetikasına xas olan struktur-ifadə elmidir.

Dastanlarda sözlə onun ritmik ifadə stili bir-birinin içərisində, dastan drammatizminin poetik strukturundadır. Bu mənada “Kitabi-Dədə Qorqud”da “Mətnin ritmik quruluşu” (K.V. Nər. səh.39) poetik ifadə zənginliyinə malikdir. Müqəddimənin ilk cümləsində aydın olur ki, dastanları söyləyən şəxs_ozan adfi bir ozan deyil, onun şəxsiyyət özəlliyi tipik xarakterə malikdir:

Dastanın dili şairanə fantastikadır; səs sözi izləyir, söz sözü. Sanki mənalar sözlərdən irəli düşür. Bütün bu cəhətlər onu nizamlayır ki, Dədə Qorqudun bədii ifadə dili çoxçalarlı, çoxəlamətlidir.

“Kitabi_Dədə Qorqud” dastanlarında iki ifadə--forma strukturu var: birincisi təhkiyə dili, ikincisi obrazların danışiq-nitq dili. Hər ikisi qafiyəli, ritmik, dinamikdir; bədii poetizm hər ikisi üçün xarakterikdir. Dastanların dili poeziya dilidir.

Səs izləmi, Söz izləmi, Məna izləmi, Fikir izləmi

Müqəddimənin Dili ustadnəmə, Nəsihət, Hikmət dilidir. Hikmətlər kəlamlar onun bədii-poetik, lirik-emosional ifadə stilinə görə obrazlıdır.

Ozan Dədə Qorqudun dilində bütün səslər azad və sərbəstdir, bu səslər öz qoşqusunu, məna, məzmun axarını canlandırmaq tərzinə görə Türk xalq şeirinin ritmik ölçüsüdür. Ümumiyyətlə, Dədə Qorqudun söylədiyi dastanlarda səs, sözün axarı- axarı mənaların, fikrin üslubun əhvalat axarını gücləndirir.

Dastanın dili bədii strukturlar dilidir. Bədii strukturaliozmin ən aydın və ən sərbəst formasıdır, sonrakı dövrlərdə yazılı dilin strukturunda ağırlıq, ərəb-fars sözlərinin yükü altında oldu. Bədii poetika səs, söz, cümlə, üslub, məna, fikir, məzmun, forma, ölçü, nizam poetikası deməkdir.

AÇAR SÖZLƏR: Kitabi-Dədə Qorqud; Dastan Poetikası; Dədə Qorqud-da Bədii müqəddimə.

THE POETICS OF “KITABI-DADE GORGUD”: PERCEPTIVE MEANING COLORS OF WORD AND THOUGHT IN THE ARTISTIC INTRODUCTION

ABSTRACT

The linguistics of artistic-poetic expression and cognitive meaning in “Kitabi-Dade Gorgud”:

The poetics of “Kitabi-Dade Gorgud” = the poetics of the linguistics of the Turkish DASTAN. Here there is a specific poetic expression and comprehension science of the artistic word, content and meanings, ideas and thoughts. This is the science of structure-expression specific to Dastan Poetics.

In the dastans, the rhythmic expression style of the word is within each other, in the poetic structure of the dastan dramatism. In this sense, “The rhythmic structure of the text” (K.V. Nar. p.39) in “Kitabi-Dade Gorgud” has a richness of poetic expression. In the first sentence of the introduction, it becomes clear that, The person who tells the epics - the poet - is not a typical poet, his personality has a typical character:

The language of the epic is poetic fiction; the sound follows the sound, the word follows the word. It is as if the meanings come from the words. All these aspects determine that the language of artistic expression of Dede Gorgud is multifaceted, multi-character.

In the epics of "Kitabi_Dede Gorgud" there are two expression-form structures: the first is the language of narration, the second is the language of conversation and speech of the characters. Both are rhymed, rhythmic, dynamic; artistic poetics is characteristic of both. The language of epics is the language of poetry.

The language of the sound, the language of the word, the language of the meaning, the language of the thought
The language of the introduction is the language of masterwork, advice, wisdom. Wisdom and words are figurative according to his artistic-poetic, lyrical-emotional style of expression.

In the language of the poet Dede Gorgud, all sounds are free and free, this The sounds are the rhythmic dimension of Turkish folk poetry due to the way they animate their rhyme, meaning, and content flow. In general, in the epics told by Dede Gorgud, the flow of sound, words, and meanings, the flow of thought, style, and story flow are strengthened.

The language of the epic is the language of artistic structures. It is the clearest and freest form of artistic structuralism, and in later periods, the structure of the written language was burdened by Arabic-Persian words. Artistic poetics means the poetics of sound, word, sentence, style, meaning, thought, content, form, measure, and order.

KEYWORDS: Kitabi-Dede Gorgud; Epic Poetics; Artistic Introduction in Dede Gorgud.

GİRİŞ

Folklorun ən dərin süjetli yaradıcılıq janrı Dastandır. Dasatndan da qədim olan- onu söyləyən Ozandır. Dastan xalq yaradıcılığının bir sıra janrları ilə sıx bağlıdır: onun bədii ifadə tipi, söz söyləmi, lirik-epik təsvir və tərənnüm xüsusiyyətləri bayatı, gəraylı, qoşma ritmi, tərənnüm-vəsf əlamətləri dastana lirik emosionallıq bəxş etmişdir. Təhkiyə, təsvir poetizmi dastanda fərqli ahəngdədir. Dastanlar dil emosionallığı ilə xalq zehniyyətinin, xalq leksikasının məxsusi dərinliyindən xəbər verir.

Dastan söyləmində Saz, söz, musiqi, saz havaları dastan üçün də başlıca ifadə vahidləridir. Bütün bunlar dastanlarda dil faktlarını, Dastan poetikasını canlandıran əlamətlərdir. Dastan Dil faktlarının zəngunliyi ilə fərqlənən janrdır; hər şeydən əvvəl, dastan dil, söz, üslub, məna prosesini ifadə edir. Sözlər, səslər, deyimlər dastanın bədii ifadə linqvistikasını təmin edir. Hər bir Dastan canlı dil abidəsidir, burada xalq linqvistikasının ən poetik, ən psixoloji əlamətlərini görmək olar.

Dil abidəsi kimi, hər bir dastan səs, söz, məna, fikir, ideya yükü daşıyır. Folklor stilistikasına görə, dastan onlarla janrı öz ağuşuna ala bilən formadır. Bu mənada, Dastan xalq yaradıcılığında forma və məzmun tipologiyasına görə, fərqli xüsusiyyətlərə malikdir. Sözsüz ki, fərqlilikdə başlıca rolu dastanın Dil, Nitq poetikası oynayır.

Azərbaycan-Oğuz Türklərinin möhtəşəm ədəbi abidəsi olan “Kitabi-Dədə Qorqud” dastanları min altı yüz-1600 ilbundan əvvəl Azərbaycan-Oğuz Türkcəsinin- Xalq danışiq-nitq, Dil poetikasının heyratəmiz mənbə-nümunələridir. türk dünyasının ən möhtəşəm ədəbi abidələrindən biri kimi özünəməxsus ifadə tipinə fonetik, leksik-semantik və üslub sinxronizminə malikdir. Dastan təkcə türklərin—oğuzların deyil, eyni zamanda qədim dünyanın bədii yaddağının misilsiz incisidir. Azərbaycan xalq yaradıcılığının bədii-poetik məhsulu olan Dastan milli bədii təfəkkürümüzün məna və söz yaddağının möcüzəsi kimi xarakterikdir. Hələ Dünya söz demək bacarığına sahib deyildi, lakin Türklər sözün min bir libasından, üslub taktından, bədii xəyal və fantaziya, məna və fikirlərə poetik nizam vermək sənətini yaratmışlar.

“KİTABI- DƏDƏ QORQUD” DASTANINDA BƏDİİ MÜQƏDDİMƏ VƏ ONUN STRUKTUR İFADƏ RƏNGLƏRİ

Bütün xalq janrları kimi, dastanlar da xalq dilinin bədii ifadə, məna və üslub baxımından xüsusi əlamətlərə malikdir. Xalq dilinin səs, söz, məna poetikası epik lirizmin daxili rənglərini əks etdirir.

Kamil Vəli Nərimanoğlu “Kitabi-Dədə Qorqud” dastanlarının bədii, poetik ifadə xüsusiyyətlərindən bəhs edən “Dastan poetikası” adlı əsərində yazır ki:

“dil yarandığı çağdan bədii sözün rüşeymi yaranmışdır, Bəsit şəkildə desək, birinin danışdığı beşinin dinləməsi artıq ilkin ədəbiyyat işarəsidir. İnsan oğlunun sözə tapınması, dediyi kəlimələrin ovsununa inanması yenə də ədəbiyyat işartısıdır. əmək prosesində işə yüngüllük gətirən harmonik kəlimələr, ritmli sözlər, cümlələr, ilkin əmək nəğmələri, ilk düzgünlər, qoşqular, meydan tamaşaları ədəbiyyatın başlanğıcıdır” (Kamil Vəli Nərimanoğlu Səh. 31)

Türk dastanları milli mənsubluq, milli özəllik dilidir: “bu dil millətin ağzında əsrlərcə süzülə - süzülə adətə atalar sözü və vecizələr dizisi halinə gəlmiş bir dildir. Dastan dili bu baxımdan mukaddes kitabların dilinə benzer (Məhərrəm Ergin, seh.8).

Azərbaycan-Oğuz Türk dastanlarının dili bilavasitə bədii ifadə, səs, söz ritminin dili, obrazlı deyim, yığcam, qısa, lakin mənaca geniş, sürəkli təsiriyyətə dili, əhvalat, şeir, mənzum-mənsur ifadə dilidir; bu dil “işlek, açıq, veciz və anlaşılabılır bir ifadə gücünə sahibdir. Gramer baxımından misraların düzülüşü, Türk dilinin cümlə yapısına uyğundur. Bu anlatım dili, aynı zamanda müştərek konuşma dilinin ortak zenginliyini və anlaşılabilirliğini yansıtır.

Destan janrının dili mübalağa, benzetmə, tezat, mukayese gibi edebi unsurlarla süslü, zengin bir üsluba sahiptir. Fakat bu üslupta hakim unsur, mubalağa sanatıdır ve mubalağanın asıl fonksiyonunun eseri gerçeklikten uzaklaştırmak olmadığını, əksinə, gerçekleri açarak, böyüdərək ortaya qoymaq olduğunu göz önünde tutmaq lazımdır” (Türk Halk Edebiyatı, seh, 147; Yıldırım, seh 155).

Dastanın dili və üslbu xalq poetikası dilidir. Xalq bədii poetikası linqvistik stilinə görə həmişə canlı və oynaqdır. “Kitabi_Dədə Qorqud” dastanlarının- “boylarının poetik təhlili” (Kamil Vəliyev səh,20) “araşdırma aspektləri” sırasında gərəkli yer tutur; çünki “poetik təhlilin işığı altında boyların dili daha çox aydınlaşır, qrammatik təfəkkürün mahiyyəti açılır.”Dastanlar”ın dilindəki ovsunu, poetik təfəkkürün incəliklərini açmaqda linqvistik poetikanın rolu böyükdür”(Kamil Vəli,20)

Dastanın dili bədii strukturlar dilidir. Bədii strukturaliozmin ən aydın və ən sərbəst formasıdır, sonrakı dövrlərdə yazılı dilin strukturunda ağırlıq, ərəb-fars sözlərinin yükü altında oldu. Bədii poetika səs, söz, cümlə, üslub, məna, fikir, məzmun, forma, ölçü, nizam poetikası deməkdir. Bu baxımdan, K.V. Nərimanoğlunun sözlərilə desək: “ poetik struktura elə bir mexanizmdir ki, onun mürəkkəb quruluşundakı bütün hissələr bir-birini tamamlayır, birbaşa və ya dolay yolla onun vahidləri qarşılıqlı şəkildə biri digərindən asılı olur.

Bəllidir ki, hər sintaktik fiqurun özü bir anomaliyadır, hansı bir standart normadansa yayınmadır. Nitq təbiiliyinə sığan, dilin potensial imkanlarının əsasında yaranan bu anomaliya estetik dəyərliliyinə görə yaşama haqqı alır, Həmin sintaktik fiqurun üzvi hissələri bir məqsədə yönəldilir (motivlənir). Həmin fiqurdakı səslərin

ardıcıl düzüümü, səsələşməsi, sözlərin semantik tutumu, morfemlərin sırası, sözlərin birləşməsi və sıralanması birbaşa təşkiledicilər (müstəqim tərtibçilər) kimi çıxış edərək poetik mətnin qurulmasında iştirak edir” (səh. 27).

“Kitabi-Dədə Qorqud” dastanlarının poetik_sintaktik strukturunda “ hər bir cümlə böyük və ya kiçik ritmin təşkiledicisidir””səh. 35).

Dastanlarda sözlə onun ritmik ifadə stili bir-birinin içərisində, dastan dramatizminin poetik strukturundadır. Bu mənada “Kitabi-Dədə Qorqud”da “Mətnin ritmik quruluşu” (K.V. Nər. səh.39) poetik ifadə zənginliyinə malikdir. Müqəddimənin ilk cümləsində aydın olur ki, dastanları söyləyən şəxs_ozan adfı bir ozan deyil, onun şəxsiyyət özəlliyi tipik xarakterə malikdir:

“Kitabi_Dədə Qorqud” dastanlarında iki ifadə--forma strukturu var: birincisi təhkiyə dili, ikincisi obrazların danışığ-nitq dili. Hər ikisi qafiyəli, ritmik, dinamikdir; bədii poetizm hər ikisi üçün xarakterikdir. Dastanların dili poeziya dilidir. “Kitabi-Dədə Qorqud” belə başlayır:

“Rəsul əleyhüssəlam zamanına yaxın Bayat boyundan Qorqud Ata derlər, bir ər qopdu. Oğuzun ol kişi tamam bilicisiydi. Nə dersə-olardı, qayıbdən dürlü xəbər söylərdi. Həq-təala onun könlünə ilham edərdi.

Qorqud Ata ayıtdı:

--Axır zamanda xanlıq geri qayıya dəgə (çatar-Ə.), kimsənə əllərindən almaya, axır zaman olub qiyamət qopunca.

Bu dediyi Osman nəslidir, iştə sürülüb gedəyüdir (getməkdədir). Və dəxi neçə buna bənzər sözlər söylədi.

Qorqud Ata Oğuz Qovmunun müşkülünü həll edərdi. Hər nə iş olsa, Qorqud Ataya danışmayınca işləməzlərdi, Hər nə ki buyursa, qəbul edərlərdi. Sözün tutub tamam edərlərdi”.

“Kitabi_Dədə Qorqud” dastanlarında iki ifadə--forma strukturu var: birincisi təhkiyə dili, ikincisi obrazların danışığ-nitq dili. Hər ikisi qafiyəli, ritmik, dinamikdir; bədii poetizm hər ikisi üçün xarakterikdir. Dastanların dili poeziya dilidir.

Dədə Qorqud söyləmiş (söyləmiş poetik ifadəyə aiddir, “ayıtdı” isə təhkiyə ifadəsidir):

Allah-Allah deməyincə- işlər önməz.

Qadir tanrı verməyincə -ər bayımaz.

Əzəldən yazılmasa, qul başına -qəza gəlməz.

Əcəl vədə yrməyincə (gəlib çatmayınca, tamam olmayınca) kimsə ölməz.

Ölən adam dirilməz.

Çıxan can geri dönməz.

Bu deyimlər məzmunca bir mövzu üzərindədir: dünya və insan, insanın taleyi.

Dünya ilə İnsan arasındakı münasibətlərə müdrik mənalandıma verən Dədə Qorq bütün fəlsəfərdən üstü olan bir elmə sahibdir. O. Elmi öyrənməyib, əksinə elmi o yaradıb.

Bir yigidin Qaradağ yumrusunca malı olsa, yığar durur, tələb eylər, nəсібindən artıqın. (xan-ım), yeyə bilməz.

(hədisdə var: Kim nə qədər var yığır yığsın, bir qarnı tutacağı qədər yeyər).

Ulaşban sular daşsa, dəniz olmaz.

Təkəbbürlük eyləyəni tanrı sevməz.

Könlün yuca tutan ərddə dövlət olmaz.

Yad oğlu saxlamaqla oğul olmaz—

Böyüyəndə salır gedər, gördüm deməz.

Kül təcik olmaz,(göyü-giyəv) oğul olmaz.

Qara eşşək başına üyən ursan, qatır olmaz.

Qaravaşa don geyirsən. Qadın olmaz.

Yapa-yapa qarlar yağsa, yaza qalmaz.

Yapağlı kökçə çəmən güzə qalmaz.

Əski pambıq bez olmaz.

Qarı düşməni dost olmaz.

Qaraqoca (ata) qıymayınca- yol alınmaz.

Qara polad üz qılıncı çalmayınca- qırım dönməz.

Ər malına qıymayınca - adı çıxmaz.

Qız anadan görməyincə- öyüd almaz.

Oğul atadan görməyincə -süfrə yaymaz.

Oğul atanın- yetirdir,

İki gözünün -biridir.

Dövlətli oğul qopsa- ocağının közüdür,

Tirkeşində tiridir (ox qabında oxudur).

Dövlətsiz oğul qopsa- ocağının küridir.

Oğul dəxi neyləsin, baba ölüb- mal qalmasa?

Baba malından nə fayda--başda dövlət (ağıl) olmasa.

Dövlətsizlər (ağılsızlar) şərrindən Allah saxlasın, Xan-ım, sizi!

Boylarda “şifahi ədəbiyyatın poetik qrammatikası” (Lord A. B. The Book Singer of Tales. Cambridge Mass, 1960, səh. 60—sitatı K.Vəliyev təqdim etmişdir: K.V., səh.109)

Dastandakı Qorqut Atanın söylədiyi cümlələr, sözlər hamısı müdrik deyimlər, poetik janr stili, şeiriyət nümunəsidir: bu cür deyimlər şairanə və poetik ahənginə gözə titrəyişli, həyəcanlandırıcı, düşündürücü söyləmələrdir.

Kamil Vəliyev yazır: *” Bizə gəlib çatan on iki dastan və ustadnamələrin qədim şəkli olan müqəddimə--atalar sözlərinin müasir şeirə yaxın və eyni olan hissələri ona görə süjetin ayrılmaz hissəsidir, informativ-semantik yük daşıyır ki, sonrakı hissələrlə onun sistemi eyni olub. Sadəcə olaraq, yazıya alınana qədərki dövrün adi təhkiyə süjetin müəyyən hissələrini daha çox özününküləşdirmiş, şeir həddindən çıxararaq təhkiyələşdirmişdir və diqqət edilərsə, həmin yerləri ayırmaq olar”*(səh. 109).

Səs izləmi, Söz izləmi, Məna izləmi, Fikir izləmi

Hamısı İzləmdə İzləm Poetikasını yaradır.

Səs izləmi alliterasiyadır: “qədim türk şeirində qafiyə yoxdur, onun oynadığı funksiyanı alliterasiya yerinə yetirir. M.Adilov haqlı olaraq göstərir ki. “qafiyə paralel cümlələrin eyni tərzdə qurulmasının təbii nəticəsi kimi sonralar meydana çıxmış və şeirdə get-gedə üstünlük təşkil etmişdir. Qədim dövrlərdə Türk şeirində alliterasiya əsas təşkilədiçi amil olmuş, daha mühüm əhəmiyyət təşkil etmişdir” (K.Vəliyev, Dastan poet., s.79; M.Adilov.

Azərbaycan dilində sintaksis təkrarlar. Bakı, 1974; M.Adilov. xalq dilində və Füzuli şeirində alliterasiya. S.M.Kirov adına ADU-nun “Elmi Əsərlər”(Dil və Ədəbiyyat seriyası), Bakı, 1977. № 3

Alliterasiyanın iki şəkildə olmasından bəhs edilmişdir: 1) xarici alliterasiya, 2) daxili alliterasiya.

Türk destanlarının anlatımında, anlatıcının “anlamı kuvvetlendirmək və ifadə zənginliyi sağlamək üzere, başvurduğu yöntemlerden birisi ses taklidinden oluşmuş kelimelerin sıkca tekrarlanmasıdır (Yıldız, 1995, səh.54). Buradan görüldüyü kimi, səs ritmi, səs axını poetik axındır və səs təqlidinin ifadə zənginliyini artıran amillər kimi təsnif edilməsini dastan poetikasının əsas yaradıcılıq sirri kimi xarakterizə etmək olar

Ozanlar Ozanı Dədə Qorqudun nitqində səs və söz təkrarları bədii ifadə poetizmidir. Səs və söz izləmləri bədii təsvirin məna ritmini canlandırır. Ozan nitqi ilə adi adamın nitqi arasında, sözsüz ki, ciddi fərqlər vardır. Ozan nitqi ruhən, məna və üslubca alim, ozan, aşiq, müdrik filosof nitqidir.

Türk dastanlarının üslub, ifadə, forma-məzmun sistemində Dədə Qorqudun söyləmi, nağıl və təhkiyəsi müstəsna yer tutur. Dədə Qorqudun dilində bütün səslər azad və sərbəstdir, bu səslər öz qoşqusunu, mənə, məzmun axarını canlandırmaq tərzinə görə Türk xalq şeirinin rıkmik ölçüsüdür. Ümumiyyətlə, dastanlarda səsin axarı mənaların əhvalat axarını gücləndirir:

“Bu tür çeşitli seslerin taklidinden doğan kelimeler kullanılarak bir yandan anlatıma ses ve ifade zenginliyi katılmakta diğer yandan da dinleyicilerin olayı zihinlerinde daha iyi canlandırabilmelerinne imkan sağlayacak bir şekilde, adeta efekt tesiri meydana getirmektedir”(Türk Halk Edeb., seh.148).

Müqəddimənin Dili ustadnəmə, Nəsihət, Hikmət dilidir. Hikmətlər kəlamlar onun bədii-poetik, lirik-emosional ifadə stilinə görə obrazlıdır. Aşağıdakı sözlər adi kəlam deyil, poetik vəsfdir, canlı üslubdur, səs axınıdır, səslərin sözlərə hərəkət vermə tərz, sözlərin mənaları vəsf etmək stilidir:

Dədə Qorqud bir dəxi söyləmiş:

Sərp yürürkən qazılıq ata namərd yigit minə bilməz.

Minincə-- minməsə yey.

Çalıb kəsər üz qılıncı müxənnətlər çalınca, çalmasa yey.

Çala bilən yigidə oxla qılıcdan bir çomaq yey.

Qonağı gəlməyən qara evlər yıxılsa yey.

At yeməyən acı otlar (bitincə), bitməsə yey.

Adam içməz acı sular sızınca sızmasa yey.

Ata adını yürütməyən xoyrad oğul, ata belindən enincə, enməsə yey,

Ana rəhminə düşüncə, düşməsə yey.

Ata adın yürüdəndə dövlətli oğul yey.

Yalan söz bu dünyada oluncə, olmasa yey.

Gerçəklərin üç otuz on yaşını doldursa yey.

On otuz on yaşınız dolsun, haqq sizə yaman göstərməsin,

Dövlətiniz payəndə olsun, xan-ım, hey!

Sözlərin hər birində bir yük var: bu yük səslərin ritminə görə, mənaların heyvətəməz cəzbəsinə görə Dastanın Nitq üslubuna canlı bir obrazlılıq gətirmişdir:

Yenə Dədə Qorqud burada söyləmiş, görəlim, xan-ım, nə söyləmiş:

Getdikdə yerin otlaxların eyik bilir.
Gənəz yerlər çəmənlərin qulan(çöl eşşəyi) bilir.
Ayrı-ayrı yollar izin dəvə bilir.
Yeddi dəvə qoxuların tülkü bilir.
Dünlə (gecəylə) karvan keçdüyün torağay bilir.
Oğul kimdən olduğun ana bilir.
Ər ağırın, ər yünüsün at bilir.
Ağır yüklər zıhmin qatır bilir,
Nə yerdə sızlayır varsa, çəkən bilir,
Qafil başın ağrısın beyin bilir.
Qolça qopuz götürüb eldən-elə , bəydən-bəyə ozan gəzər.
Ər çomərdin, ər nakəsin ozan bilir.
Elinizdə çaləb ayıdan ozan olsun!
Azıb gələn qadanızı tanrı sovsun, xan-ım, hey! (bəyim, hey!)

Dədə Qorqudun kəlamları müdrikanə çəkisinə görə, xüsusi Dil yatımına görə fərqlənir. Dastan poetikasında söz fantaziyası, xəyalı gerçəkliyi ifadə poetizminə xidmət edir.

Bualo dastanının bədii ifadəsində xəyalın və poetik canlandırmanın xüsusi rol oynadığını söyləyir:

“33. Dastan isə daha ülvə və daha gözəldir. Dastanın yolu təntənəli və ahəstədir, onun kökü əsatirlə bağlıdır, lakin əsatirdən aldıqlarını uydurma və xəyalın gücü ilə daha da gözəlləşdirib yaşadır. Bizi məftun etmək üçün dastandakı xəyalın hüdudları tükənməzdir. Bu xəyalın qanadlarında hər şey ağla, cana gəlir: Venera--əbədi gözəlliyin, Minerva isə aydın zəka və dərüni fikirlərin təcəssümüdür, leysan yağışının müjdəçisi olan göy gurultularını ildırım buladlar deyil, Neptun yaradır; dənizdə dalğaları göyə qaldıraraq köpükləndirən külək deyil, hiddətlənərək coşan Neptundur; dağlarda sizin çağırışınıza cavab verən əks-səda deyil, Nərgizin dərindən göz yaşı tökən su pərisinin çəkdiyi “ah”ın səsidir.

Dastançı şair uydurma və xəyalın əlvan iplərini sənətkarlıqla toxuyaraq hər şeyə gözəllik verib canlandırır, hər şeyi istədiyi əlvan boyalarla boyaya bilər: onun ətrafı solmayan gül-çiçəklərlə doludur” (Bualo, Poeziya sənəti. Bakı, Azərənəşr, 1969, 184 səh, səh. 51).

Türk dastan yaradıcılığında bu poetik sənətkarlığını bütün özəllikləri canlanıb.

Dastan nitqi öz səs yatımı, söz yatımı, təsvir, vəsf yatımı vardır. Bütün səslər fonoloji struktura ahəng, təqə verir. Məna ritmləri ifadə, məzmun xarakterinə görə canlıdır. Sözlərin ən yatımlı, poetik ahəngi səslərin ritmik düzülüşündə nizam tapır, bədii simasına görə Dədə Qorqudun deyimləri hikmət mənalərini açır, səsi və sözü əlamətlər yaradan dildir onun dili. Üslubu da Dədə Qorqud üslubudur. Üslublar səsinə görə ahəng yaradan tərənnüm əlamətləri kimi təzahür edir.

Dastanların dili şairanə fantastikadır; səs sözi izləyir, söz sözü. Sanki mənalər sözlərdən irəli düşür. Bütün bu cəhətlər onu nizamlayır ki, Dədə Qorqudun bədii ifadə dili çoxçalarlı, çoxəlamətli. Dədə Qorqudun dilində, bədii tərənnüm stilində kompozisiya tərkibləri ilk baxışda təsadüfi ifadələr kimi görünə bilər; əslində belə deyildir: onun dilində sözlər və mənalər təzələnilir, canlı olur. Aşağıdakı deyimləri təsvir poetizminə, söz mənalandırmalarına nəzərən müdrik deyimlərdir. Şairanəlik onun nitqinin ruhundadır:

Dədə Qorqud yenə söyləmiş, görəlmiş, xan-ım, nə söyləmiş:

Ağız açılıb öyər olsam, üstümüzə tanrı görklü.

Tanrı dostu, din sərvəri Muhəmməd görklü.

Məhəmmədin sağ yanında namaz qılan Əbubəkr görklü.

Axır separə başıdır əmmə görklü.

Hecəsindən düz oxunsa, Yasin görklü.

Qılıç çaldı, din açdı Şahi- Mərdan Əli görklü.

Əlinin oğulları, Peyğəmbər nəvələri, Kərbəla yazəsində

Yezidilər əlində şəhid oldu Həsənlə Hüseyn, iki qardaş belə görklü.

Yazılıb-düzülüb göydən endi Tanrı elmi “Quran” görklü.

Ol “Quran”ı yazdı-düzdü üləmələr öyrənincə görklü.

Biçdi, alimlər sərvəri Osman Üffan oğlu görklü.

Alçaq yerdə yapılbıdır tanrı evi Məkkə görklü.

Ol Məkkəyə sağ varsa, əsən gəlsə, sidqi bütün hacı görklü.

Sağış (məşəd) günündə ayna (cümə) görklü.

Ayna günü oxuyanda xütbə görklü.

Qulaq urub dinləyəndə ümmət görklü.

Minarədən banlayanda (azan verəndə) fəqih görklü.

Dizin basıb oturanda halal görklü.

Dölümündən ağarsa, baba görklü.

Ağ südün doya əmizirsə, ana görklü.

Yanaşıb yola girəndə qara ayğır görklü.

Sevgili qardaş görklü.

Bunar ala ev yanında tikilsə, gördək görklü.

Uzunca tənəfi görklü.

Oğul görklü.

Qamusuna bənzəmədi cümlə aləmləri yaradan Allah—Tanrı görklü.

Ol ögdüğüm yuca Tanrı dost oluban mədəd irsin, xan-ım hey!

Dastanın lirik simptomları obrazlı deyim tərzinə görə fərqli xüsusiyyətlərə malikdir. Şeir dili dastan lirikasının ən tipik əlamətlərini əks etdirir.

Təhkiyə dilində də şairanə poetizm güclüdür. Məsələn müqəddimədə qadınlar haqqındakı deyimlər adi təhkiyə dili deyil, poeziya dilidir:

(Dədə Qorqud dilindən) Ozan aydır:

Qarılar dörd dürlüdür:

Birisi solduran soydur,

Birisi dolduran toydur,

Birisi evin dayağıdır,

Birisi, necə söylərlər, bayağıdır.

Bu deyimlər bayatı üstündədir: təhkiyəyə şirinlik verir; eyni zamanda qadınlar haqqında məlumat-xarakterizə vermək üçün hikmətamiz başlanğıcdır, sonralar bu tərz "ustadnamə" adlandırmışlar. Səs izləmi bu deyimlərin ilkin hərəkət təqtidir: birinci misradakı səslənmələr axara bənzər bir tərzdədir: r səsi hərəkətin ritmini tutur, sözlərin ahəngli səslənməsinə rəvac verir, sözləri bir-birinə bənd edir: araba çarxı kimi fırlanma hərəkəti edir və səslənməyə uyarlıq qatır.

Digər bir aktiv səs "D-de"dir. Hər iki samit səs sait tələb edir, əslində onların hərəkərini nizamlayan da saitlərdir. Səs axını mənaya ritm tutur. Ritmik ahəng lirik vəzn ahəngidir. Dastan lirizmini ən yaxşı formada inikas etdirən təqət olmaqla ritmik ahəng həm nitqin poeziyası kimi, həm də mənaları qüvvətləndirən amil kimi

xarakterik əlamətdir. A və Ü səsləri bu nizamda əsas fiqurdur. Sonrakı misralar da bu üç sözlü və yeddi hecalı birinci misranın qoşqusundadır. Bu yazıda sonrakı misralarda artıq heca-sait səs vardır, lakin nitq zamanı bu “artıqlıq” olmur. Bu, ozan dilinin, dastan strukturunun əsas özəlliklərindən biridir.

Dörd misralı hikmətli, obrazlı deyimdən sonra o obrazlılığı açan—təhlil edən təsvir gəlir:

Ozan, evin dayağı oldur ki, yazıdan-yabandan evə bir qonaq gəlsə, ər adam evdə olmasa, onu ol yedirər-içirər, ağırlar, əzizlər, göndərər. Ol Ayışə, Fatimə soyudur. Xanım, onun bəbəkləri bitsin (balaları yetişsin).

Ocağına buncılayın övrət gəlsin.

Gəldin ol kim solduran soydur: sabahdanca yerindən uru durar, əlin-yüzün yumadan doqquz bazlamac ilə bir güvələk yoğurd güvəzlər, doyunca tıxa-basa yeyər, əlin böyrünə urar, ayıdar: -- Bu evi xarab olası, ərə varılandan bəri dəxi qarnım doymadı, yüzüm gülmədi, ayağım başmaq, yüzüm yaşmaq görmədi,--deyər. A nolaydı, bu öləydi, birinə dəxi varaydım, umarımdan yaxşı o barı olaydı,--deyər.

Onun kiminin, xanım, bəbəkləri bitməsin, ocağına buncılayın övrət gəlməsin.

Gəldin ol kim, Dolduran toydur, təcəncə yerindən uru durdu. əlin-yüzün yumadan obanın ol ucundan bu ucuna, bu ucundan ol ucuna çarpışdırdı. Qu qıldı

(söz gəzdirdi- Ə. Ə.), dək dinlədi(qapı pusdu-Ə.) (sabahdanca öyləyə dəkincə) gəzdi, öylədən sonra evinə gəldi. Gördü kim. Oğu köpək yeyə-dada evini bir-birinə qatmış, toyuq komasına, sığır damına (qaramal damına-H.A.) dönmüş.

Qonşuların çağırar kim: qız, Züleyxa! Zübeydə! Ürüdə! Can qız, can paşa! Ayna Mələk! Qutlu Mələk! Ölməyə, itməyə getmişdim? Yatacaq yerim yenə bu xarab olasıydı. Nolaydı, mənim evimə bir ləhzə baxaydınız. Qonşu haqqı—Tanrı haqqı.—deyib söylər.

Bunun kiminin, Xanım, bəbəkləri bitməsin. Ocağına bunun kimi övrət gəlməsin!

Gəldin ol kim, necə söylərsən, bayağıdır:

Evinə yazıdan-yabandan bir udlu(abırlı, utancaq—H.A.) qonaq gəlsə, ər adam evdə olsa, (əri ona desə ki, dur, (övrət) ətmək gətir, yeyəyin, bu da yesin. Bişmiş ətməyin bəqası olmaz, yemək gərəkdir.

Övrət aydır:

--Neyləyim? Bu yıxılacaq evdə un yox, ələk yox.

Dəvə dəyirmədən gəlmədi,-deyər.

Nə gələrsə, mənim süfrəmə gəlsin.—deyü əlin... urar.

Yönün anar və sağrısın ərinə döndərər.

Bin söylərsən, birisini qoymaz,

ərin sözün qulağına qoymaz.

O Nuh peyğəmbərin eşşəgi əslidir.

Ondan, dəxi sizi, xanım, Allah saxlasın!

Ocağınıza buncılayın övrət gəlməsin!”

Göründüyü kimi, ozanın təhlil və təsnifləri, təsvirləri mənalı və ifadəlidir. Hər bir xarakterin öz tərzidir. Bu tərz bilavasitə ozan Dədə Qorqudun yaradıcılıq dühasının tipik məzmunundan irəli gəlir. Sözdən sərraf kimi istifadə etmək üslubu Dədə Qorqud nitqinin və bədii yaradıcılığının əsas əlamətidir.

Beləliklə, ozanlar ozanı, müdriklər müdriki Dədə Qorqudun dastan dili bədii-poetik ifadə psixologizminə nadir ədəbi mənbə-nümunədir.

NƏTİCƏ

Ümumiyyətlə, “Kitabi-Dədə Qorqud” dastanları bütün ifadə tərkiblərinə, dil strukturlarına görə fantastik dərəcədə təsirli və oynaq üsluba malikdir. Dastanın söz söyləmi, nitq ifadəsi də bu strukturda canlı, cəlbedicidir. Dil, bədii-poetik ifadə sintaksisi ilə səs və söz bağlantıları dastanda türk poeziyasının ən tipik əlamətləri kimi diqqəti cəlb edir.

Dədə Qorqud dilinin bədii-poetik xüsusiyyətlərindən bəhs edir. Ə.Əzimli təhlil üçün Dastanın Müqəddiməsinə müraciət edib. Onun nəzərinə görə, “Kitabi-Dədə Qorqud”un Müqəddiməsi ustadnamə, müdrik ifadə formasıdır. Dədə Qorqudun bədii ifadə dilini səciyyələndirən tədqiqatçı bədii mətnin lirik ifadə üslubu ilə təhkiyə üslubu arasında üzvi bağlılıq olduğunu göstərir. Dil faktları poetik ifadə nəzərində təhlil mərkəzinə çəkilir.

Dədə Qorqudun dilinə xas olan ifadə, bədii təsvir və tərənnüm əlamətlərini təhlil edərkən xalq dilinə xas olan ifadə gözəlliyini dastan linqvistikası üçün ən xarakterik cəhətlərdir.

“Kitabi-Dədə Qorqud” dastanı dil faktlarına görə zəngindir. Ə.Əzimli də bu zənginlikdən çıxış edərək dastanın bədii strukturunu təhlil obyektinə götürüb. Dastan dilinin ən mükəmməl ifadə tərzləri onun poetikasının əsasında dayanır.

Sözlərin məna silsiləsində bədii ifadə psixologizmini təhlil mərkəzinə çəkməklə tədqiqatçı türk xalq təsəvvürünün ən dolğun məzmun və forma cəhətlərini açıqlayır.

Dədə Qorqudun tərənnüm və təhkiyə poetikası ən ciddi psixoloji yük daşıyır. Tədqiqatçı təhlil obyektləri sırasında səs və söz izləmi, məna tiplərinin doğruluşunda onların rolu məsələsini təhlil edir.

Ozan Dədə Qorqudun dili- xalq-Millətin danışığı,söyləm,yaradıcılıq dilidir. Bədii ifadə linqvistikasına görə dünyada ən zəngin ifadə dilidir.

Bədii ifadə poetikasında dastan psixologizmi var. “Kitabi-Dədə Qorqud” dastanında bədii müqəddimə və onun struktur ifadə rəngləri xalq dilinin və düşüncəsinin, müdrikliyinin poetizmini yansıdır.

Burada poetik-psixoloji inikas-ifadələr dastana xas olan bədii müqəddimə özəlliklərinin inikasıdır. Sös və söz izləminin Dədə Qorqud dilindəki struktur əlamətləri də bu linqvistik poetikada ön xəttə çıxır.

Dastanın poetika sistemində, bədii ifadə sintezində Söz başlıca obrazdır. Bu mənada, “Kitabi-Dədə Qorqud” dastanlarında poetik rənglər Sözün ifadə gücündən, təhkiyə dinamizmindən, obrazların daxili aləminin ifadə psixologizmindən asılıdır. Dastanda bədii sözün poetik linqvistikası dil faktlarının zənginliyinə, ifadə strukturuna görə tamam fərqli özəlliklərə malikdir; dünya ədəbiyyatında bugünədək bu cür ifadə tərzinə, forma, məzmun tipinə görə ikinci bir əsər olmayıb. Dastanın dili mükəmməl ifadə xüsusiyyətlərinə görə fərqlənir. Bədii sözün poetik siması canlı və dramatikdir.

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İFADƏ VƏ İNŞA YAZILARINDA ORFOQRAFİK ÇƏTİNLİKLƏR

Gültəkin Atəş qızı Abdullayeva

pedaqogika üzrə fəlsəfə doktoru, dosent

Azərbaycan Dövlət Pedaqoji Universiteti, Filologiya fakültəsi

ORCID: 0009-0009-5332-2146

Pion2691@rambler.ru

Xülasə

Rabitəli nitqin inkişafının mühüm vasitəsi olan ifadə və inşə yazılar orfoqrafiya təliminə də xidmət edə bilər. Bunun üçün yazının həmin növlərinin qarşısında müəyyən orfoqrafik tapşırıq qoymaq lazımdır. İmlaya nisbətən ifadə və inşanı orfoqrafik səhvə yol vermədən yazmaq daha çətindir. Xüsusi orfoqrafik çalışmalarda sözləri, cümlələri, mətni savadlı yazmağı bacaran şagird ifadə və inşada səhvə yol verirsə, qrammatik-orfoqrafik qaydaları, yazılışı çətin sözlərin səs-hərf tərkibini yaxşı mənimsəmədiyini biruzə verir. İmlada ən çətin orfoqramları yazma bilən şagirdin ifadə və inşada səhvə yol verməsinə səbəb odur ki, birinci halda şagirdlərin diqqəti, əsasən, orfoqrafik qaydanın tətbiqinə, ifadə və inşada isə diqqət üç cəhətə (məzmunun düzgün verilməsinə, üslub xətlərinin buraxılmamasına və orfoqrafik çətinliklərə) yönəldilir. Bu isə asan məsələ deyil. Bunu hiss edən bəzi müəllimlər orfoqrafik səhvlərin xəbərdarlığı imkanlı olmadığından, yazıda çoxlu səhvə yol veriləcəyindən ehtiyat edərək ifadə və inşə yazdırmaqdan çəkinirlər.

Buna görə də ifadə və inşə yazılarında orfoqrafik bacarıqların formalaşdırılması məqsədyönlü və sistemli şəkildə aparılmalıdır. Müəllim yazıdan əvvəl şagirdlərin diqqətini mümkün orfoqrafik çətinliklərə yönəltməli, yazı prosesində isə onların müstəqil düşünməsinə şərait yaratmalıdır. Yazıdan sonra aparılan təhlil və səhvlər üzərində iş şagirdlərin qaydaları daha yaxşı mənimsəməsinə kömək edir. Xüsusilə yazılışı çətin sözlərin müntəzəm təkrarı və kontekstdə işlədilməsi orfoqrafik savadlılığı artırır. Bu baxımdan ifadə və inşə yazıları yalnız nitqin inkişafına deyil, həm də orfoqrafiya təliminin möhkəmlənməsinə xidmət edir. Nəticədə şagirdlər yazılı nitqdə daha düzgün və səlis ifadə bacarığı qazanırlar.

Açar sözlər: ifadə, inşə, orfoqrafik çətinliklər

ORTHOGRAPHIC DIFFICULTIES IN ESSAY AND COMPOSITION WRITING

Abstract

Essay and composition writing, as essential tools for the development of coherent written discourse, also play a significant role in orthography instruction. In order to enhance orthographic competence, specific orthographic tasks should be incorporated into these types of writing activities. Compared with dictation, producing essays and compositions without orthographic errors is considerably more challenging. When students who demonstrate accuracy in spelling during focused orthographic exercises commit errors in essays and compositions, this indicates an inadequate mastery of grammatical and orthographic rules, as well as insufficient awareness of the phoneme–grapheme structure of orthographically complex words.

One of the main reasons for this discrepancy is that during dictation tasks students primarily concentrate on the application of orthographic rules, whereas essay and composition writing requires simultaneous attention to multiple components, including accurate content representation, stylistic appropriateness, and orthographic accuracy. This cognitive load poses considerable difficulty for learners. Acknowledging this challenge, some teachers refrain from assigning essay and composition tasks due to concerns about the high frequency of orthographic errors and the limited possibility of immediate error prevention.

Therefore, the systematic and purposeful development of orthographic skills within essay and composition writing is essential. Teachers should draw students' attention to potential orthographic difficulties prior to writing and encourage independent thinking during the writing process. Post-writing analysis and focused work on errors contribute significantly to the internalization of orthographic rules. In particular, the regular repetition and contextualized use of words with complex spelling enhance orthographic competence. From this perspective, essay and composition writing serves not only the development of written discourse but also the consolidation of orthographic instruction. Consequently, students develop the ability to express their ideas more accurately and fluently in written form.

Keywords: essay, composition, orthographic difficulties

ÇOCUKLARDA DAYANIKLILIK VE DUYGUSAL ÖZ DÜZENLEMENİN OLUŞTURULMASI

Natevan Paşayeva

Azərbaycan Dövlət Pedaqoji Universiteti

ORCID: 0009-0001-4269-7681

ÖZET

Modern eğitim ve terbiye yaklaşımlarında çocuklarda dayanıklılığın (rezilyansın) ve duygusal öz düzenlemenin geliştirilmesi, kişiliğin bütüncül gelişimini sağlayan temel öncelik alanlarından biri olarak kabul edilmektedir. Hızla değişen sosyal çevre, artan akademik beklentiler ve duygusal yüklenmeler çocuklardan yalnızca bilişsel beceriler değil, aynı zamanda psikolojik dayanıklılık ve duygusal denge de talep etmektedir. Bu bağlamda dayanıklılık, çocuğun stresli durumlara, zorluklara ve başarısızlıklara karşı direnç göstermesi, bu deneyimlerden ders çıkararak yeniden uyum sağlaması ve gelişimini sürdürmesi becerisi olarak tanımlanmaktadır. Duygusal öz düzenleme ise bireyin kendi duygusal tepkilerini fark etmesi, bunları kontrol edebilmesi ve farklı sosyal durumlarda uygun biçimde ifade edebilmesi sürecini kapsamaktadır.

Tezde, dayanıklılık ve duygusal öz düzenleme kavramlarının psikolojik ve pedagojik literatürde yer alan kuramsal temelleri sistematik biçimde analiz edilmekte; bu becerilerin çocukların psikolojik sağlığına, akademik başarılarına, özgüvenlerine ve sosyal ilişkilerinin niteliğine olan etkileri incelenmektedir. Araştırmalar, bu becerilerin erken yaşlardan itibaren geliştirilmesinin çocukların stresle başa çıkma kapasitelerini artırdığını, davranış problemlerini azalttığını ve uzun vadeli sosyal uyumu desteklediğini ortaya koymaktadır.

Aynı zamanda tezde, aile ortamının, ebeveynlerin duygusal açıdan destekleyici tutumlarının, öğretmenlerin pedagojik yaklaşımlarının ve okullarda uygulanan sosyal-duygusal öğrenme programlarının çocuklarda dayanıklılık ve duygusal öz düzenlemenin gelişimindeki rolü bilimsel kaynaklara dayalı olarak ele alınmaktadır. Sonuç olarak, tezin temel amacı çocuklarda duygusal dayanıklılığın güçlendirilmesi, sağlıklı kişilik gelişiminin desteklenmesi ve bu doğrultuda etkili pedagojik ve psikolojik yaklaşımların belirlenmesidir.

Anahtar kelimeler: çocuklarda dayanıklılık, duygusal öz düzenleme, psikolojik sağlamlık, sosyal-duygusal öğrenme, ebeveyn tutumları, aile ortamı, pedagojik yaklaşımlar, akademik başarı.

BUILDING RESILIENCE AND EMOTIONAL SELF-REGULATION IN CHILDREN

Natavan Pashayeva

Azerbaijan State Pedagogical University

ORCID: 0009-0001-4269-7681

ABSTRACT

In contemporary educational and upbringing approaches, the development of resilience and emotional self-regulation in children is regarded as one of the key priority areas ensuring holistic personality development. Rapidly changing social environments, increasing academic demands, and heightened emotional pressures require children not only to possess cognitive skills but also to demonstrate psychological resilience and emotional balance. In this context, resilience is characterized as a child's ability to withstand stressful situations, challenges, and failures, to learn from these experiences, and to adapt and continue personal growth. Emotional self-regulation, on the other hand, encompasses an individual's capacity to recognize their emotional responses, manage them effectively, and express them appropriately across diverse social situations.

This thesis systematically examines the theoretical foundations of resilience and emotional self-regulation as presented in the psychological and pedagogical literature and explores the impact of these competencies on children's psychological well-being, academic achievement, self-confidence, and the quality of their social relationships. Research findings indicate that fostering these skills from an early age enhances children's ability to cope with stress, reduces behavioral problems, and supports long-term social adjustment.

Furthermore, the thesis highlights the role of the family environment, emotionally supportive parental behaviors, teachers' pedagogical approaches, and school-based social-emotional learning programs in the development of resilience and emotional self-regulation in children, drawing on scientific sources. Ultimately, the primary aim of the thesis is to strengthen children's emotional resilience, promote healthy personality development, and identify effective pedagogical and psychological approaches in this regard.

Keywords: children's resilience, emotional self-regulation, psychological well-being, social-emotional learning, parental attitudes, family environment, pedagogical approaches, academic achievement.

FROM GREEK WISDOM TO ARABIC THOUGHT: TRANSLATION METHODS AT BAYT AL- ḤIKMA

Omar El Ghazi¹

¹Professor at the National Higher School of Art and Design, member of Language and
Linguistics Studies Laboratory, Faculty of Arts and Humanities Ain Chock, Hassan II
University of Casablanca, Morocco

Abstract

The Abbasid translation movement, centered at Bayt al-Ḥikma in Baghdad, represents one of the earliest systematic attempts to theorize translation practice. This paper examines the ²translation methods employed by Bayt al-Ḥikma translators, with particular emphasis on the methodological dichotomy articulated by Ṣalāḥ al-Dīn al-Ṣafadī between word-for-word and sense-for-sense translation. Drawing on classical Arabic sources and their modern scholarly interpretations, the study demonstrates that Abbasid translators were not merely transmitters of Greek, Persian, and Indian knowledge, but reflective practitioners who developed principled approaches to linguistic and conceptual transfer. The paper argues that the preference for sense-oriented translation, exemplified by figures such as Ḥunayn ibn Ishāq, anticipates central debates in modern translation studies concerning equivalence, fidelity, and translator competence. By situating Arabic translation theorization within a broader historical continuum, the study contributes to a more inclusive understanding of the intellectual foundations of translation studies beyond its traditionally Eurocentric narratives.

Keywords: Arabic translation theory, Abbasid translation movement, Bayt Al-Ḥikma, history of translation, literal translation, sense-for-sense translation, word-for-word translation

1. Introduction

The Abbasid era (750–1258 CE) marks one of the most intellectually dynamic periods in the history of human civilization, largely due to an unprecedented translation movement that transformed Arabic into a principal language of science, philosophy, medicine, astronomy, and mathematics. This large-scale endeavor was not incidental but the result of deliberate political, cultural, and intellectual patronage exercised by Abbasid caliphs, particularly during the reigns of al-Manṣūr, Hārūn al-Rashīd, and al-Ma'mūn. Through systematic translation activity, knowledge originating in Greek, Persian, Indian, and Syriac traditions was transmitted, preserved, and rearticulated within an Arabic intellectual framework.

At the heart of this movement stood Bayt al-Ḥikma (the House of Wisdom) in Baghdad. Far more than a library, Bayt al-Ḥikma functioned as a translation workshop, research institution, and scholarly meeting place. It brought together translators, philosophers, physicians, mathematicians, and astronomers from diverse linguistic and religious backgrounds, including Muslims, Christians, and Jews. This multicultural environment fostered rigorous intellectual exchange and facilitated the development of sophisticated translation practices.

Crucially, Abbasid translation was not conceived as a mechanical or purely linguistic operation. Translators engaged in interpretive processes that required deep understanding of both source texts and target audiences. As demonstrated by classical Arabic sources and modern scholarship, Abbasid translators developed principled approaches to translation that reveal an early awareness of theoretical concerns central to contemporary translation studies, such as equivalence, fidelity, intelligibility, and the relationship between language and thought (El Ghazi & Bnini, 2020). These concerns were articulated explicitly in medieval Arabic discussions of translation and implicitly reflected in translation practice itself. The Abbasid translation movement thus constitutes not only a historical episode of knowledge transfer but also a foundational moment in the theorization of translation as an intellectual discipline.

2. Translation Methods at Bayt al-Ḥikma

The existence of explicit methodological reflection distinguishes the Abbasid translation movement from earlier translation efforts in both the Islamic and pre-Islamic worlds. Classical Arabic scholarship provides detailed accounts of how translation was conceptualized, practiced, and evaluated. Among the most significant contributions in this regard is the methodological distinction articulated by Ṣalāḥ al-Dīn al-Ṣafadī (d. 1363 CE), preserved in al-ʿĀmilī's *al-Kashkūl*. According to al-Ṣafadī, translators working in the Abbasid period followed two principal methods: word-for-word translation and sense-for-sense translation (Munday, 2001, Rosenthal, 2005; Baker & Saldanha, 2009;).

This distinction demonstrates a high level of theoretical consciousness. Rather than treating translation as a uniform practice, Abbasid scholars recognized methodological plurality and evaluated translation quality based on linguistic, semantic, and rhetorical criteria. Al-Şafadī does not merely describe these methods; he subjects them to critical scrutiny, assessing their strengths and weaknesses in light of the communicative goals of translation. His analysis suggests that translation was understood as a purposeful act shaped by linguistic constraints, textual genres, and disciplinary requirements. Such reflections anticipate later theoretical discussions in translation studies and testify to the intellectual maturity of Abbasid translation culture. (El Ghazi & Bnini, 2020)

2.1 Word-for-Word Translation

The word-for-word method represents one of the earliest approaches adopted by Abbasid translators, particularly during the initial stages of the translation movement. This method is associated with translators such as Youḥannā ibn al-Baṭrīq and Ibn Nāʿima al-Ḥimşī, who sought to preserve formal correspondence between source and target texts by translating each Greek lexical item individually into Arabic. The underlying assumption of this approach was that fidelity could be achieved through close adherence to the linguistic form of the source text.

However, al-Şafadī offers a detailed critique of this method, identifying several inherent limitations. First, he observes that exact lexical equivalence between Greek and Arabic is often unattainable. The two languages differ significantly in morphology, syntax, and semantic organization, making one-to-one correspondence impossible in many cases. As a result, translators frequently resorted to borrowing Greek terms directly into Arabic, producing hybrid texts that were linguistically awkward and difficult for Arabic readers to comprehend. Second, the word-for-word method fails to account for syntactic and rhetorical differences between languages. Greek and Arabic employ distinct sentence structures and stylistic conventions, particularly in the use of metaphor, abstraction, and philosophical terminology. Translating such features mechanically often leads to distorted meanings and obscured arguments. Al-Şafadī emphasizes that metaphorical expressions, which are pervasive in philosophical and scientific discourse, cannot be adequately rendered through literal substitution alone.

Consequently, translations produced using this method were often criticized for their opacity, rigidity, and lack of fluency. Many such translations required later revision or correction by more experienced translators. While the word-for-word method played a role in the early phases of the translation movement, its limitations became

increasingly evident as Arabic emerged as a fully developed language of science and philosophy (as cited in El Ghazi & Bnini, 2020).

2.2 Sense-for-Sense Translation

In response to the shortcomings of literal translation, Abbasid translators gradually developed and refined a sense-for-sense approach, which came to be regarded as methodologically superior. This approach is exemplified by figures such as Ḥunayn ibn Ishāq, al-Jawharī, and their collaborators, who emphasized semantic comprehension over formal correspondence. Rather than translating words in isolation, translators adopting this method sought to understand the full meaning of a sentence or passage within its intellectual and disciplinary context.

Sense-for-sense translation involved a two-stage process. First, the translator engaged in careful reading and interpretation of the source text, ensuring a thorough grasp of its conceptual content. Second, the translator reformulated that content in clear, idiomatic Arabic, even if this required departing from the syntactic structure or lexical choices of the original. Fidelity, in this framework, was defined not in terms of formal similarity but in terms of semantic accuracy and communicative effectiveness.

This method produced translations that were more accessible, coherent, and intellectually productive. It also presupposed a high degree of linguistic competence in both source and target languages, as well as specialized knowledge of the subject matter being translated. As El Ghazi and Bnini (2020) note, this emphasis on specialization explains why many of Ḥunayn ibn Ishāq's translations—particularly in medicine, philosophy, and logic—were regarded as authoritative and required little or no subsequent revision.

Sense-for-sense translation thus reflects a mature conception of translation as an interpretive act grounded in expertise, responsibility, and scholarly judgment. It also underscores the translator's active role in mediating knowledge across linguistic and cultural boundaries.

3. Discussion

The Abbasid distinction between word-for-word and sense-for-sense translation anticipates major theoretical debates in the history of translation. Similar dichotomies can be traced from Cicero's opposition between *verbum e verbo* and *sensum de sensu* to modern discussions of equivalence, functionalism, and communicative translation. What distinguishes the Abbasid contribution, however, is the extent to which these methodological reflections were embedded in sustained translation practice across multiple disciplines. (Munday, 2016)

More importantly, the Abbasid model foregrounds the translator as an intellectual agent rather than a passive intermediary. Translators at Bayt al-Ḥikma were scholars in their own right, often trained in medicine,

philosophy, mathematics, or astronomy. Translation was inseparable from interpretation, commentary, and adaptation. Through sense-oriented translation, foreign knowledge was not merely transferred but integrated into Arabic intellectual culture, reshaped in accordance with its conceptual frameworks and epistemological assumptions. (Bsoul, 2019)

This process had far-reaching consequences. By rendering Greek, Persian, and Indian sciences intelligible in Arabic, Abbasid translators enabled original contributions that went beyond mere preservation. Translation thus became a catalyst for innovation, critical inquiry, and intellectual synthesis. Recognizing this role challenges reductive narratives that portray medieval translation as derivative and underscores its creative and transformative dimensions.

4. Conclusion

The translation methods developed at Bayt al-Ḥikma reflect a sophisticated and self-aware understanding of linguistic mediation. Abbasid translators articulated and evaluated competing translation strategies, emphasizing the primacy of meaning, the importance of specialization, and the necessity of linguistic naturalness. These principles reveal that translation theory was not an exclusively modern or Western concern but formed an integral part of medieval Arabic scholarship.

By situating translation within a broader intellectual and disciplinary context, Abbasid scholars laid conceptual foundations that continue to inform contemporary translation studies. Their work invites a reassessment of the global history of translation theory and highlights the need to incorporate non-Western traditions into its historiography. Bayt al-Ḥikma thus stands as both a historical institution and a symbol of translation as a rigorous, reflective, and culturally embedded intellectual practice.

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ARTIFICIAL INTELLIGENCE IN THE FORMATION OF THE SOCIO-PSYCHOLOGICAL CLIMATE

Askar Aimukatov Candidate of Pedagogical Sciences, Academician of the International Academy of Informatization. Aktobe Regional University, Kazakhstan.

nastavnik1961@mail.ru

Key words: Artificial intelligence, deviant behavior, psychology

Abstract

This paper explores the application of artificial intelligence in promoting a socio-psychological climate in educational institutions. It is widely recognized that the socio-psychological climate within educational institutions is a key factor shaping adolescents' behavioral patterns. A favorable atmosphere reduces stress and conflict, fosters trust and cooperation, and enhances intrinsic motivation and readiness for positive behavior.

AI technologies provide innovative tools for monitoring the socio-psychological climate through anonymous surveys, communication analysis, and assessment of emotional states among participants in the educational process. These systems enable real-time identification of interpersonal trends, allowing educators and psychologists to respond promptly to emerging challenges. The integration of AI into psychological and pedagogical practice reduces professional workload by automating routine tasks related to data administration and analysis, thereby strengthening the prevention of deviant behavior among adolescents. At the same time, AI-based systems support risk-oriented intervention programs and increase the effectiveness of preventive measures. Continuous monitoring combined with a supportive socio-psychological climate increases adolescents' responsiveness to preventive initiatives, strengthens positive attitudes, and reduces the likelihood of destructive stress-related reactions. This approach promotes the involvement of all stakeholders in preventive efforts and contributes to the development of a positive educational environment grounded in objective data. Furthermore, a supportive and trusting climate enhances adolescents' receptiveness to prevention programs and reduces the risk of destructive responses to stressful situations.

In conclusion, the integration of AI into psychological and pedagogical prevention enables early identification of risk factors and optimization of preventive practices. Improvements in the socio-psychological climate enhance the effectiveness of prevention by fostering a stable environment, while ensuring consideration of ethical and social aspects.

TÜRK ÇOCUK ŞİİRİNİN GELİŞİMİNİN YENİ AŞAMASI (TEVFİK FİKRET'İN ŞİİRLERİNDEN DAYALI)

Prof. Dr. Elman QULİYEV

Azerbaycan Devlet Pedagoji Üniversitesi

Türkoloji merkezin Türk edebiyatı bölümünün başkanı

elman.guliyev1958@gmail.com

Orcid: 0000-0001-5413-9479

Özet

Tevfik Fikret Türk edebiyatının en sevilen şairlerindendir. Tevfik Fikret sadece bir eğitimci olarak değil, aynı zamanda bir yurttaş şairi olarak çocuklara ve gençlere seslenerek onların "vatan görevi"nin ne olduğunu anlatmış ve esasen gençler arasında vatanseverlik duygularını güçlendirme etkisine sahip şiirler yazmıştır. Şairin 1911'de "Halukun Defteri" ve 1914'te "Şermin" şiir koleksiyonunda toplanan şiirleri, gençlere doğrudan öğütler, onlarda yurttaşlık ruhunun oluşmasına hizmet eder vb. açısından anlamlıdır.

Tevfik Fikret'in şiirlerinde çocuk şiirlerinin ayrı bir yeri vardır. 1914. yılında yayınlanan "Şermin" şiir koleksiyonu, hece ile yazılmış çocuk şiirlerinden oluşmaktadır. Bu şiirlerde ağırlıklı olarak çocuk ruhu ve çocuk psikolojisinin yansımaları başrolde.

"Şermin" şiir koleksiyonu, Tevfik Fikret'in bir tür pedagojik toplantılarının yansıması ve yüceltilmesi açısından da karakteristiktir. Burada derse ilgi, bugünün ve yarının derslerine karşı tutum ve bunların öğrenme metodolojisi ve b. sorunlar pedagojik ilkeler açısından çözülmüştür. Çalışkanlık ve çalışma tutumu konuları Tevfik Fikret'in çocuk şiirlerinin ana temasıdır. "Atölye", "Marangoz", "Kırık At", "Yusufçuk ve Karınca" ve diğerlerinde rol aldı. Şiirlerinde çocukları çalışmayı sevmeye çağırır, onlara derin bir çalışma sevgisi aşılar. Bu tür şairlerin şiirlerinde kişinin şöhreti çok çalışarak elde ettiği gösterilir.

Anahtar kelimeler: Tevfik Fikret , çocuk edebiyatı, şiir, eğitim,Vatan

NEW STAGE OF DEVELOPMENT OF TURKISH CHILDREN'S POETRY (BASED ON THE POEMS OF TOFIK FIKRET)

Summary

Tevfik Fikret is one of the most popular poets of Turkish literature. Tevfik Fikret addressed children and young people not only as an educator but also as a citizen poet, explaining what their "patriotic duty" was and essentially wrote poems that had the effect of strengthening the feelings of patriotism among young people. The poet's poems, collected in the poetry collection "Halukun Notebook" in 1911 and "Shermin" in 1914, directly advise young people, serve to form the spirit of citizenship in them, etc. is meaningful in terms of. Children's poems have a special place in Tevfik Fikret's poems. The poetry collection "Shermin", published in 1914, consists of children's poems written in syllabary. In these poems, reflections of child spirit and child psychology play a leading role.

The poetry collection "Shermin" is also characteristic in terms of reflection and exaltation of a kind of pedagogical meetings of Tevfik Fikret. Here interest in the course, attitude towards today's and tomorrow's lessons and their learning methodology, and b. The problems are solved in terms of pedagogical principles. The subjects of diligence and work attitude are the main themes of Tevfik Fikret's children's poems. He starred in "Workshop", "Carpenter", "Broken Horse", "Dragonfly and the Ant" and others. In his poems, he calls children to love working and instills in them a deep love of work. In the poems of such poets, it is shown that a person achieves fame by working hard.

Key words: Tevfik Fikret, children's literature, poetry, education, Homeland

GİRİŞ

Tevfik Fikret, sanatın çeşitli dallarında eserler vermiş, başarılı ve aynı zamanda çelişkili bir yaratıcı yol izlemiş büyük bir türk şairidir. Resim ve müzikle de uğraşsa da sanat dünyasının önde gelen şairlerinden biri olarak tanınır. "Rubabi-şikeste", "Haluk'un defteri", "Rubab'ın cevabı", "Şermin", "Doksan beşe doğru" şiir kitapları onun zengin bir yaratıcı mirasa sahip olduğunu gösteriyor.

Tevfik Fikret'in yaratıcılığı hem konu hem de biçim açısından yenidir. Tevfik Fikret'in karmaşık sosyo-politik süreç ve girdaplar çağında yaşadığı bir sır değildir. Doğal olarak meydana gelen olaylar onun yaratıcılığını doğrudan etkilemiş ve sanatına çeşitli döngüler şeklinde yansımıştır. Tevfik Fikret'in yaratıcılığının ilk dönemi 1888-1896 yıllarını kapsar. Bu yıllarda yazdığı şiirlerinin çoğunda divan edebiyatı ile Avrupa yanlısı edebiyat arasındaki paralellik göze çarpar. Tevfik Fikret'in yaratıcılığının ilk aşamasında narsisizm bağımlılığı ve kendini beğenmiş ifadelerin özel bir yeri vardır. Yaratıcılığının "Zenginlik" dönemi 1896-1901 yıllarını kapsar. Bu dönem, fikir ve inanç mücadelesi dönemi ile karakterizedir. Daha ziyade eski edebiyatla mücadele, tiranlığın yıkılması, II. 1908 Türkiye devrimi, Tevfik Fikret'in yaratıcılığına geniş alanlar açtı. Devrimci niteliği ve etkinliği ile karakterize edilen bu aşamada, dönemin doğrudan ve keskin suçlamaları özel bir yer tutar, kamusal yaşamın dayanılmaz nedenleri ortaya çıkarılır ve durumdan çıkış yolları düşünülür. Şairin eserlerinde vatan, hürriyet, savaş vb. konuların yer alması bu nedenledir. Tevfik Fikret'in eserlerinin derinlemesine analizi, ona vatanın şairi demek için tam sebep veriyor.

Bahsettiğimiz gibi Tevfik Fikret'in hem konu hem de biçim açısından yeni olan yaratıcılığı, "Tanzimat", "Servati-fünun", "Fecri-ati" ve diğer edebi kuruluşlar. Tevfik Fikret'in eserinde şatafatlı ifadelerle bağımlılık, vatan, hürriyet, savaş vb. fikir ve kanaat mücadelesiyle karakterize edilir. Tevfik Fikret, ülkedeki sosyal ve siyasi karışıklıkların ve çelişkilerin, dış baskı ve müdahalelerin, ülkenin ve milletin istikbalini söz konusu ettiği, içinde bulunulan siyasi krizin Osmanlı devletinin gücünü günden güne azalttığı bir dönemde yaşamıştır. Kuşkusuz ülkenin böylesine gergin ve zor bir dönemi, aydınları özel bir şekilde düşündürdü ve onları çözüm aramaya zorladı. Milletin güzel geleceğini bazen "kanlı", bazen de "kansız" mücadelede gören Tevfik Fikret, belli bir anlamda daha "tek çözüm" olduğuna inanıyordu: "Milletin kültürel seviyesini yükseltmek, zeki, yaratıcı yetiştirmek ve yetenekli gençler yetiştirmek." Gençleri ülkenin geleceği olarak gören Tevfik Fikret, her şeyden önce yeni tip okullar açmak, bu okullarda çocukları milli ve vatansever bir ruhla yetiştirmek, "sadece bilim insanı değil, aynı zamanda birer bilim adamı" olarak yetişmelerini istiyordu". Görev yaptığı Galatasaray, İstanbul ve Robert okullarında bu amaçla bizzat özel girişimlerde bulunmuş, ülke gençliğinin geleceğinin umudu uğruna eğitimin kalitesinin yükseltilmesi alanında ciddi çalışmalar yapmıştır.

YÖNTEM

Tevfik Fikret sadece bir eğitimci olarak değil, aynı zamanda bir yurttaş şairi olarak çocuklara ve gençlere seslenerek onların "vatan görevi"nin ne olduğunu anlatmış ve esasen gençler arasında vatanseverlik duygularını güçlendirme etkisine sahip şiirler yazmıştır. Şairin 1911'de "Halukun Defteri" ve 1914'te "Şermin" şiir koleksiyonunda toplanan şiirleri, gençlere doğrudan öğütler, onlarda yurttaşlık ruhunun oluşmasına hizmet eder vb. açısından anlamlıdır.

Tevfik Fikret'in şiirlerinde çocuk şiirlerinin ayrı bir yeri vardır. 1914. yılında yayınlanan "Şermin" şiir koleksiyonu, hece ile yazılmış çocuk şiirlerinden oluşmaktadır. Bu şiirlerde ağırlıklı olarak çocuk ruhu ve çocuk psikolojisinin yansımaları başrolde.

"Şermin" şiir koleksiyonu, Tevfik Fikret'in bir tür pedagojik toplantılarının yansıması ve yüceltilmesi açısından da karakteristiktir. Burada derse ilgi, bugünün ve yarının derslerine karşı tutum ve bunların öğrenme metodolojisi ve b. sorunlar pedagojik ilkeler açısından çözülmüştür. Çalışkanlık ve çalışma tutumu konuları Tevfik Fikret'in çocuk şiirlerinin ana temasıdır. "Atölye", "Marangoz", "Kırık At", "Yusufçuk ve Karınca" ve diğerlerinde rol aldı. Şiirlerinde çocukları çalışmayı sevmeye çağırır, onlara derin bir çalışma sevgisi aşılar. Bu tür şairlerin şiirlerinde kişinin şöhreti çok çalışarak elde ettiği gösterilir. Hayatta çok çalışmanın yenemeyeceği hiçbir şey yoktur:

*Çalışqan hər işi görür,
İnsan üçün sənət çoxdur,
Edilməyəcək iş yoxdur.*

Tevfik Fikret'in anaokulu çağındaki çocuklar için yazdığı şiirleri vardır. Adından da anlaşılacağı gibi, "İthaf" şiiri aslında anaokulu çağındaki çocuklara adanmıştır. Bu grup şiirlerde fikir çocuk psikolojisi ruhuyla telkin edilse ve "yuva" tabiri bir bahçeyi ifade etse de, meselelere yaklaşımda bir anlamda felsefi mahiyet ön plana çıkmaktadır. "Yuva", bir tür vatan, ana kucağı olarak anlaşılır. Yuvanın bir aydınlanma ve erdem yuvası (mekanı) olarak sunulması her çocukta vatan sevgisini artırmakta ve millî tarihle ilgili düşünceleri genişletmektedir:

*Yuva şevkat yuvasıdır,
Ninelerdir onu yapan...
Haydi yuvana, yavru çox
O marifet yuvasıdır.
Ve fazilet yuvasıdır.*

*Orda firkin uyanacak
Orda kanat açacaktır,
Yükseklere uçacaksın!*

BULGULAR

"Hasbi-hal" şiirinde şair ilginç bir konuya değinir. Çocuklara hitaben yazılan bu şiir, iki farklı kuşağın temsilcilerinin okul hayatını karşılaştırır. Şair, günümüz çocuklarının okul hayatını, okul koşullarını, okuma düzeylerini çağıyla karşılaştırdığında farklılıklara daha fazla yer ayırır: Güzel ders kitabı, temiz okul, sıra ve sandalye vb. Ama Tevfik Fikret'in asıl amacı geçmişle günümüz okulları arasındaki farkı göstermek değil, iyi okumak, öğrenmek, bilimle amaca ulaşmak vs. teşvik etmektir:

*Okuyunuz, okuyanlar
Çok şey bilir, çok şey yapar
Muradına onlar erer
Cennete de onlar girer
Onlar cidden mesut olur...*

Şaire göre bilimleri öğrenmek çocukların mutlu gelecekleri için en önemli temeldir. Bu sebebdan Tevfik Fikret her bir öğrenciğe iyi okumak talebi ile seslenir:

*İnsan öyrəndiyi şeyi,
Daha iyi öyrənməli.*

Tevfik Fikret, doğru eğitim ve güçlü vatanseverlik duygusuyla her çocuğun gelecekte değerli birer vatandaş olarak yetişmesini görmektedir. Bu nedenle şairin çocuk şiirlerinde vatanseverlik, çalışkanlık, kahramanlık, estetik zevk vb. konulara daha fazla önem verilmektedir. Bu şiirler hem sosyal-politik, hem ahlaki-didaktik hem de pedagojik açıdan dikkat çekebilir. Tevfik Fikret, "Utanç" adlı şiir koleksiyonunda, gerçek yaşam gerçeklerini çocukların dünyasının benzersiz yönlerine dayandırmış ve gerçek yaşamın arka planına karşı çocuklar üzerindeki etkisini yansıtmıştır. Bu tür şiirlerde propaganda yaygın değildir. Şairin çocuklara nasihati, onların ilgi dünyalarının coğrafyası yaklaşık değildir. Örneğin "Umacı" şiirinde şair ilginç bir konuyu ele almıştır. Tüm ailelerin çocukları bir şeyler yapmalarını engellemek için "umacı" ile korkutması tipik bir durumdur. Bu konuya değinen Tevfik Fikret, hem çocuk psikolojisini, hem aile eğitimini, çocuklar üzerindeki etkisini yansıtmış hem de çocuk zihninin ve ruhunun doğru oluşumunda yetiştirilmenin rolünü özel olarak değerlendirmiştir. Şiirde cinlerden ve xoxanlardan değil, kötülüklerden korkun çağrısı, Şermin örneğinde

asında bütün çocuklara seslenmektedir. Çünkü şair, cinlerin ve şeytanların gerçek varlıklar olmadıklarını ve insanlar üzerindeki tesirlerinin imkansızlığını şu ifadeleriyle ortaya koymaktadır:

*Ağabeyi der ki “Şermin,
Seni titreyen şu hain,
Şu korkunc şey ki kutudan
Çıkıverdi, bir kuzudan
Koparılmış bir avuç yün,
Bir az kağıt, bir az da dün
Sana verdim tel yoxmu.
İşte ondan ibaret bu.”*

Şair, bu tür deyim, anlatım ve açıklamalarıyla çocukları mitolojinin yarattığı korkunç etkilerden uzaklaştırmakta, onların yaş düzeylerine göre hayat görüşlerini şekillendirmektedir. Şiirin son iki mısrası, her bir çocuğun yaşamsal konumu hakkında bir fikir vermesi şeklinde dikkat çeker:

*Aklı başında insanlar
Yalnız fenalıktan korkar!*

Tevfik Fikret'in çocuk şiirlerinde ahlaki ve öğretici üslubu önemli yer tutar. Bu tür şiirlerde yüce duygu ve duyguların samimiyeti çocuklarda daha çok dikkat çeker. Genel olarak Doğu edebiyatı ve edebi-sanatsal düşüncesi için önemli olan didaktik, nasihat sadece bir çocuk konusu değildi. Doğu literatüründe bu konu, Doğu-İslam bağlamında etkisini büyük ölçüde genişletmiş, Y.Balasagunlu, N.Tusi, S.Şirazi, N.Gencevi, A.Cami vb. sanatçıların eserlerinde yer alan manevi değerler, çok renkli ifade ve deyimler şeklinde yüzyıllar boyunca manevi bir hazine kaynağı olmuştur. Tevfik Fikret'in didaktik bir tema üzerine yazdığı çocuk şiirleri, doğu gelenekçiliğinin dışında kalmıyor. Aksine bu tür şiirlerdeki konu ve fikir klasik Doğu geleneğindeki ile aynı olsa da deyim ve anlatım çocuğun psikolojisine ve yaşına uygundur. Şairin "İki Yolcu" şiiri bu yönüyle dikkat çekmektedir. Şiirin ilginç bir teması var: "Bir yaz sabahı iki gezgin yürüyor. Biri yolda düşmüş bir kestane görür. İki gezgin arasında kestaneyi bölmek için kavga çıkar. Hikayeyi öğrendikten sonra yoldan geçen biri kestaneleri soyar, çekirdeklerini yer ve kabuklarını onlara verir. Bu şekilde nasibini alan o iki kişinin şaşkırmaktan başka çaresi yok."

*Hoca kestaneyi kırdı
Kabuklarından birini
Bir yolçuya, diğerini*

Bir yolçuya uzatarak

İçini kendisi yedi

Sonra: “Haydi buyurun!”dedi.

“Az hırs çok zarar verir” şiirinin son mısrası çocukların dünya görüşünün bir fikir şeklinde oluşmasında olumlu rol oynamakta, dostluk ve sadakat eğilimlerini güçlendirmekte, açgözlülüğün zararlarına dair izlenimlerini genişletmektedir. Tevfik Fikret'in yaratıcılığının ilk döneminden (1888-1896) farklı olarak, daha doğrusu 1908'den başlayarak daha sonraki yaratıcılık döneminin, devrimciliği ve hareketliliğiyle öne çıkan bir aşamaya girdiği belirtilmelidir. Bu aşamada dönemin doğrudan ve keskin suçlamalarının ayrı bir yeri vardır. Kamusal hayatın katlanılmaz nedenleri açıklanır, bu durumdan çıkış yolları hakkında fikirler tartışılır. Şairin eserlerinde vatan, hürriyet, mücadele vb. konuların yer alması bu nedenledir. Konular yeni literatürün gereklerine göre çözüm bulabilmiştir. Tevfik Fikret'in eserlerinin derinlemesine analizi, ona vatanın şairi demek için tam sebep veriyor. Genel olarak vatanseverlik Tevfik Fikret'in eserlerinde geniş bir kavramdır. Onun gözünde vatan, ecdadımızın şimdiki ve gelecek nesillere emanet ettiği ebedi mukaddes mekandır:

Can da sən, şən da sən, həpsi sənsən yaşa,

Ey vətən, ey mübarək vətən, min yaşa!

Tevfik Fikret'in eserlerine yakından bakıldığında, sanatında vatansever fikirlerin yüceltilmesinin, dış müdahalenin Türkiye'yi haritadan silme planlarına karşı daha yoğun olduğu görülüyor. Kuşkusuz bu durum şairin çocuk şiirlerinde de yer almaktadır. Ancak diğer grup şiirlerinden farklı olarak Tofik Fikret, çocuk şiirlerinde onların yaşını ve psikolojisini dikkate almış ve fikirlerini bir nevi nasihat, sevgi, meydan okuma ve teşvik şeklinde yaymıştır.

Tofik Fikret'in çocuk şiirlerinde nasihat, çocuklara ülkenin geleceği olan insanları hatırlatan bir bilge insan modelidir. Doğal olarak bu hatırlatmalar arasında çocuklarda vatanseverlik duygularını güçlendirme eğilimi daha güçlüdür. Tevfik Fikret'in vatanseverlik ruhunu yücelten şiirlerinde ilginç bir biçim seçilmiştir. Çocuk psikolojisine uygun olarak ülkenin güzelliklerini yücelterek bu duyguyu aşılar. Daha doğrusu, vatanın doğal güzellikleri karşısında çocukların bu topraklara olan sevgisi artar ve çocukların gözünde eşi benzeri olmayan vatan imajı canlanır:

Bahar olsun da seyr edin,

Necə süslər bayırları,

Zümrüd kimi çayırıları...

"Küçük asker" şiirinde küçük bir çocuğun vatanı koruması, kahramanca bir yola girmesi, elinde silahla düşmana acımasız davranması vb. bir kahraman canlandı. Bu şiirde vatan anadır, vatan için ölmek kutsal bir görevdir, kahramanlık öyle bir şekilde aşılanır ki, bunlar çocukların değerli yurttaşlar olarak yetişmelerine ve hayatta alacakları konuma doğrudan etki eder:

*Kiçik əsgər, silah əldə
Qəhrəman tək irəliləyir
Qabağında bütün el də:
"Qəhrəmanım, yaşa" deyir.
Kiçik əsgər, kişik əsgər!
Vətən səndən xidmət istər.
Kiçik əsgər, dinlə məni
Gözlə, boşə silah atma
Silahını, mərmini
Haqsızlığa qarşı saxla
Kiçik əsgər, kişik əsgər!
Haqq da səndən qüvvət istər.*

Tevfik Fikret'in çocuk şiirlerinde doğa tasviri önemli yer tutar. "Günlük", "Bahar Kalfa", "Yaz dokuz", "Hazan Teyze", "Kiş Baba", "Yaz", "Kış" vb. doğa ile doğrudan temas, her mevsimin kendi renkleri ve özellikleri şiirlerde çocukların ilgi alanlarına göre anlatılmıştır. Bu şiirlerde bahar "gelin kılığında tomurcuklanmış dudaklar" ("Bahar Kalfa"), yaz "kızgın güneşle parıldayan" ("Yaz anası"), sonbahar "sisli, altın" ("Hazan Teyze") vesaire. formdaki sunumu, çocuk psikolojisinin gereklilikleriyle doğrudan bağlantılıdır, her bölüm hakkındaki ilk fikirlerini hem sağlar hem de biraz genişletir. Örneğin şairin iki farklı şiirinde iki farklı mevsimin (yaz ve kış) kendine has ve farklı tabiat özellikleri dikkatlerden kaçmaz:

*Örtül pərdə, örtül pərdə,
Örtül tez ol, şüşələrdən
Günəş içəriyə vurur,
Dəftərimi soldurur... ("Yayda")*

Ve ya:

*Açıl pərdə, açıl qarda,
Sən açıldın, günəş harda?*

Yoxsa bizi unutmuşdur?

Xeyr, onu bulud udmuşdur.

Çox soyuq var

Hər tərəf qar... ("Qışda")

Genel olarak Tofiq Fikret'in eserlerinde doğa tasviri geniş yer tutar. Çeşitli konulardaki şiirlerinde, meselenin betimlenmesi özellikle dikkat çekicidir. Dolayısıyla Tofiq Fikret'e ressam-şair diyenler hiç de haksız değiller. Onun örtüşen ve birbirini tamamlayan şair-sanatçı yeteneği ve yeteneği, eserlerinde tabiatın güzelliklerinin ve tabiattaki renk inceliklerinin son derece canlı bir şekilde verilmesini sağlamıştır.

Yaratıcılığının farklı dönemlerinde yazdığı şiirlerinde, doğanın güzel manzaralarının, insan duygularının kutlanmasının ve insanların basit günlük yaşamının ressam fırçasıyla çizdiği sosyo-psikolojik tablolardan etkilendiği söylenebilir:

Safi rakid... Hanı axşamkı təgəyyür, həyəcan?

Bir cocuq ruhu qədər pir-nisyan,

Bir cocuq ruhu qədər şimdi münəvvər, ləkəsiz,

Uyuyur mavi dəniz.

...Sənə baxdıqca təsəlli buluram, aldanıram,

Mavi bir göz ələmi qəlbimə ağlar sanıram.

SONUÇ

Tevfik Fikret'in çocuk şiirlerinde okula, derse, öğrenme metodolojisine ilgiden tutmuş emeğe sevgi, vatan sevgisi, anne baba sevgisi ve bu türlü durumların tebliği, genç neslin eğitiminde ve vatandaş olarak şekillenmesinde önemli bir rol oynayabilmiştir. Tevfik Fikret'in "Hasbi-hal", "Hediye", "Melek Kuzusu", "Kış Dede", "Aslan", "İki Yolcu", "Yusufçuk ve Karınca" şiirlerinde şair basit sözler ve kolay ifadeler, çocukların ilgi dünyasına doğrudan müdahale ederek üslubunu ortaya koymuş ve fikirlerine şiirsel bir şekilde dikkat çekmeğe çalışmıştır. Tevfik Fikret'in çocuk şiirlerinin dili sade ve anlaşılır, konusu canlı ve güncel, fikri toplumsal ve ahlakidir. Bu şiirlerde ne eski edebiyata karşı mücadele ne de Tevfik Fikret'in lirik yaratıcılığının özelliği olan güçlü siyasi saik eğilimleri görülmez. Bu şiirlerde çok çalışmak, vatanseverlik, okula çağırmak, vatan sevgisini aşılacak gibi çocukların dünya psikolojisinin tüm yönleri doğa imgeleri şeklinde işlenmiştir. Tevfik Fikret'in eğitim kurumlarını genç neslin geleceği olarak "şefkatin, aydınlanmanın, erdemin yuvası" ("Adanmışlık") olarak görmesi, çocukları şeytandan ve kötülükten ("Umaji") korkmaya teşvik ediyor. Çocuklara alfabeyi ("Utanç Alfabesi") öğrenmeye sevgi ve ilgi aşılayan, çok çalışmanın insan hayatındaki

önemini yeniden canlandıran ("Yusufçuk ve Karınca"), doğa işaretlerini tasvir ederek çocuklara ülke sevgisini aşılayan Şermin örneği ("Kışın", "İlkbahar", "Büyükbaba Kışı"), vb. çocuk psikolojisine dair derin bilgisini teyit eder, çocukların vatandaş olarak yetişmesinde önemli rol oynar ve aynı zamanda şairin çocuk şiirindeki başarısı hakkında bilgi verir.

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SCHOLARLY AND THEORETICAL APPROACHES OF LITERARY SCHOLARS TO FOLKLORE

Dr. Ülker Bahşıyeva

ADPU-nun Filoloji fakültesinin

Edebiyatın tedrisi teknolojisi

bölümünün baş öğretim üyesi

ulker.baxsiyeva@mail.ru

ORCID İD 0000-0002-5994-2356

Abstract

Folklore is a product of the people's creative thinking, a carrier of national memory, and a cultural code of self-awareness. There is a deep and reciprocal connection between literary studies and folklore studies. Literary scholars have examined folklore not only from an aesthetic and poetic perspective but also as a socio-historical phenomenon that plays a significant role in shaping the spiritual and cultural existence of a nation. Although these approaches have evolved over time, several main scholarly and theoretical directions have been established. The scientific and theoretical approaches to folklore have changed in accordance with the developmental stages of literary studies and have been shaped on various methodological foundations.

Keywords: Folklore, literary studies, M. Ibrahimov, research, people

Introduction

Azerbaijani folklore is distinguished by its antiquity and richness. Folklore is a treasure that preserves our nation's spiritual and moral values, national identity, history, and culture. Academician Mirza Ibrahimov conducted significant scholarly research on various stages of Azerbaijani literature, numerous literary figures, as well as on folklore itself. This article analyzes his research related to folklore.

One of the key approaches of Soviet philology in the 20th century was the understanding of folklore primarily as "oral literature." Accordingly, in Soviet (including Azerbaijani Soviet) folklore studies, the subject of research was the people's direct artistic verbal creativity. For decades (and even to some extent today), this approach led to classifying oral folklore samples into three types—epic, lyrical, and dramatic—just like written literature. In this framework, folklore referred solely to artistic verbal texts such as myths, legends, fairy tales, epics, folk songs (qoşma, gəraylı), traditional games, and performances. Thus, the classification of oral literary samples into epic, lyrical, and dramatic forms was considered justifiable.

However, it is important to remember that a folklore text is not made up of words alone. For instance, an epic (dastan) is a complex folklore phenomenon. The ashik (folk bard) acts like an actor—he narrates the prose

part (called "yurd"), performs dialogues, sings poems accompanied by instruments like the saz or balaban, and even dances. Nevertheless, folklorists who recorded these epics often transcribed only the verbal component, neglecting aspects like music and performance. These dimensions were left to ethnographers and musicians. As a result, a unified folklore text was divided into separate structural components studied by different specialists, and thus, no single scholar (including folklorists) could present the folklore piece in its full integrity. This tradition, still continuing in some cases, was neither appropriate in the past nor is it today.

In contrast, Western humanities in the 20th century approached folklore differently. For example, Benjamin A. Botkin wrote in 1938:

"Folklore is the traditional belief, custom, and expression spread largely by word of mouth, outside of commercial and academic institutions. Every group—educated or uneducated, urban or rural—united by common interests and purposes has folklore. This includes personal, popular, and even literary elements, all of which are shaped and adapted through repetition and variation, and hold special meaning for the group" (3, p.17).

Similarly, Jan Brunvand in his 1978 work *The Study of American Folklore* stated: "Folklore comprises the unwritten traditions of people; it includes the forms and contents of these traditions, their transmission styles, and interpersonal communication techniques... Folklore is the traditional and unofficial part of culture. Through traditional examples and oral expression, it encompasses knowledge, values, attitudes, feelings, and people" (3, p.18).

A summary from the American Folklore Society's website "AFSNet" under the title *What is Folklore?* explains:

"Folklore is the traditional art, literature, knowledge, and practices that are passed through oral communication and behavioral examples. Each group expresses its identity through shared traditions, including what people traditionally believe (farming practices, family customs, worldview elements), do (dance, compose music, sew clothes), create (architecture, visual art), and say (personal narratives, riddles, lyrical songs). There is no strict separation between these categories in everyday life or scholarly presentations" (3, p.13).

From these perspectives, it becomes clear that the Western notion of folklore greatly differs from the Soviet view, which equated it with oral literature. In Western scholarship, folklore encompasses "traditional beliefs, customs, and expressions," "the traditional and unofficial part of culture," and "everything people traditionally believe, do, create, and say." Within this context, when examining Mirza Ibrahimov's contributions to folklore studies, it is evident that he too equated folklore with oral folk literature. This is understandable,

given the scientific norms and principles of his time. According to these standards, folklore meant oral folk literature, and like others, Ibrahimov approached it as the verbal creativity of the people. However, one must note an important distinction.

Though he considered folklore to be verbal artistry, Ibrahimov viewed it as more than literature. For him, folklore was a reflection of national consciousness, a repository of cultural memory, and a spiritual treasury of national identity. As S. Rzasoy put it, folklore is the memory of the people—individual, ethnic, national, and collective memory. The existence of a people is mirrored through the codes of word and art in this memory. This memory transcends the physical-spiritual existence of a people living in the rhythm of a "coming and going" world. The nation's history passes not only through the collective fate of the people but also through the fate of every individual, traveling into the future. Folklore is the destiny of the people; the fate of an ethnic group is directly tied to its connection with national memory. A people capable of returning to its memory can rise to the status of a nation among other nations. The wholeness and security of any nation or country directly depend on how the ethno-cosmic memory sustains it (3, p.3).

S. Rzasoy's view represents a modern 21st-century perspective on folklore. Nevertheless, based on Ibrahimov's own research, it is clear that he, too, considered folklore—first and foremost—as the memory of the people, a verbal treasury that reflected the nation's identity and spiritual values. He believed that the fate of a people was intrinsically linked to its folklore memory. However, due to the repressive ideological constraints of the Soviet era, and despite his unwavering love for his nation, language, and culture, Ibrahimov could not express these views openly. Instead, he used metaphorical language to convey his national sentiments and identity. This highlights the need to always take into account the harsh ideological constraints and rigid frameworks of the Soviet period when studying the works of its authors. Researchers must be attentive, sensitive, and skilled at uncovering the underlying meanings of texts. When approached with these criteria, Ibrahimov's folklore studies portray him as a true patriot, a national figure, and a literary scholar with a unique intellectual perspective.

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YAZILI TARİXİ ABİDƏLƏRLƏ DİALEKT LEKSİKASI ARASINDA ƏLAQƏNİN İZLƏRİ

Rəhilə Hümətova

f.ü.f.d., dosent, Azərbaycan Dövlət Pedaqoji Universiteti Filologiya fakültəsi Azərbaycan dili və onun tədrisi texnologiyası bölümü, rahilahummetova@gmail.com

ORCID 0000-0003-2521-6361

Açar sözlər: dialekt sözlər, ədəbi dil, qədim türk sözləri, yazılı abidələr

ÖZET

Dilin müxtəlif zaman kəsirlərində dialekt sözlər olaraq canlı ünsiyyətə xidmət göstərən bir sıra leksemlər sonralar aktiv fonda keçərək ümumişlək səciyyə daşmışdır. Bununla yanaşı, ədəbi dilin passiv lüğət fonduna keçmiş və yaxud ədəbi dildən tamamilə çıxmış bir sıra leksik vahidlər, eləcə də qrammatik formalar, köməkçi nitq hissələrinə aid olunan bir sıra dil vahidləri dialekt müstəvisində fəaliyyətini davam etdirməkdədir. Bu danılmaz faktdır ki, bu gün öz ədəbi dilinin, üslublar sisteminin mövcudluğu ilə öyünən hər bir xalq dilinin var olma səbəbi kimi dialektə, canlı danışığa borcludur. Məlum faktdır ki, dialektlər yad dillərin təsirinə daha az məruz qalır. Dilimizin müxtəlif inkişaf dövrlərinə aid olan dil vahidlərini, xüsusilə leksik vahidləri günümüzdə qədər saxlamış dialekt və şivələrimiz canlı və etibarlı mənbə kimi çıxış edir. Eyni zamanda ədəbi dilimizin inkişaf tarixinə nəzər saldıqda qədim türk-Azərbaycan sözlərinin, eləcə də onlarla alınma sözün, xüsusən ərəb-fars mənşəli sözlərin aktiv lüğət fondundan çıxdığını, lakin regional müstəvidə ünsiyyətə xidmət göstərdiyini müşahidə etmək mümkündür. Bu da öz növbəsində bir daha sübut edir ki, dialektlər mühafizəkardır və xüsusilə qərb qrupu dialekti dilin keçdiyi inkişaf yolunun araşdırılmasında qiymətli material verə bilər. Bu baxımdan mövzu aktualdır.

Onu da qeyd edək ki, ədəbi dilin lüğət tərkibi daima zənginləşmə prosesi keçirir. Zənginləşmə dilin həm daxili imkanları, həm də alınma sözlər vasitəsilə həyata keçirilir. Dialektlər ədəbi dilin lüğət tərkibinin zənginləşməsində mühüm rol oynayan daxili imkanlardır. Bu proses dilimizin tarixi inkişafının bütün mərhələlərində davam etmişdir. Əvvəlki sətirlərdə də qeyd etdiyimiz kimi, bu gün dilimizin aktiv fondunda ümumişlək səciyyə daşıyan bir çox sözlər dilin müəyyən inkişaf dövründə dialekt sözü kimi fəaliyyət göstərmişdir. Azərbaycan dialektologiyasında xüsusi çəkiyə malik olan qərb qrupu bu baxımdan olduqca zəngindir. Qərb qrupu dialekt leksikası vaxtilə dilin aktiv lüğət fondunda intensiv fəaliyyət göstərən, lakin obyektiv dil qanunauyğunluğu əsasında zaman keçdikcə arxaikləşən qədim türk, eyni zamanda qeyri-türk mənşəli dil vahidlərini qoruyub-saxlayır. Məqalədə qərb qrupu dialekt leksikasında mühafizə olunan *anarı*,

armax, kür, sümsük, varmaq, dısqarı, tazımaq, onalmaq və s. kimi vahidlərin yazılı abidələrin dilində müşahidə edildiyi konkret nümunələrlə öz əksini tapıb.

GİRİŞ

Məlumdur ki, dialekt və şivələr ədəbi dilin lüğət tərkibinin zənginləşməsində mühüm rol oynayır. Digər dil qatlarında olduğu kimi, ədəbi dilimizin leksik layının formalaşmasında da dialekt və şivələrdən bəhrələnmə əsas yollardan biridir. Bu proses dilimizin tarixi inkişafının bütün mərhələlərində davam etmişdir. Bu gün dilimizdə ümumişlək səciyyə daşıyan bir çox sözlər kimi dilin müəyyən inkişaf dövründə dialekt sözü xarakterik olmuşdur.

ARAŞDIRMA

Ədəbi dillə dialekt sözlər həmişə əlaqədə olmuş, bir-birinə təsir edərək zənginləşmişdir. Ədəbi dil dialektlərdən söz və ifadələr aldığı kimi, dialektlər də öz növbəsində ədəbi dilin fonetik və qrammatik sisteminə, tələffüz normalarına uyğunlaşır. Lakin ədəbi dilin normalarına yaxınlaşma və uyğunlaşma dialektlərin sıradan çıxması, yox olması demək deyildir. Bu danılmaz faktdır ki, bu gün öz ədəbi dilinin, üslublar sisteminin mövcudluğu ilə öyünən hər bir xalq dilinin var olma səbəbi kimi dialektə, canlı danışığa borcludur. Dialekt sözlər hər bir dilin ən sağlam, təmiz və mötəbər mənbəyidir. Təbii ki, bu cür elmi nəticəyə gəlməyin səbəbi dialektlərin başqa dillərin təsirinə daha az məruz qalmasıdır. Dilimizin müxtəlif inkişaf dövrlərinə, mərhələlərinə aid dil vahidlərini, xüsusilə leksik vahidləri günümüzə qədər saxlamış dialekt və şivələrimiz, onların lüğət fondu canlı və etibarlı mənbə kimi çıxış edir. Eyni zamanda ədəbi dilimizin inkişaf tarixinə nəzər saldıqda onlarla alınma sözün, xüsusən ərəb-fars mənşəli sözlərin aktiv lüğət fondundan çıxdığını, lakin regional müstəvidə ünsiyyətə xidmət göstərdiyini müşahidə etmək mümkündür. Bu da öz növbəsində bir daha sübut edir ki, dialektlər mühafizəkardır və dilin keçdiyi inkişaf yolunun araşdırılmasında qiymətli mənbələrdən biridir. M.Şirəliyev yazırdı: “Dialekt və şivələrimizin lüğət tərkibində keçmiş ictimai quruluş, həyat, məişət, adət, təsərrüfat və s. ilə bağlı olan bir çox arxaik sözlərə rast gəlirik ki, bunları müasir dilimizdə görə bilmirik”. (M.Şirəliyev, 2008)

Dialektlər ədəbi dilin lüğət tərkibinin zənginləşməsində müəyyən rol oynayır. Bu proses dilimizin tarixi inkişafının bütün mərhələlərində davam etmişdir. Bu gün dilimizin aktiv fondunda ümumişlək səciyyə daşıyan bir çox sözlər dilin müəyyən inkişaf dövründə dialekt sözü kimi fəaliyyət göstərmişdir. Bununla yanaşı, ədəbi dilin passiv lüğət fonduna keçmiş və yaxud ədəbi dildən tamamilə çıxmış bir sıra leksik vahidlər dialekt müstəvisində fəaliyyətini davam etdirməkdədir. Onların bəzilərinin leksik-semantik xüsusiyyətlərinə nəzər salaq: *Anarı –o tərəf, o yan, o biri tərəf, kənar. Anarı* dur. (Azərbaycan dilinin dialektoloji lüğəti, 2007) *Anarı*

sözü bəzən *bəri* zərfi ilə yanaşı işlənərək əşya məzmunu bildirir: Gedim uşaxlarçün bir az *anarı-bəri* alım. “Orxon –Yenisey” abidəsinin dilində də müşahidə edilir: “... önra Türk kağanğaru süləlim, -timiz. *Anaru* süləməsar, kaç nan ersar, ol bizni...” Tərcüməsi: şərqdə Türk xaqanlığı üzərinə hücumla keçək, -demişlər. Əgər ora (o tərəfə) qoşun çəkməsək, hər necə olsa, o bizi (məğlub edəcək)” . (Ə.Şükürlü, 1993)

”Kitabi-Dədə Qorqud” da: “ Nə gəlırsə, mənım süfrəmə gəlsin deyü əlin ... urar. Yönün *anaru*, sağrısın ərinə döndərər”. (Azərbaycan ədəbiyyatı inciləri, 1987)

Armax – həvəskar, həvəsli. Dialektde: Hörmə işdərinə yaman *armaxdı*. Qərb dialektində üstün mövqeyi ilə seçilən *armax* vahidi “Orxon –Yenisey” abidəsində *armakçı* fonetik tərkibdə müşahidə edilib və “başdan çıxaran, aldadan, şirnikləndirən, aldatdığına görə” mənalarını bildirir: “Bəgləri, bodunu tüzəsiz üçün, tabğac bodın təbligın kürlig üçün, *armakçısın* üçün... “. Tərcüməsi: Bəyləri, xalqları düz (ilqarlı olmadıqlarına görə) tabğac xalqı aranı qarışdırdığı üçün, yalançı vədlər verdiyi üçün...”. (Ə.Şükürlü, 1993)

Kür – *ipə-sapa yatmayan, nadinc*. *Kür* sözü qərb qrupu dialektində olduqca intensiv işlənir: Uşax yaman *kürdü*. “Kitabi-Dədə Qorqud” da: “Yarımasın, yarçımasın sənın oğlun *kür* qopdu, ərcil qopdu. ... Ağ saqqallı qocanın ağzın söydü. Ağ birçəkli qarının saçın dartdı”. (Azərbaycan ədəbiyyatı inciləri, 1987)

Sümsüx \\\sülənməx – *burnunu hər yerə soxub dilənmək; boş-boş gəzmək, gününü keçirmək, avaralanmaq*. Dialektde: “Səhərdən-axşama *sülənir*, onnan iş görən olmaz”. (Qazax, Gəncə, Şəmkir, Tovuz) Dialektlərdə istifadə edilən *sülənmək* sözü “Orxon-Yenisey” abidələrində müşahidə edilən *sü* (qoşun, ordu), eləcə də həmin sözdən düzələn *sünüş* (döyüş, vuruş, müharibə), *sülə* (qoşun çəkmək) ifadələri ilə bağlıdır. Bu haqda Ə.Şükürlü yazır: “ Maraqlıdır ki, ədəbi dilimizdə unudulmuş bəzi sadə və düzəltmə sözlərdə bu və ya digər şəkildə və mənada dilimizin dialekt və şivələrində hələ də rast gəlmək mümkündür. Məsələn ... sülə –qoşun çəkmək sözü dilimizdə *sülənmək* şəklində *burnunu hər yerə soxub dilənmək* mənalı söz kimi işlənəlməkdədir...” (Ə.Şükürlü, 1993)

Tazımax\\dazımax\\dızıxmax – qaçmaq, sürətlə getmək. Qeyd edək ki, dialekt leksikasında daha çox “tazımax” feli üstünlük təşkil edir və bu söz də “qaçmaq, yüyürmək, sürətlə getmək və s.” anlamlarını bildirir. Aparılmış tədqiqatlardan məlum olur ki, dialekt leksikasında üstün mövqeyi ilə seçilən “tazımaq” (təzmək, tozmaq) vahidi qədim türkcədə “yerimək, yüyürmək, getmək” kimi hərəkət anlayışını bildirən sözlərin ilkin allamorfları olmuşdur. Bu sözlərin bir çoxu nəinki müasir türk dillərində, qədim türkcəyə aid yazılı mənbələrdə, o cümlədən dialekt leksikasında öz izini qoruyub-saxlaya bilmişdir. Araşdırmaların nəticəsi olaraq deyə bilərik ki, dazımaq\\ tazımaq \\tozmaq (gəzmək anlamında) sözlərinin əsasında təz\\toz allamorfları dayanır. “Qədim türk lüğət” ində *təz\\toz* sözü aşağıdakı mənalarda işlənmişdir: 1. ”Qaçmaq, yüyürmək, sürətlə getmək, qaçıb

gizlənmək, qaçıb qurtarmaq, qaçıb getmək”. 2. Uzaqlaşmaq, çəkilmək, rədd olmaq, getmək”. (Древнетюркский словарь, 1969)

Qərb qrupu dialektində həmçinin “azan-tazan” qoşa sözündən də istifadə edilir: A bala, qapıyı bağla, *azan-tazan* içəri girər. Bu leksik vahidin ikinci tərəfindəki “tazan” ifadəsinin də əsasında məhz *təz\toz* allamorfları durur, mənası isə “yolla keçən, gedən-gələn və s.” deməkdir. Göründüyü kimi, qədim türkcədə işlənən və müasir ədəbi dilimizdə müşahidə edilməyən “tazımaq” ifadəsi dialekt müstəvisində fəaliyyətini davam etdirir. *Dışqarı\dışqarı* – *çöl, bayır, el adətindən kənara çıxmaq*. Yeri gəlmişkən, qeyd edək ki, “taşra”, “tışra”, “dışqaru”, “dışarı”, “dış” vahidləri “Kitabi-Dədə Qorqud” un dilində, klassik ədəbiyyatda, folklorda üstün mövqeyi ilə seçilən dil vahidləri olmuşdur: “... tışra çıxar andan yağma edərdi...”. (KDQ) Ey Nəsimi, hər qatında çün, yəqin, iman imiş, Hər şəhadət kim yaxından *tışradır*, iman degil! (*İ.Nəsimi*) Qəməzlərin sirrini canda dedim saxlayım, *Daşra* buraxdı könül pərdədən əsrarımız. (*İ.Nəsimi*) *Daşqaru* çıxmağa bulmadı aman, *Daşqaru* çıxdı bəhri-dərdü bəla. (“*Əsrarnamə*”) Bu leksik vahidlərdəki -qaru,-ra,-arı şəkilçi morfemlər olaraq yer zərfi yaratmağa xidmət göstərmişdir. “-ra, ru, -qaru, -ara, aru. Bu şəkilçi vasitəsilə bir sıra zərflər düzəlmişdir. ... Müasir ədəbi dilimizdəki *ora, bura, yuxarı, içəri, sonra* və s. kimi zərflərdə -arı, -əri, ra şəkilçisi daşlaşmış vəziyyətdədir”. (Ə.Tanrıverdi, 2010)

Divan” da “yok – qaru” (MK, I,142) (yuxarı) zərfi yönəlmə, istiqamət halından təcrid olunmuş “yok” (təpə, yüksəklik) ismi əsasında yaranmışdır”. (M.Şirəliyev, 2008) Bu fikirlərdən bir daha aydın olur ki, tarixən “təpə, yüksəklik” məzmununda olan və müasir dildə şəkilçidən (qaru) ayrı işlənməyən *yuxarı* zərfində əvvəlki mənə – *yüksək yer* (şəkilçi ilə birlikdə) qorunub-saxlanılır. Klassik ədəbi dilimizdə aktiv istifadə edilən “dışra”, “taşra”, “dışqarı” dil vahidləri arxaikləşərək dilimizin passiv lüğət fonduna keçmiş olsa da, regional müstəvidə əvvəlki semantik tutumu ilə işlənməkdədir: – Eldən *dışqarı* ha döysən, yol-ərkan bilmirsənmi? – A bala, o dindən *dışqarı* səni də pis yola çəkər.

Varmaq – getmək. Onu qeyd edək ki, qərb qrupu dialektində işləkliyi ilə müşahidə edilən *varmaq* leksik vahidi daha çox *getmək* feili ilə müvazi işlənir: *Varıf gedirəm*. “Orxon –Yenisey” abidəsində “bar” (maq) şəklində müşahidə edilir: “Bəg ər yontınaru *barmıs*, ak bisi kulunlamıs...”. Tərcüməsi:Bəy kişi ilxısına getmiş, ağ madyanı qulunlamış ”. (Ə.Şükürlü, 1993)

“ Qədim türkcədə *barmaq* sözünün ifadə etdiyi mənalar belə olmuşdur: “getmək (piyada)”, “yola düşmək, yollanmaq” (məs.: beş yegirmi yaşında tabqac qanqa *bardım* –on beş yaşında tabqac hökmdarına tərəf getdim), “ yerimək, veyllənmək, avara gəzmək, dolanmaq, dolaşmaq” (məs.: *barmış* nenin saqınma –yox olmuş mal\var haqqında təəssüflənmə). ...*Barmaq* sözünün qədim türkcədəki “ölmək” mənası Azərbaycan dilinin dialekt və

şivələrinin əksəriyyətində *varıb getdi*, *vardı getdi* şəklində işlənir. Azərbaycan dilinin dialekt və şivələrində *var get*, *var azarına get* ifadələri də işlənir. Bu da onu göstərir ki, *barmaq* və *varmaq* sözləri eyni mənanı bildirir. Qədim türkcədə *barmaq* sözü sonralar *b-v* əvəzlənməsi ilə *varmaq* şəklinə düşmüşdür”. (B.Xəlilov, 2010) *Varmaq* feli “Kitabi-Dədə Qorqud”da, eləcə də klassik ədəbiyyatda işlək dil vahidlərindən olmuşdur. Müşahidələr göstərir ki, yazılı abidələrin dilində *varmaq* feli ilə yanaşı, *getmək* feli də işlək olmuşdur: “Xan babamın qatına mən *varayım*, Azğın dinli kafirlərə (mən) *varayım*. Boynu uzun bədöy atlar *gedərsə*, mənim *gedər*”. (Azərbaycan ədəbiyyatı inciləri, 1987) Cümlələri ağlaşuvan *varurlar* imdi. (“*Qisseyi-Yusif*) Bu yola *varmaq* olmaz rəhnümasız, Necə kim, olasan sən soraqan var. (*Ş.İ.Xətai*) Dil bazarçısı yalandır, *varmazam* bazarinə, Gerçək olmaz əgridil, inanmazam iqrarinə. (*İ.Nəsimi*)

Onu da qeyd edək ki, *varmaq* feli ədəbi dilin lüğət tərkibinin aktiv fondundan çıxmış olsa da, müasir ədəbi dilimizdə bir çox mürəkkəb söz və tərkiblərin daxilində öz əvvəlki semantik məzmununu qoruyub-saxlayır: *var-gəl etmək*, *fərqiə varmaq*, *dərinliyinə varmaq*, *əhəmiyyətinə varmaq* və s.

Onalmaq\önəlmək – *sağalmaq*, *yaxşılaşmaq*. *Dialekt*də: Bu mərət məni yamanca yaxaladı, heç *onalamıram* (bu sözdəki “n” səsi sağır səsdır). “Kitabi-Dədə Qorqud” da: “Oğlanın qırx gündə yarası *önəldi*, sapasağ oldu”. (Azərbaycan ədəbiyyatı inciləri, 1987)

Dialekt leksikasının əhəmiyyəti dilin tarixi inkişaf mərhələlərində leksik vahidlərin fəaliyyətini işıqlandırmaqla məhdudlaşmır, eyni zamanda xalq poeziyasına, aşiq yaradıcılığına çox zəngin material verir. Bəzən leksik təkrarlardan qaçmaq, bəzən də ədəbi dildə fəaliyyət göstərən dil vahidləri ilə sıralanaraq onların semantikasını qüvvətləndirmək üçün işlədilən dialektlər ən çox insanların gündəlik həyat tərzilə bağlı, məişət leksikasına daxil olan sözlərdən ibarət olur. Bu da, təbii ki, real həyat həqiqətlərinin daha inandırıcı çatdırılmasına şərait yaradır. Yerində və çox böyük ustalıqla işlədilmiş dialektizmlər bədii üslub baxımından olduqca qüvvətli, təsirli ifadə vasitələrindəndir.

NƏTİCƏ

* Yazılı abidələrin dilində zaman-zaman intensiv işlənmiş bir sıra qədim türk sözləri müasir Azərbaycan ədəbi dilinin lüğət tərkibindən çıxmışdır.

* Dialekt sözlərin bir qismi (armax, varmaq, dısqarı, tazımaq, sümsük və s.) regional müstəvidə işlənəlməkdədir.

* Bəzi leksik vahidlər müəyyən fonetik, semantik dəyişikliyə uğrasa da, öz əvvəlki məzmununu qoruyub-saxlayır.

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PRAGMATICS AND POLITENESS

Azerbaijan-Baku, Gunel Shefiyeva

Orcid id: 0000-0001-5105-2749

agakishiyeva.g@mail.ru

Azerbaijan State Pedagogical University, Faculty of Philology, Foreign Languages Center

KEY WORDS: Context, face, politeness strategies, face-threatening acts.

Pragmatics is a branch of linguistics that studies how meaning is constructed and interpreted in context. Unlike semantics, which focuses on literal meaning, pragmatics examines how speakers use language in real social interactions. One of the central concerns of pragmatics is politeness, which plays a crucial role in maintaining social harmony and managing interpersonal relationships. Politeness strategies allow speakers to express intentions indirectly, reduce conflict, and show respect according to social norms.

Pragmatics emphasizes the importance of context in understanding meaning. Context includes factors such as the relationship between speakers, their social status, cultural background, and the situation in which communication occurs. For example, the utterance “Can you open the window?” is pragmatically interpreted as a request rather than a question about ability. Such interpretations rely on shared knowledge and social expectations. Politeness is deeply embedded in this contextual framework, as speakers choose linguistic forms that align with social conventions and expectations.

Politeness refers to the strategies speakers use to maintain positive social relations and avoid causing offense. It is not simply a matter of being “nice,” but rather a socially and culturally regulated practice. What counts as polite behaviour varies across cultures and contexts. In pragmatics, politeness is studied as a systematic aspect of language use that reflects social values, power relations, and interpersonal distance.

One of the most influential models of politeness was proposed by Brown and Levinson (1987). Their theory is based on the concept of face, which refers to an individual’s public self-image. They distinguish between positive face, the desire to be liked and approved of, and negative face, the desire for autonomy and freedom from imposition.

According to this theory, many speech acts, such as requests, orders, or criticisms, are potentially face-threatening acts (FTAs). Speakers use politeness strategies to minimize these threats. Brown and Levinson identify several strategies, including positive politeness, negative politeness, indirectness, and avoidance of the act altogether. The choice of strategy depends on factors such as social distance, power relations, and the degree of imposition.

Politeness is culturally specific, and pragmatic norms vary widely across societies. What is considered polite in one culture may be interpreted as rude or inappropriate in another. For example, indirectness is often associated with politeness in many cultures, while directness may be valued as honesty and clarity in others. Pragmatic competence therefore requires not only linguistic knowledge but also cultural awareness. Misunderstandings in intercultural communication often arise from differing politeness norms rather than from grammatical errors.

While Brown and Levinson's model has been highly influential, it has also been criticized for being overly universal and for underrepresenting cultural diversity. Later approaches emphasize politeness as a dynamic and interactional process rather than a fixed set of strategies. Scholars argue that politeness is co-constructed by participants in interaction and is closely linked to context, identity, and power relations. These perspectives have broadened the scope of pragmatic research on politeness.

Pragmatics and politeness are closely interconnected, as politeness cannot be fully understood without considering context and language use in interaction. Politeness strategies enable speakers to manage social relationships, negotiate meaning, and maintain social order. Through pragmatic analysis, researchers can better understand how language reflects and shapes social norms, cultural values, and power structures. As communication becomes increasingly global, the study of pragmatics and politeness remains essential for effective and respectful interaction across cultures.

ARİSTOTELİN “POETİKA” ƏSƏRİNİN MƏZMUNUNUN TƏHLİLİ

Ulduz Fərhad Qəhrəmanova, filologiya üzrə fəlsəfə doktoru,

Azərbaycan Dövlət Pedaqoji Universiteti, “Ədəbiyyat” kafedrasında dosent əvəzi

ulduzkahraman1@gmail.com,

Orcid ID: 0009-0003-4418-9319

Abstrakt:

Aristotel “Poetika” əsərində fabulanı belə izah etmişdir ki, fabulanın açılması fabulanın özündən doğmalıdır, yaxşı düzəlmiş fabula sadə olmalıdır və fabula təqlid etdiyi hərəkətlərə əsasən 3 yerə ayrılır:

1. Sadə fabula: Sadə fabula taleyin dəyişməsi, peripetiyalarsız və tanımalarsız olmalıdır. Sadə fabula və hərəkətlər içərisində ən pisi episodik olanlardır. Episodik fabula onun ehtiva etdiyi episodilər bir-birinin dalınca gəlir, amma heç bir ehtimala və zərurətə əsaslanmır. Daxili məzmunun ziddinə gedib fabulanı uzatmaqla hadisə və hərəkətin təbii sırasını pozmağa məcbur olurlar.
2. Dolaşq fabula: Taleyin dəyişməsi peripetiya və tanıma ilə olur. Fabulada **peripetiya** hadisələrin öz əksinə geri dönməsidir. Peripetiya ehtimal və zərurət qanunları üzrə olur. Fabulada **tanıma** əsərdəki obrazların bir-birini şəxsən özlərin tanıması deməkdir. Aristotela görə, tanıma zahiri əlamətlər vasitəsilə yaranır. Yəni tanıma təbiətin özünün verdiyi əlamətlərdir. Bəzən şairin özünün yaratdığı qeyri-bədi, qondarma tanımalar da var. Bu tanımalar fabuladan doğmur. Aristotel deyirdi ki, xatırlama vasitəsilə olan tanımalar, əqli-nəticələrə görə və s. tipli tanımalar da vardır. Tanımalardan ən yaxşısı hadisələrin özündən doğandır. Belə tanımalar müəyyən uydurma əlamətlərsiz başa gəlir.
3. İztirab: Fəciədə məhvə və ya ağrıya bais olan hərəkətdir. Səhnədə hər cür ölüm, işgəncə, yaralanma və digərləri bura daxildir.

Açar sözlər: Aristotel, “Poetika” əsəri, sadə fabula, dolaşq fabula, tanıma, peripetiya, iztirab

ANALYSIS OF THE CONTENT OF ARISTOTLE'S "POETICS"

Abstract:

Aristotle explained the fable in his "Poetics" as follows: the opening of the fable should be born from the fable itself, a well-made fable should be simple, and the fable is divided into 3 types based on the actions it imitates:

1. Simple fable: A simple fable should be without changes in fate, peripetias, and recognitions. The worst of simple fables and actions are episodic ones. The episodes it contains follow one another, but are not based on any probability or necessity. They are forced to violate the natural order of events and actions by going against the internal content and prolonging the fable.
2. Convolved fable: The change of fate occurs through peripetia and recognition. In fable, peripetia is the reversal of events. Peripetia occurs according to the laws of probability and necessity. Recognition in fable means that the characters in the work recognize each other personally. According to Aristotle, recognition occurs through external signs. That is, recognition is the signs given by nature itself. Sometimes there are also non-fictional, fictional recognitions created by the poet himself. These recognitions do not arise from the fable. Aristotle said that there are also recognitions through memory, recognitions based on rational conclusions, etc. The best of recognitions is that which arises from the events themselves. Such recognitions are complete without certain fictional signs.
3. Suffering: In tragedy, it is an action that causes destruction or pain. This includes all kinds of death, torture, injury, and others on stage.

Keywords: Aristotle, "Poetics", simple fable, complex fable, recognition, peripeteia, suffering

Aristotel bədii ədəbiyyatı təqlidi sənət adlandırırdı. Aristotelə görə, təqlidçilərin hamısı hərəkət və fəaliyyət adamlarını təqlid edir. Bu adamlar isə mütləq ya yaxşı, ya da pis olurlar. Aristotelə görə, Poliqont yaxşı, Pavson pis, Dionisey adi adamları, Homer yaxşı, Kleofant adi adamları, Nikoxar pis adamları əsərlərində təsvir etmişlər. Aristotelə görə, parodiyanın ilk yaradıcısı Nikoxardı. Aristotel bildirirdi ki, dorilər faciə və komediyanın mənşəcə onlara mənsub olduğunu iddia edirlər. Komediya isə maqeralılar, siciliyalılar sahib çıxmağa çalışırlar. Faciəyə isə Poloponnes dorilərinin bəziləri sahib çıxmağa çalışır və faciənin adının onlarla əlaqədar olduğunu buna sübut gətirirlər. Aristotelə görə, Evripid sənətkarlar arasında ən yaxşı faciənəvisdir.

Əsərlə tanış olanda məlum olur ki, təqlid uşaqlıqdan bütün insanlara xasdır və onlar digər heyvanlardan bununla fərqlənirlər ki, insanlar təqlidə daha qabildirlər. Həyatda insanlara iyrənc görünən şeylərin təsvirinə baxarkən xoşumuz gəlir, məsələn iyrənc heyvanların və meyitin təsviri. Təqlid də, harmoniya və ritm də insan təbiətinə xasdır. Hələ ən qədim zamanlardan həmin təbii qabiliyyətə malik olanlar onu tədricən inkişaf etdirərək, improvizasiyadan (əsil) poeziyanı yaratmışlar. Əsərdən məlum olur ki, gülünc metrə indiyə kimi yambik (ölçü) metr deyilir, çünki bir-birilərinə həmin metrə gülmüşlər. Qədim şairləri Aristotel əsərində belə qruplaşdırmışdır:

1. Bəziləri qəhrəmani şeir yaradanlar
2. Bəziləri yamb yaradıcıları: Yəni bu o demək idi ki, satira antik yunan ədəbiyyatında yambik janr adı altında göstərirdi. Yamb janrını gülüş janrı hesab edirdilər. Yəni, yamb satirik oda, həcviyyə deməkdir.

Aristotel əsərində Homeri ciddi poeziyanın ən böyük şairi hesab edirdi. Göstərirdi ki, Homer komediyanın əsas formasını ədəbiyyata gətirmişdi. O deyirdi: “Homer gülməlini dramatik cəhətdən işləyib mənalandırmışdır. Faciə və komediya meydana gələndə yambla əsər yazılmadı”. Komediya pis adamların əks etdirilməsidir, gülməli, özü də eybəcərliyin bir hissəsidir. Əvvəllər o həvəskarlardan düzəlirdi. Komediyanı ilk dəfə Afina komik şairlərindən birinci olaraq Kratet yambik şeirdən əl çəkib, dialoq və fabulaları ümumi şəkildə işləyərək yaratdı. Faciə hərəkətin təqlididir. Hərəkəti doğuran 2 səbəb meydana çıxır:

1. Fikir
2. Xarakter

Aristotel bildirirdi ki, fabula hərəkətin təqlid olunmasıdır. Faciədə 6 hissənin olması zəruridir.

- Fabula
- Xarakterlər

- Fikir
- Səhnə şəraiti
- Sözlə ifadə
- Musiqi kompozisiyası

Aristotel faciəni belə təhlil etmişdir: “Faciə insanların təqlidi deyil, hərəkət və həyatın, xoşbəxtlik və bədbəxtliyin təqlididir. Xoşbəxtlik və bədbəxtlik isə hərəkət sayəsində meydana gəlir”. Faciənin məqsədi müəyyən hərəkəti təsvir etməkdir. Hərəkət və fabula faciənin məqsədidir. Faciə hərəkət olmadan keçinə bilməz, xaraktersiz isə keçinə bilər. Faciədə keçmişdə götürülən adlar verilir. Bəzi faciələrdə bir-iki məlum addan başqa qalan adların hamısı uydurma olur. Şair metr (vəzn) yaradıcısı olmaqdan daha çox fabula yaradıcısı olmalıdır, o hərəkəti təqlid edir. Fabula faciənin əsası və bir növ canıdır, xarakterlər isə ondan sonra gəlir. Həddən artıq kiçik varlıqlar gözəl ola bilməz, həddən artıq böyük varlıqlar da gözəl ola bilməz.

Aristotel epik tərkibli faciələr dedikdə çoxfabulalı faciəni nəzərdə tuturdu. Fabula faciədə olduğu kimi əvvəli, ortası, sonu olan müəyyən bir bütöv və bitmiş hərəkəti təmsil edir. Fabula adi təhkiyəyə bənzəməməlidir. Aristotela görə, hər bir faciədə 2 hissə var.

1. Düyün: Dramdan xaric hadisələri və dramın daxilindəki əhvalatların bəzilərini əhatə edir. Faciənin əvvəlindən başlayaraq ta bədbəxtlikdən xoşbəxtliyə, yaxud xoşbəxtlikdən bədbəxtliyə keçid həddi olan nöqtədir.
2. Açıqla: Dramın daxilindəki əhvalatların yerdə qalanlarını əhatə edir. Açıqla keçidin başlanmasından sonadək davam edən hissədir.

Aristotel “Poetika” əsərində faciənin həcm etibarı ilə bölmələri belə müəyyənləşdirmişdir:

- Proloq: faciədə xorun daxil olmasınadək olan tam hissəni əhatə edir.
- Episodiy: faciənin bitkin xor nəğmələri arasında olan tam hissəni əhatə edir.
- Eksod: Faciənin xor nəğməsi olmayan tam hissədir.
- Porod və stasimə bölünən xor hissəsi: Porod I tam xor nitqidir.
- Stasim: anapestasız və troxeyasız xor nəğməsidir.
- Kommos: Xor və aktyorların ümumi hüznü nəğməsidir.

Aristotel “Poetika” əsərində fabulanı belə izah etmişdir ki, fabulanın açılması fabulanın özündən doğmalıdır, yaxşı düzəlmiş fabula sadə olmalıdır və fabula təqlid etdiyi hərəkətlərə əsasən 3 yerə ayrılır:

4. Sadə fabula: Sadə fabula taleyin dəyişməsi, peripetiyalarsız və tanımlarsız olmalıdır. Sadə fabula və hərəkətlər içərisində ən pisi episodik olanlardır. Episodik fabula onun ehtiva etdiyi episodilər bir-birinin

dalınca gəlir, amma heç bir ehtimala və zərurətə əsaslanmır. Daxili məzmunun ziddinə gedib fabulanı uzatmaqla hadisə və hərəkətin təbii sırasını pozmağa məcbur olurlar.

5. Dolaşiq fabula: Taleyin dəyişməsi peripetiya və tanıma ilə olur. Fabulada **peripetiya** hadisələrin öz əksinə geri dönməsidir. Peripetiya ehtimal və zərurət qanunları üzrə olur. Fabulada **tanıma** əsərdəki obrazların bir-birini şəxsən özlərin tanıması deməkdir. Aristotələ görə, tanıma zahiri əlamətlər vasitəsilə yaranır. Yəni tanıma təbiətin özünün verdiyi əlamətlərdir. Bəzən şairin özünün yaratdığı qeyri-bədii, qondarma tanımlar da var. Bu tanımlar fabuladan doğmur. Aristotel deyirdi ki, xatırlama vasitəsilə olan tanımlar, əqli-nəticələrə görə və s. tipli tanımlar da vardır. Tanımlardan ən yaxşısı hadisələrin özündən doğandır. Belə tanımlar müəyyən uydurma əlamətlərsiz başa gəlir.
6. İztirab: Fəciədə məhvə və ya ağrıya bəis olan hərəkətdir. Səhnədə hər cür ölüm, işgəncə, yaralanma və digərləri bura daxildir.

Aristotel “Poetika” əsərində xarakterləri 4 cür xarakterizə etmişdir:

1. Nəcib olsun: Xarakter iradənin nəcib istiqamətini təmsil etməlidir.
2. Yaraşsın: Xakeri mərdanə göstərmək olar, amma mərdanə, zəhimli olmaq qadına yaraşmır.
3. Həqiqətə uyğun olsun.
4. Ardıcıl olsun.

Ədəbiyyat:

1. Xəlid Əlimirzəyev, (2008) “Ədəbiyyatşünaslığın elmi-nəzəri əsasları”, Bakı
2. Mir Cəlal, Pənah Xəlilov, (2005) “Ədəbiyyatşünaslığın əsasları”, Bakı, Çarşıoğlu
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ARTIFICIAL INTELLIGENCE AND SOCIAL ETHICS: IMPLICATIONS FOR HUMAN CAPITAL AND ORGANIZATIONAL CULTURE IN EDUCATIONAL AND RESEARCH INSTITUTIONS

PhD Petronela Daniela FERARU¹

Abstract

This paper examines the accelerated integration of artificial intelligence (AI) within educational and research institutions, focusing on its implications for human capital development, organizational culture, and social ethics. Grounded in knowledge economy theory and scholarship on labour automation, the study analyses how AI reshapes the production, validation, and dissemination of knowledge. While AI-based technologies can enhance analytical capacity, streamline institutional processes, support data-driven decision-making, and generate new professional roles, they also raise ethical concerns related to algorithmic bias, the erosion of professional autonomy, labour displacement, and the potential homogenization of epistemic diversity through automated systems. The study further explores tensions between technological promise and socio-cultural complexity by examining how AI affects academic identity, collegial relations, and governance mechanisms when embedded in teaching, research management, and institutional evaluation. Methodologically, the paper adopts a cross-sectional approach and draws on survey-based evidence to assess perceptions of AI across key institutional dimensions. The findings suggest that AI adoption requires a balanced strategy prioritizing ethical accountability, collective governance, and sustained investment in staff professional development. The paper argues that AI-driven transformation is not merely technological but profoundly sociological, reshaping relationships between individuals, institutions, and the production of scientific knowledge.

Keywords: artificial intelligence, organizational culture, human capital, social ethics, automation

¹ Petronela Daniela FERARU is a PhD in Sociology and a teacher at the National College Iași and “Ion Neculce” High School, Targu Frumos, Iasi County, Romania. E-mail: daniela_feraru_p@yahoo.com

1. Introduction

The rapid expansion of artificial intelligence (AI) technologies has become one of the defining features of contemporary societies, profoundly transforming the production, circulation, and validation of knowledge across institutional contexts. Situated at the intersection of digitalization, automation, and the knowledge economy, AI is no longer a peripheral technological tool but an increasingly central actor in organizational decision-making, academic labour, and institutional governance. As academic institutions integrate algorithmic systems into teaching, evaluation, data management, and research processes, the sociological implications of this transformation demand systematic and critical examination (Brynjolfsson & McAfee, 2014; OECD, 2021).

From a sociological perspective, the integration of AI reshapes not only technical workflows but also the social architecture of institutions. Educational and research organizations have traditionally relied on professional autonomy, collegial governance, and epistemic plurality as core cultural values. The introduction of AI-based systems—such as automated assessment tools, predictive analytics, research evaluation algorithms, and learning management platforms—reconfigures these values by embedding decision-making processes within opaque technological infrastructures. This shift raises fundamental questions regarding the redefinition of academic authority, the redistribution of symbolic and professional capital, and the transformation of organizational culture in knowledge-intensive environments (Bourdieu, 1988; Musselin, 2007).

At the same time, AI technologies are widely promoted as instruments for enhancing efficiency, objectivity, and innovation. In educational and research settings, algorithmic systems are credited with expanding analytical capacity, optimizing institutional performance, supporting evidence-based governance, and fostering new forms of human capital development aligned with digital competencies and interdisciplinary skills (Becker, 1993; World Economic Forum, 2020). These narratives resonate strongly with the logic of the knowledge economy, in which human capital, innovation, and technological adaptability are positioned as primary drivers of institutional competitiveness and social progress.

However, alongside these promises, a growing body of critical literature highlights the ethical and social risks associated with the institutionalization of AI. Algorithmic bias, data asymmetries, surveillance practices, and the potential deskilling or displacement of academic labour represent significant challenges for educational and research organizations (Eubanks, 2018; Noble, 2018). Moreover, the reliance on standardized, data-driven systems may contribute to the homogenization of epistemic practices, privileging quantifiable outputs over reflexive, critical, and context-sensitive forms of knowledge production. In this sense, AI does not merely

automate tasks but actively participates in shaping what counts as legitimate knowledge, merit, and academic performance.

Within organizational contexts, these transformations generate tensions between efficiency-oriented governance models and the normative foundations of academic culture. The increasing delegation of evaluative and managerial functions to algorithmic systems can erode professional autonomy, alter collegial relations, and redefine trust within institutions. Scholars have argued that such shifts risk transforming universities and research organizations into data-driven bureaucracies, where algorithmic authority competes with professional judgment and ethical deliberation (Power, 1997; Kitchin, 2017). Consequently, AI-driven change must be understood as a sociotechnical process embedded in power relations, institutional norms, and broader socio-economic dynamics.

Despite the expanding literature on AI and digital transformation, empirical sociological research focusing specifically on the intersection between artificial intelligence, human capital development, organizational culture, and social ethics in educational and research institutions remains fragmented. Much of the existing research prioritizes technical performance, policy frameworks, or macroeconomic effects, while offering limited insight into how AI reshapes everyday institutional practices, academic identities, and collective governance structures. Addressing this gap is essential for understanding the long-term implications of AI-driven transformation within knowledge-producing organizations.

Against this background, the present study aims to examine the sociological implications of artificial intelligence integration in educational and research institutions, with particular attention to its impact on human capital, organizational culture, and ethical governance. The research adopts a cross-sectional analytical perspective to explore how AI-based systems influence institutional practices, professional relations, and normative frameworks within contemporary educational and research environments. By situating AI within broader theories of the knowledge economy, labour automation, and organizational sociology, the paper seeks to contribute to ongoing debates regarding the social responsibility of technological innovation and the future of academic institutions in algorithmically mediated societies.

2. Theoretical Framework

The sociological analysis of artificial intelligence in educational and research institutions requires an integrated theoretical framework that connects technological change to broader transformations in the knowledge economy, labour structures, organizational culture, and ethical governance. AI-based systems do not operate in a social vacuum; rather, they are embedded within institutional logics, power relations, and normative

frameworks that shape both their implementation and their consequences. From this perspective, artificial intelligence must be understood not merely as a set of technical tools but as a structural force that reconfigures human capital, professional identities, and organizational values.

Classical and contemporary sociological theories provide essential analytical resources for interpreting these dynamics. Human capital theory highlights the role of education, skills, and competencies in economic and institutional performance, while organizational sociology emphasizes the cultural and normative dimensions of institutional change. At the same time, critical approaches to automation and algorithmic governance draw attention to issues of inequality, control, and ethical accountability in technologically mediated environments. Bringing these perspectives together allows for a multidimensional understanding of AI as both an enabling and a disruptive force within educational and research institutions.

This chapter outlines the main theoretical lenses that inform the present study. It begins by situating artificial intelligence within the broader context of the knowledge economy, followed by an examination of human capital transformation under conditions of automation. Subsequently, it addresses organizational culture and algorithmic governance, before turning to the ethical implications of AI integration in academic and research settings.

2.1. Artificial Intelligence and the Knowledge Economy

The concept of the knowledge economy has become central to understanding contemporary social and institutional transformations, particularly in sectors where education, research, and innovation play a pivotal role. In this economic paradigm, knowledge production, information processing, and intellectual capital are primary sources of value creation, surpassing traditional factors such as physical labour or material resources (Powell & Snellman, 2004). Artificial intelligence emerges as a key technological driver within this context, amplifying the capacity of institutions to generate, manage, and exploit knowledge at unprecedented scales.

From a sociological standpoint, AI extends the logic of the knowledge economy by accelerating processes of datafication, quantification, and algorithmic reasoning. Educational and research institutions increasingly rely on AI-based systems for data analysis, learning analytics, research evaluation, and strategic planning. These technologies reshape how knowledge is produced and validated, increasingly privileging computational efficiency, predictive accuracy, and measurable outputs. As a result, institutional success becomes closely tied to the ability to integrate algorithmic tools into core academic functions, reinforcing a performance-oriented model of knowledge production (Castells, 2010).

However, the incorporation of AI into the knowledge economy also alters the social relations underpinning academic work. Knowledge production is no longer exclusively the result of human intellectual labour but increasingly the outcome of human–machine collaboration. This shift challenges traditional distinctions between expert judgment and technical processing, raising questions about authorship, responsibility, and epistemic authority. Scholars argue that algorithmic systems can subtly redefine what counts as legitimate knowledge by embedding specific assumptions, classifications, and priorities into their design (Kitchin, 2014; Beer, 2017).

Moreover, the knowledge economy framework often promotes narratives of innovation, competitiveness, and efficiency that obscure underlying power asymmetries. While AI technologies promise enhanced productivity and institutional optimization, they may also intensify inequalities between institutions with unequal access to technological resources, data infrastructures, and specialized expertise. In this sense, AI can function as a mechanism of stratification within the global academic field, reinforcing existing hierarchies between well-resourced research centers and peripheral institutions (Marginson, 2016).

Critically, the expansion of AI within the knowledge economy redefines the role of educational and research institutions themselves. Universities and research organizations are increasingly positioned as data-driven enterprises, expected to align academic missions with market-oriented logics and technological innovation agendas. This transformation risks marginalizing reflexive, critical, and socially oriented forms of knowledge in favour of instrumental and commercially valuable outputs. Consequently, understanding AI within the knowledge economy requires attention not only to economic efficiency but also to the cultural and ethical dimensions of institutional change.

Within this context, the transformation of human capital emerges as a central mechanism through which artificial intelligence reshapes academic work and institutional performance.

2.2. Human Capital in the Age of Automation

Human capital theory provides a foundational framework for understanding the implications of artificial intelligence within educational and research institutions, particularly in relation to skills formation, professional development, and institutional performance. Traditionally conceptualized as the accumulation of education, knowledge, competencies, and experience that enhance individual productivity, human capital has been central to both economic and sociological analyses of education and labour markets (Becker, 1993). In the context of AI-driven automation, however, the nature, value, and governance of human capital undergo significant transformation.

Artificial intelligence alters the demand for skills by reshaping the division of labour between humans and machines. In educational and research institutions, routine cognitive tasks—such as data processing, grading, bibliometric analysis, and administrative reporting—are increasingly automated, while complex, non-routine activities involving critical thinking, ethical judgment, creativity, and interpersonal interaction gain prominence. This reconfiguration places pressure on institutions to invest in continuous professional development, emphasizing digital literacy, interdisciplinary competencies, and adaptive learning capacities among academic staff (Autor, Levy, & Murnane, 2003; World Economic Forum, 2020).

From a sociological perspective, the automation of academic work raises concerns regarding the potential deskilling of professionals. While AI systems can augment analytical capacity and reduce administrative burdens, they may also diminish opportunities for experiential learning and professional discretion if over-relied upon. The delegation of evaluative or pedagogical functions to algorithmic systems risks transforming academic roles into supervisory or technical positions, thereby narrowing the scope of professional autonomy and weakening the symbolic capital traditionally associated with academic expertise (Freidson, 2001; Susskind & Susskind, 2015).

At the same time, AI-driven transformation generates new forms of human capital that are unevenly distributed across institutional and social contexts. Access to advanced technological infrastructure, training programs, and interdisciplinary collaboration significantly influences who benefits from AI integration. Researchers and educators equipped with advanced digital competencies are more likely to experience AI as an enabling resource, while those lacking institutional support may face marginalization or increased precarity. This dynamic contributes to the stratification of academic labour markets, reinforcing inequalities along generational, disciplinary, and institutional lines (Brown, Lauder, & Ashton, 2011).

Moreover, the redefinition of human capital in the age of automation extends beyond individual skills to encompass collective and organizational capacities. Institutions increasingly value teams capable of integrating human expertise with algorithmic systems, fostering collaborative knowledge production across disciplinary boundaries. In this sense, human capital becomes relational and embedded within organizational cultures that support learning, experimentation, and ethical reflection. However, when institutional strategies prioritize technological efficiency over professional development, investments in human capital risk becoming narrowly instrumental, undermining long-term academic sustainability.

Critically, the discourse surrounding AI and human capital often emphasizes adaptability and lifelong learning while downplaying issues of power and responsibility. Sociological critiques argue that framing

automation as an inevitable technological progression shifts the burden of adjustment onto individuals, obscuring the role of institutional governance and policy choices in shaping labour outcomes. Within educational and research institutions, this narrative may legitimize intensified performance pressures and the individualization of risk, rather than fostering collective approaches to professional development and ethical accountability (Standing, 2011). In this context, institutional strategies that prioritize technological efficiency without parallel investments in training and participatory governance risk deepening professional inequalities and undermining long-term organizational resilience.

In sum, the transformation of human capital under conditions of AI-driven automation represents a complex and ambivalent process. While artificial intelligence offers opportunities for skill enhancement, innovation, and organizational learning, it also poses risks related to deskilling, inequality, and the erosion of professional autonomy. Understanding these dynamics is essential for developing institutional strategies that align technological innovation with ethical responsibility and sustainable human capital development in educational and research environments.

2.3. Organizational Culture and Algorithmic Governance

Organizational culture constitutes a central analytical dimension for understanding how artificial intelligence reshapes educational and research institutions. Defined as the set of shared values, norms, practices, and symbolic meanings that structure institutional life, organizational culture mediates the ways in which technological innovations are interpreted, adopted, and institutionalized (Schein, 2010). In academic environments, organizational culture has traditionally been grounded in principles such as professional autonomy, collegial decision-making, academic freedom, and epistemic pluralism. The growing integration of AI-based systems introduces new governance logics that interact—often tensely—with these established cultural foundations.

Algorithmic governance refers to the increasing reliance on automated systems, data analytics, and computational models to support or replace human decision-making within organizations. In educational and research institutions, algorithmic governance manifests through performance evaluation metrics, learning analytics, research assessment tools, and predictive models used in strategic planning and resource allocation. These systems promise objectivity, transparency, and efficiency; however, sociological research suggests that they also embed normative assumptions and power relations that may remain opaque to institutional actors (Kitchin, 2017; Yeung, 2018).

The expansion of algorithmic governance has significant implications for organizational culture, particularly in relation to professional autonomy and trust. When evaluative judgments are increasingly mediated by algorithms, academic staff may experience a shift from collegial forms of accountability to technocratic oversight. This transition can weaken informal norms of peer evaluation and replace them with standardized performance indicators, reshaping how merit, excellence, and productivity are defined and recognized within institutions (Power, 1997). As a result, academic organizational culture may evolve toward compliance-oriented practices, prioritizing metric alignment over intellectual risk-taking and critical inquiry.

Furthermore, algorithmic governance influences social relations and communication patterns within institutions. The use of data dashboards, rankings, and automated feedback systems alters how individuals perceive their professional standing and how they relate to colleagues. Competition may intensify as performance becomes more visible and continuously monitored, potentially undermining collaborative cultures and reinforcing individualistic orientations. Such dynamics are particularly salient in research environments, where algorithmic metrics increasingly shape funding decisions, career trajectories, and institutional reputation (Espeland & Stevens, 2008).

At the same time, organizational responses to AI-driven governance are not uniform. Institutional cultures characterized by participatory leadership, strong ethical norms, and reflexive practices may integrate algorithmic systems in ways that support professional judgment rather than replace it. In these contexts, AI tools are more likely to be framed as decision-support mechanisms, complementing human expertise and fostering collective learning. Conversely, in organizations with hierarchical governance structures and weak deliberative cultures, algorithmic systems may reinforce top-down control and exacerbate power asymmetries (Aneesh, 2009).

Importantly, algorithmic governance also raises questions about accountability and transparency within educational and research institutions. Decision-making processes embedded in proprietary or complex AI systems may be difficult to scrutinize, limiting opportunities for contestation and ethical deliberation. This opacity challenges traditional mechanisms of institutional legitimacy, which rely on shared understanding, procedural fairness, and the possibility of reasoned critique. From a sociological standpoint, these developments underscore the need to examine how organizational cultures adapt—or resist—the normalization of algorithmic authority.

In sum, the interaction between organizational culture and algorithmic governance represents a critical site of sociological inquiry in the context of AI integration. While algorithmic systems have the potential to

enhance institutional coordination and evidence-based decision-making, their impact on academic culture depends largely on how they are embedded within existing norms, values, and governance practices. Understanding these dynamics is essential for assessing whether AI-driven transformation strengthens or undermines the social foundations of educational and research institutions.

2.4. Social Ethics, Academic Autonomy and Epistemic Diversity

The ethical implications of artificial intelligence represent a central concern in sociological analyses of digital transformation, particularly within educational and research institutions where normative commitments to autonomy, integrity, and epistemic plurality are foundational. Social ethics, understood as the collective evaluation of technological practices in relation to social values, justice, and responsibility, provides a critical lens for examining how AI systems reshape institutional norms and professional conduct (Floridi et al., 2018). In academic contexts, ethical considerations extend beyond individual behavior to encompass institutional governance, accountability mechanisms, and the societal role of knowledge production.

One of the most pressing ethical challenges associated with AI integration is its impact on academic autonomy. Autonomy has long been regarded as a defining feature of academic professions, enabling scholars and educators to exercise independent judgment in teaching, research, and evaluation. The increasing reliance on algorithmic systems for assessment, monitoring, and decision-making introduces new constraints on this autonomy by embedding predefined criteria and priorities into technical infrastructures. As a result, academic discretion may be gradually subordinated to algorithmic logic, limiting the capacity of professionals to contest or reinterpret institutional norms (Foucault, 1977; Shore & Wright, 2015).

Closely related to concerns about autonomy is the issue of epistemic diversity. Educational and research institutions play a crucial role in sustaining diverse forms of knowledge, methodologies, and perspectives. However, AI systems often rely on standardized datasets, classification schemes, and optimization models that favor dominant paradigms and measurable outputs. This standardization risks marginalizing alternative epistemologies, critical approaches, and context-sensitive forms of inquiry that do not easily conform to algorithmic evaluation. Scholars warn that such processes may lead to a form of epistemic homogenization, where diversity of thought is constrained by technological design choices and data availability (Noble, 2018; O'Neil, 2016).

From a social ethics perspective, algorithmic bias constitutes another significant concern. AI systems trained on historical or incomplete data can reproduce and amplify existing social inequalities, affecting decisions related to recruitment, evaluation, funding, and academic recognition. In educational and research

settings, biased algorithms may disproportionately disadvantage certain disciplines, demographic groups, or institutional profiles, undermining principles of fairness and inclusivity. Addressing these risks requires not only technical solutions but also ethical oversight and participatory governance structures that involve diverse institutional stakeholders (Eubanks, 2018).

Moreover, the ethical governance of AI raises questions about responsibility and accountability. When decisions are mediated by complex algorithmic systems, it becomes increasingly difficult to attribute responsibility for outcomes, particularly in cases of error, exclusion, or harm. This diffusion of responsibility challenges traditional ethical frameworks based on human agency and intentionality. Sociological analyses emphasize the need for collective forms of accountability that recognize the distributed nature of decision-making in AI-mediated environments, while preserving the possibility of ethical deliberation and institutional critique (Latour, 2005; Yeung, 2018).

Importantly, ethical approaches to AI in educational and research institutions must balance innovation with social responsibility. While technological advancement is often framed as an ethical imperative in itself, sociological perspectives caution against equating innovation with progress. Instead, ethical AI governance should prioritize transparency, inclusivity, and the protection of professional autonomy, ensuring that technological systems serve institutional missions rather than redefine them unilaterally. This requires sustained investment in ethical literacy, interdisciplinary dialogue, and reflexive organizational cultures capable of critically engaging with AI-driven change.

In conclusion, the intersection of social ethics, academic autonomy, and epistemic diversity constitutes a critical terrain for evaluating the sociological impact of artificial intelligence in educational and research institutions. AI-driven transformation is not value-neutral; it actively reshapes the moral and epistemic foundations of academic life. Understanding these dynamics is essential for developing governance frameworks that align technological innovation with democratic values, social justice, and the long-term sustainability of knowledge-producing organizations.

These theoretical considerations provide the analytical foundation for the empirical investigation presented in the following sections.

3. Methodology

3.1. Research Design

The present study employs a **cross-sectional research design**, aiming to capture a systematic snapshot of perceptions, practices, and institutional dynamics related to the integration of artificial intelligence within

educational and research institutions. Cross-sectional studies are particularly suitable for sociological analyses that seek to examine patterns, relationships, and variations across defined populations at a specific point in time, without implying causal inference (Creswell, 2014).

This design allows for the comparative analysis of attitudes toward AI, perceptions of ethical risks, and assessments of organizational culture as they coexist within contemporary institutional contexts. Given the accelerated pace of AI adoption in education and research, a cross-sectional approach provides valuable empirical insight into how technological transformation is currently negotiated at the institutional and professional levels.

3.2. Population and Unit of Analysis

The target population of the study consists of professionals affiliated with **educational and research institutions**, including teaching staff, researchers, and individuals involved in academic management and institutional governance. These categories were selected due to their direct engagement with AI-based systems in pedagogical, research, evaluative, or administrative processes.

The **unit of analysis** is the individual respondent, whose perceptions and experiences offer insight into broader organizational and cultural patterns. At the same time, the aggregation of individual responses enables the examination of institutional-level tendencies regarding human capital development, organizational culture, and ethical governance in AI-mediated environments.

3.3. Data Collection Method and Instrument

Data were collected using a structured **survey questionnaire**, designed to capture multiple dimensions of AI integration within educational and research institutions. The questionnaire included both closed-ended items and Likert-type scales, allowing for quantitative assessment of respondents' perceptions, attitudes, and evaluations.

The instrument was structured around several analytical dimensions derived from the theoretical framework: perceptions of AI's impact on professional roles and human capital; assessments of organizational culture and decision-making processes; evaluations of ethical risks associated with AI use; attitudes toward institutional governance and accountability mechanisms.

The questionnaire was administered during a defined data collection period, ensuring consistency in contextual conditions across respondents. Participation was voluntary, and respondents were informed about the academic purpose of the study.

3.4. Variables and Analytical Dimensions

Based on the theoretical framework, the study operationalized key sociological constructs into measurable variables. The main analytical dimensions include: **Human capital transformation**, operationalized through indicators related to skills development, professional autonomy, and perceived changes in academic roles; **Organizational culture**, measured through items assessing collegiality, trust, transparency, and attitudes toward algorithmic decision-making; **Ethical perceptions of AI**, including concerns about bias, fairness, accountability, and data governance; **Institutional governance**, capturing perceptions of participation, oversight, and responsibility in AI-related decisions.

These variables allow for a multidimensional analysis of AI integration, connecting individual-level perceptions with broader institutional and ethical dynamics.

3.5. Data Analysis Strategy

The data analysis focused on **descriptive and comparative statistical procedures**, appropriate for cross-sectional survey research. Frequencies, percentages, and measures of central tendency were used to summarize respondents' views across the main analytical dimensions.

Comparative analyses were employed to identify patterns and contrasts between categories of respondents, highlighting variations in perceptions related to professional role, institutional position, or experience with AI-based systems. The analytical strategy was designed to support sociological interpretation rather than predictive modeling, emphasizing the contextual and normative dimensions of AI adoption in educational and research institutions (Bryman, 2016).

3.6. Ethical Considerations

Ethical considerations were central to the research process. The study adhered to principles of informed consent, confidentiality, and anonymity. No personally identifiable information was collected, and respondents were assured that their participation would not affect their professional standing.

Given the sensitivity of issues related to institutional governance and ethical evaluation of AI, particular care was taken to frame questions in a non-intrusive and neutral manner. The research design aligns with ethical standards for sociological research and reflects the study's broader commitment to ethical accountability in the analysis of AI-driven institutional transformation (Israel & Hay, 2006).

3.7. Methodological Limitations

As a cross-sectional study, the research captures perceptions and institutional dynamics at a specific point in time and does not allow for causal inference or longitudinal analysis. Additionally, the reliance on self-

reported data may introduce subjective bias, reflecting respondents' individual experiences and institutional contexts.

Despite these limitations, the methodological approach provides valuable insight into current sociological patterns associated with AI integration in educational and research institutions. The findings offer a robust empirical foundation for interpreting the ethical, cultural, and organizational implications of AI within contemporary knowledge-producing organizations.

4. Results

This chapter presents the empirical findings of the study, structured around the main analytical dimensions derived from the theoretical framework: human capital transformation, organizational culture, ethical perceptions of artificial intelligence, and institutional governance in educational and research environments. The results are based on the analysis of data collected through the cross-sectional survey and aim to provide a systematic overview of respondents' perceptions and evaluations regarding the integration of AI within their institutions.

The presentation of results follows a structured and progressive logic, allowing for both descriptive and interpretative analysis. Each figure addresses a specific analytical dimension and is accompanied by a brief introduction, a detailed description of the empirical distributions, and a sociological interpretation that situates the findings within broader institutional and ethical contexts. This approach facilitates the connection between empirical data and the theoretical perspectives discussed in the previous chapters.

The results do not seek to establish causal relationships but rather to identify patterns, tendencies, and contrasts in how artificial intelligence is perceived and experienced across educational and research institutions. By foregrounding institutional dynamics and professional perspectives, the chapter contributes to a nuanced understanding of the social implications of AI-driven transformation in contemporary knowledge-producing organizations.

Figure 1 illustrates respondents' assessments of the extent to which artificial intelligence influences professional roles within educational and research institutions. The figure captures a continuum of perceived impact, ranging from no perceived influence to very high levels of transformation, offering insight into how AI is positioned within everyday professional practices.

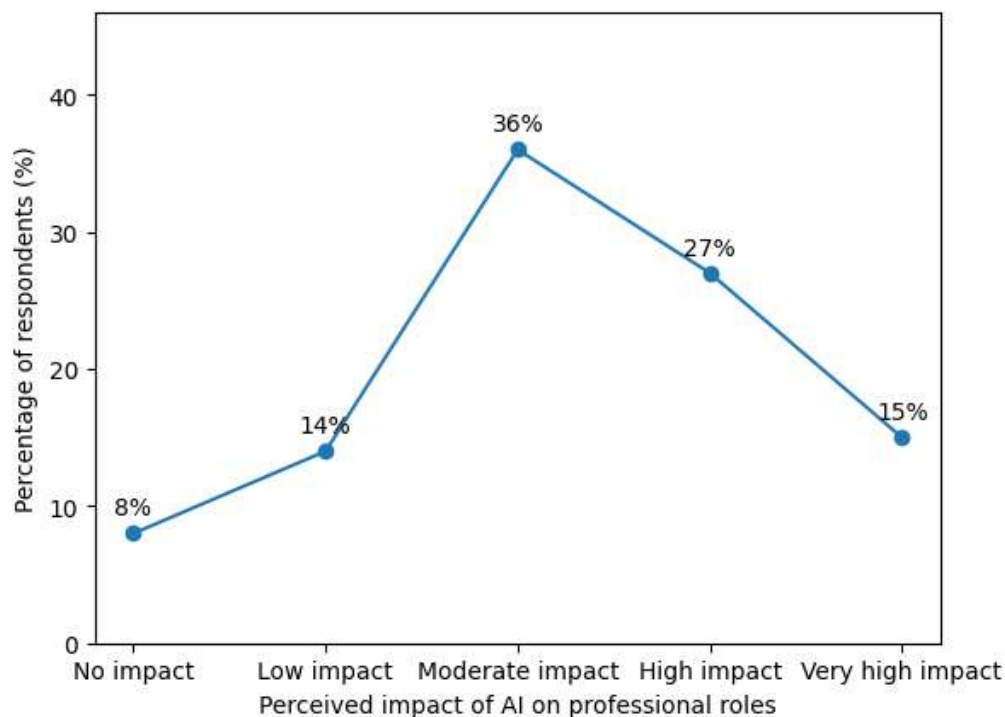


Figure 1. Perceived impact of artificial intelligence on professional roles in educational and research institutions

Note. Percentages represent respondents' distribution across perceived levels of AI impact on professional roles.

Source. Authors' own research (cross-sectional survey).

The data presented in Figure 1 show that the largest proportion of respondents perceive the impact of artificial intelligence on professional roles as **moderate (36%)**, followed by those who report a **high impact (27%)**. A smaller yet significant share indicates a **very high impact (15%)**, suggesting the presence of institutional contexts where AI plays a more transformative role. Lower levels of perceived impact are reported by **14%** of respondents, while **8%** consider that AI has no impact on their professional activity. The overall trend line highlights a concentration of responses in the medium-to-high impact range.

Sociologically, the distribution observed in Figure 1 reflects a phase of negotiated adaptation to AI-driven transformation within educational and research institutions. The predominance of moderate impact perceptions indicates that artificial intelligence is largely experienced as an embedded organizational tool rather than a disruptive force, supporting existing professional practices while gradually reshaping them. This pattern is consistent with incremental models of technological change, where institutional norms and professional identities evolve through accommodation rather than rupture.

The presence of a substantial proportion of respondents perceiving high or very high impact suggests emerging zones of intensified algorithmic mediation, particularly in areas related to evaluation, administrative coordination, or research management. These perceptions may signal processes of role redefinition and increased reflexivity among academic professionals, who are required to reconcile traditional norms of autonomy with data-driven governance structures.

At the lower end of the distribution, limited or absent perceptions of AI impact point to uneven institutional diffusion and differentiated access to technological resources. Such heterogeneity reinforces sociological arguments regarding stratification within the academic field, where organizational capacity and governance strategies shape distinct experiences of digital transformation. Overall, Figure 1 underscores the ambivalent and stratified character of AI integration, highlighting its role as both a stabilizing and transformative force in contemporary academic work.

Figure 2 presents respondents' evaluations of artificial intelligence as a driver of skills development and human capital enhancement within educational and research institutions. This dimension was included to assess whether AI is perceived primarily as a resource for professional learning and competence development or as a neutral or contested factor in institutional contexts.

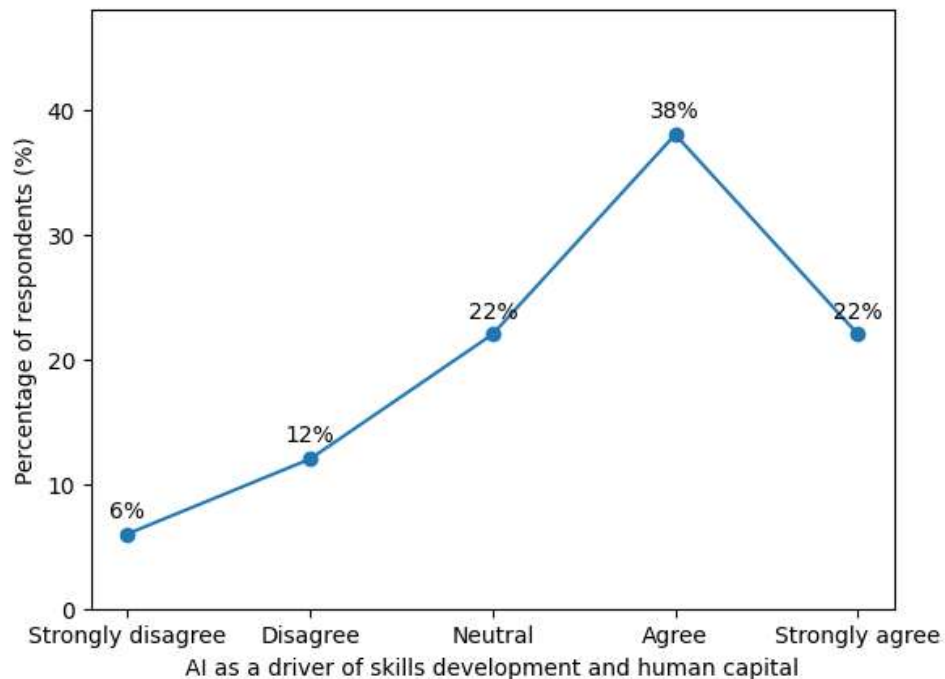


Figure 2. Perceptions of artificial intelligence as a driver of skills development and human capital enhancement

Note. Percentages reflect respondents' levels of agreement regarding the role of artificial intelligence in supporting skills development and human capital formation.

Source. Authors' own research (cross-sectional survey).

The data displayed in Figure 2 indicate that a clear majority of respondents associate artificial intelligence with positive effects on skills development. A total of **38%** of respondents agree that AI supports human capital enhancement, while an additional **22%** strongly agree with this assessment. Neutral positions are expressed by **22%** of respondents, suggesting ambivalence or conditional acceptance of AI's role in professional learning. Lower levels of agreement are reported by **12%** of respondents who disagree and **6%** who strongly disagree. The trend line highlights a concentration of responses toward the agreement end of the scale.

From a sociological perspective, the distribution observed in Figure 2 reflects the growing normalization of AI as a legitimate component of professional development in knowledge-intensive institutions. The predominance of agreement suggests that many educators and researchers perceive AI not merely as an efficiency-enhancing tool but as a catalyst for reskilling and continuous learning. This finding aligns with contemporary theories of human capital that emphasize adaptability, lifelong learning, and the accumulation of digital competencies in response to technological change.

At the same time, the presence of a substantial neutral segment points to uncertainty regarding the conditions under which AI contributes to meaningful skill development. This ambivalence may reflect disparities in access to training, uneven institutional support, or concerns about the relevance of AI-mediated learning to disciplinary-specific expertise. Sociologically, such patterns indicate that human capital enhancement through AI is not automatic but mediated by organizational culture and governance strategies.

The minority of respondents expressing disagreement highlights the persistence of critical perspectives toward AI-driven professional learning. These views may be associated with concerns about deskilling, over-standardization, or the instrumentalization of education. Collectively, the findings illustrated in Figure 2 underscore the contested yet predominantly optimistic framing of AI as a driver of human capital development within educational and research institutions.

Figure 3 examines respondents' perceptions of how artificial intelligence affects organizational culture and collegial relations in educational and research institutions. This dimension was included to explore whether

AI-based systems are perceived as reinforcing collaboration, transparency, and shared norms, or as generating tensions, fragmentation, and reduced interpersonal engagement within institutional environments.

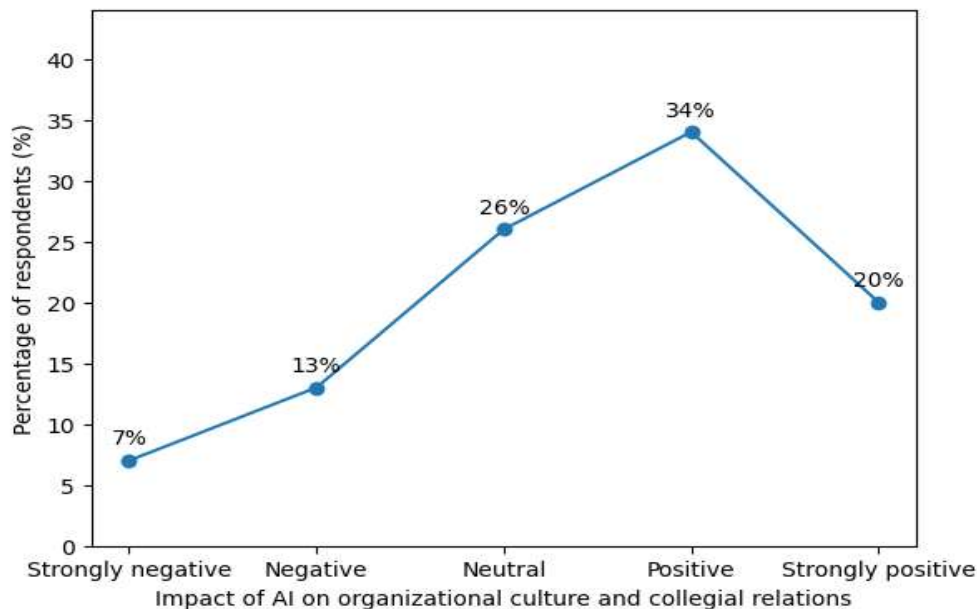


Figure 3. Perceptions of the impact of artificial intelligence on organizational culture and collegial relations

Note. Percentages reflect respondents' evaluations of the influence of artificial intelligence on organizational culture and collegial interactions within educational and research institutions.

Source. Authors' own research (cross-sectional survey).

The data presented in Figure 3 indicate that a plurality of respondents perceive the impact of artificial intelligence on organizational culture as **positive (34%)**, while an additional **20%** characterize it as **strongly positive**. Neutral evaluations account for **26%** of responses, suggesting ambivalence or context-dependent assessments of AI's influence. Negative perceptions are expressed by **13%** of respondents, and **7%** report a strongly negative impact. The overall trend line shows a gradual shift toward positive evaluations, with a noticeable peak in the positive category.

Sociologically, the distribution illustrated in Figure 3 suggests that artificial intelligence is increasingly integrated into organizational cultures in ways that are perceived as supportive rather than disruptive. Positive evaluations may reflect experiences where AI facilitates coordination, information sharing, and administrative efficiency, thereby enabling more structured and predictable organizational interactions. In such contexts, AI functions as an infrastructural resource that stabilizes institutional routines and supports collective action.

However, the substantial proportion of neutral responses points to ongoing uncertainty regarding the cultural implications of AI integration. This ambivalence may arise from tensions between efficiency-oriented technological systems and the relational, informal dimensions of collegial life that characterize academic organizations. AI-driven processes may coexist with traditional cultural norms without fully reshaping them, resulting in hybrid organizational cultures.

Negative and strongly negative perceptions, although less prevalent, signal areas of cultural strain. These responses may be associated with experiences of increased surveillance, reduced face-to-face interaction, or intensified performance monitoring, which can undermine trust and collegial solidarity. From a sociological perspective, such patterns highlight the importance of governance arrangements and cultural mediation in shaping the organizational consequences of AI adoption.

Overall, Figure 3 underscores the differentiated cultural effects of artificial intelligence within educational and research institutions. Rather than producing uniform outcomes, AI interacts with existing organizational norms and power relations, contributing to both cultural reinforcement and contestation.

Figure 4 presents respondents' perceptions of the ethical risks associated with the use of artificial intelligence in educational and research institutions. This figure addresses the normative dimension of AI integration, focusing on concerns related to fairness, accountability, transparency, and the potential social consequences of algorithmic systems in academic environments.

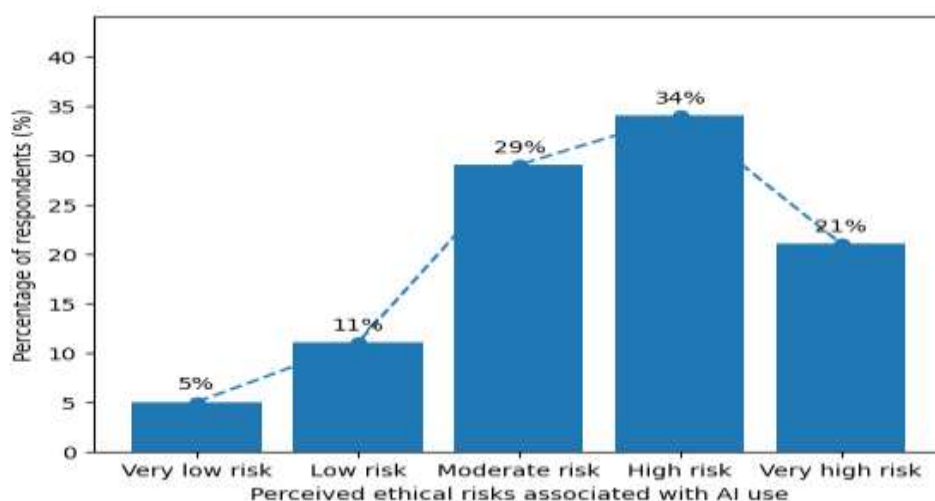


Figure 4. Perceptions of ethical risks associated with the use of artificial intelligence in educational and research institutions

Note. Percentages indicate respondents' assessments of the level of ethical risk associated with the institutional use of artificial intelligence.

Source. Authors' own research (cross-sectional survey).

The data displayed in Figure 4 show that ethical concerns are prominently present among respondents. A combined **55%** of respondents perceive the ethical risks of AI as **high (34%)** or **very high (21%)**, indicating a strong awareness of potential normative challenges. **29%** of respondents assess the risks as moderate, suggesting cautious acceptance of AI under certain conditions. In contrast, lower levels of perceived risk are reported by **11%** of respondents, while only **5%** consider the ethical risks to be very low.

From a sociological perspective, the distribution illustrated in Figure 4 highlights ethics as a central axis of AI-related concern within educational and research institutions. The predominance of high and very high risk perceptions reflects anxieties regarding algorithmic bias, data governance, surveillance practices, and the erosion of professional and institutional accountability. These concerns resonate with critical sociological approaches that emphasize the moral and political dimensions of technological governance.

The substantial proportion of moderate risk assessments suggests a conditional acceptance of AI, where respondents recognize both its potential benefits and its ethical vulnerabilities. This ambivalence points to the importance of institutional safeguards, transparent governance frameworks, and participatory decision-making processes in shaping ethical evaluations of AI.

Lower risk perceptions, while limited, may reflect contexts in which AI systems are narrowly applied, well-regulated, or perceived as supplementary rather than authoritative. Overall, Figure 4 underscores that ethical considerations are not peripheral but integral to how artificial intelligence is socially interpreted and institutionally negotiated in academic settings.

Figure 5 examines respondents' perceptions regarding the impact of artificial intelligence on academic autonomy within educational and research institutions. This dimension addresses a core normative principle of academic life, focusing on whether AI-based systems are perceived as constraining, neutral, or supportive of professional independence in pedagogical and research activities.

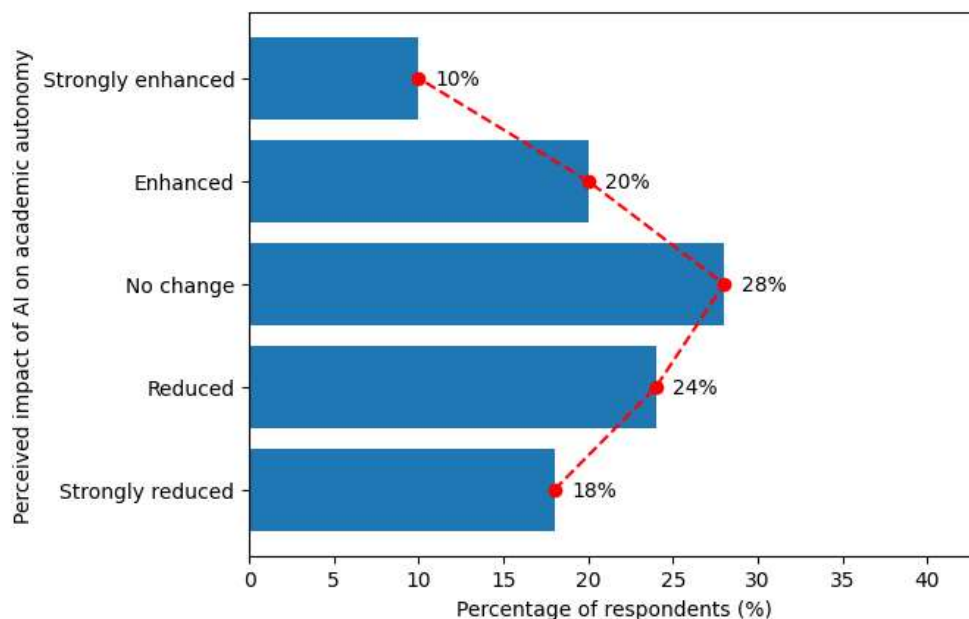


Figure 5. Perceptions of the impact of artificial intelligence on academic autonomy

Note. Percentages represent respondents' assessments of how artificial intelligence affects academic autonomy in teaching, research, and evaluative practices.

Source. Authors' own research (cross-sectional survey).

The data presented in Figure 5 indicate a diversified distribution of perceptions. A combined **42%** of respondents perceive artificial intelligence as having a **reducing effect** on academic autonomy, with **18%** reporting a strongly reduced impact and **24%** indicating a reduced impact. The largest single category, **28%**, reports no significant change in autonomy, suggesting institutional contexts where AI is integrated without fundamentally altering professional discretion. In contrast, **20%** of respondents perceive AI as enhancing academic autonomy, while **10%** report a strongly enhanced effect.

From a sociological perspective, the distribution illustrated in Figure 5 highlights the contested nature of academic autonomy in AI-mediated institutional environments. The relatively high proportion of respondents perceiving a reduction in autonomy reflects concerns about algorithmic oversight, standardized evaluation criteria, and the growing influence of data-driven governance mechanisms. These perceptions resonate with critical sociological accounts that view automation as a potential source of professional constraint rather than empowerment.

The prominence of neutral responses suggests that autonomy is often negotiated rather than uniformly diminished, depending on how AI systems are embedded within organizational practices. In institutions where

AI functions as a decision-support tool rather than a decision-making authority, professional autonomy may remain largely intact.

Positive perceptions of enhanced autonomy, although less prevalent, indicate contexts in which AI reduces administrative burdens, facilitates access to information, or supports individualized pedagogical strategies. Overall, Figure 5 underscores that the impact of artificial intelligence on academic autonomy is neither uniform nor deterministic, but mediated by institutional culture, governance arrangements, and professional norms.

Figure 6 examines respondents' levels of trust in algorithmic decision-making within educational and research institutions. Trust is conceptualized as a key mediating factor in the legitimacy and acceptance of AI-driven governance mechanisms.

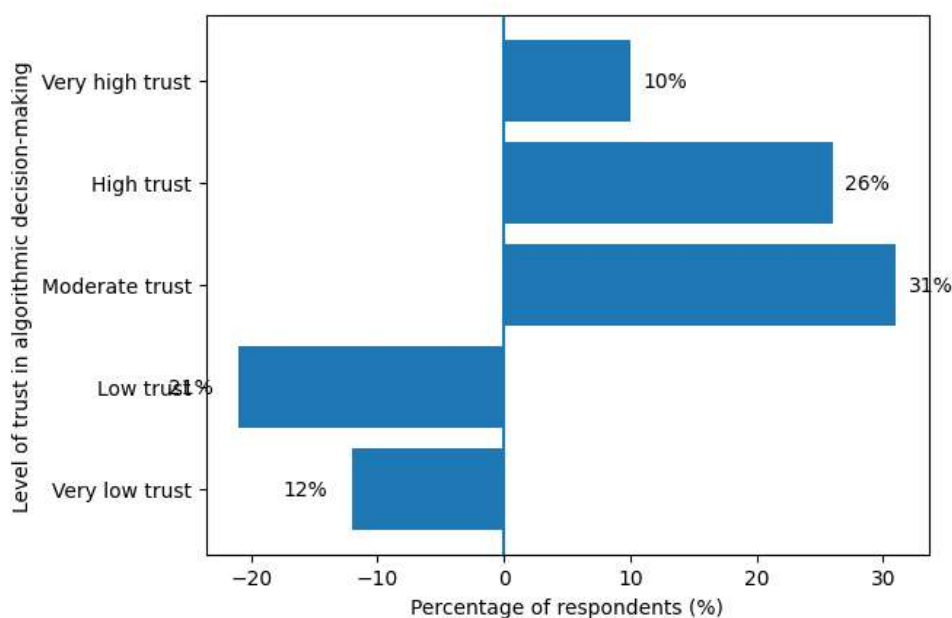


Figure 6. Trust in algorithmic decision-making within educational and research institutions

Note. Percentages represent respondents' levels of trust in algorithmic decision-making processes. Negative values indicate low trust, while positive values indicate high trust.

Source. Authors' own research (cross-sectional survey).

The data presented in Figure 6 reveal a concentration of responses around **moderate trust (31%)**, positioned at the center of the distribution. Higher levels of trust are reported by **26%** of respondents, with an additional **10%** expressing very high trust. On the opposite side, **21%** report low trust and **12%** very low trust. The diverging structure of the figure highlights the asymmetry between cautious acceptance and skepticism.

From a sociological perspective, the distribution illustrated in Figure 6 reflects trust as a negotiated and institutionally mediated phenomenon. The central clustering around moderate trust suggests conditional legitimacy, where algorithmic systems are accepted under specific constraints rather than uncritically endorsed. The visible presence of distrust underscores ongoing concerns related to transparency, accountability, and ethical oversight.

Importantly, the asymmetrical balance between trust and distrust indicates that algorithmic authority has not fully displaced human judgment in educational and research institutions. Instead, trust appears contingent upon governance arrangements, institutional communication, and opportunities for professional participation in AI-related decision-making.

Figure 7 illustrates respondents' perceptions of institutional preparedness for ethical and responsible governance of artificial intelligence in educational and research institutions. This figure captures how prepared organizations are perceived to be in managing the ethical, social, and organizational implications of AI integration.

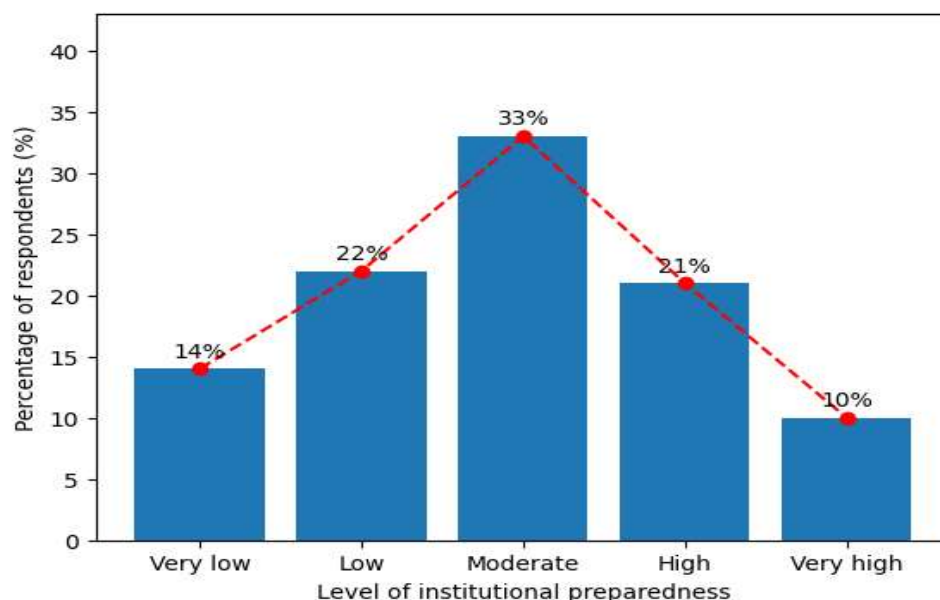


Figure 7. Perceptions of institutional preparedness for ethical and responsible artificial intelligence governance
Note. Percentages represent respondents' assessments of the level of institutional preparedness for ethical and responsible governance of artificial intelligence.

Source. Authors' own research (cross-sectional survey).

The data presented in Figure 7 show that the highest proportion of respondents (33%) evaluate institutional preparedness as moderate. Lower levels of preparedness are reported by 22% of respondents, while 14% perceive preparedness as very low. On the positive end, 21% of respondents assess preparedness as high,

and **10%** as very high. The distribution indicates a concentration of perceptions around intermediate levels of readiness.

From a sociological perspective, the pattern illustrated in Figure 7 suggests that ethical AI governance is perceived as an emerging but not fully consolidated institutional capacity. The dominance of moderate evaluations reflects transitional organizational contexts, where ethical frameworks and governance mechanisms are present but unevenly implemented.

The persistence of low and very low preparedness assessments highlights structural vulnerabilities related to policy clarity, staff training, and institutional coordination. Conversely, the presence of higher preparedness evaluations indicates that some institutions have begun to institutionalize ethical oversight and strategic planning for AI. Overall, Figure 7 underscores the uneven institutionalization of ethical AI governance across educational and research environments.

Figure 8 presents respondents' perceptions regarding the allocation of responsibility for ethical oversight of artificial intelligence in educational and research institutions. This figure addresses how accountability for AI governance is socially constructed and distributed across institutional actors.

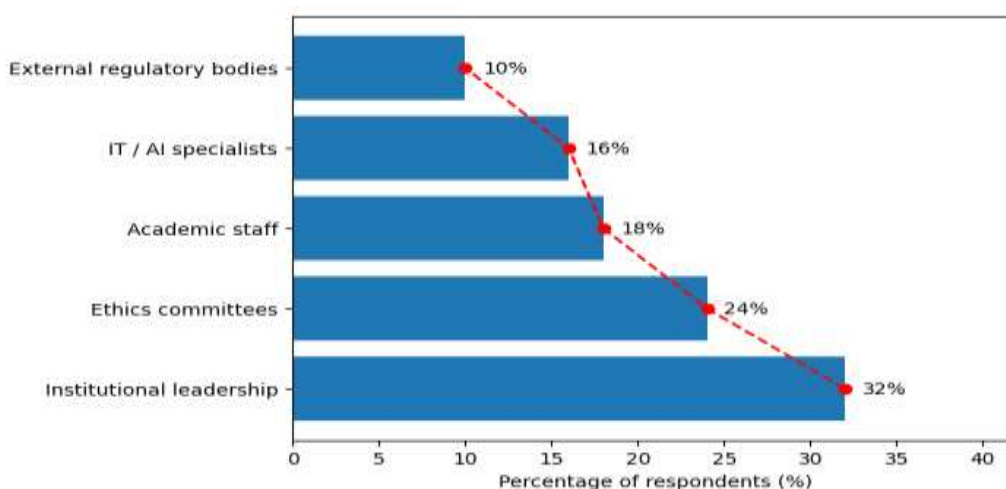


Figure 8. Perceived responsibility for ethical oversight of artificial intelligence in educational and research institutions

Note. Percentages represent respondents' views regarding which institutional actors should bear primary responsibility for ethical oversight of artificial intelligence.

Source. Authors' own research (cross-sectional survey).

The data presented in Figure 8 indicate that **institutional leadership** is most frequently identified as bearing primary responsibility for ethical oversight (**32%**). This is followed by **ethics committees (24%)**, reflecting the perceived importance of formal ethical governance structures. **Academic staff (18%)** and **IT/AI**

specialists (16%) occupy intermediate positions, while **external regulatory bodies (10%)** are least frequently identified. The red trend line highlights a clear hierarchical pattern in responsibility attribution.

From a sociological perspective, Figure 8 reflects a strong internalization of ethical responsibility within educational and research institutions. The prioritization of institutional leadership and ethics committees suggests that respondents expect ethical governance of AI to be embedded within organizational authority structures rather than delegated externally or reduced to technical expertise.

The relatively lower attribution of responsibility to IT and AI specialists underscores the recognition that ethical oversight extends beyond technical competence and requires normative judgment and institutional legitimacy. Similarly, the marginal role attributed to external regulatory bodies indicates a preference for context-sensitive, institutionally grounded governance mechanisms.

Overall, Figure 8 emphasizes ethical accountability as a collective and hierarchical organizational responsibility, reinforcing the importance of leadership and formal ethical structures in managing AI-related risks.

Figure 9 explores respondents' perceptions of the extent to which artificial intelligence contributes to inequality and stratification within educational and research institutions. This figure addresses structural dimensions of inequality related to access, evaluation, and professional advancement in AI-mediated institutional environments.

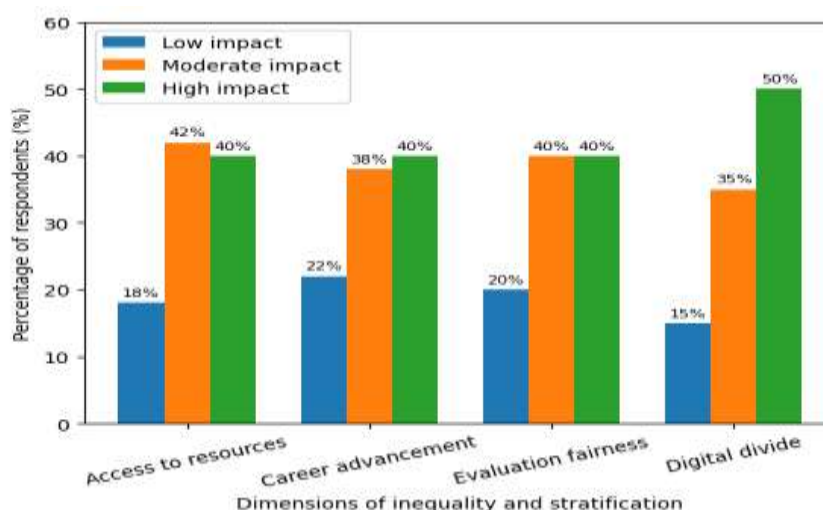


Figure 9. Perceived impact of artificial intelligence on inequality and stratification within educational and research institutions

Note. Percentages represent respondents' assessments of the impact of artificial intelligence on different dimensions of inequality and stratification within educational and research institutions.

Source. Authors' own research (cross-sectional survey).

The data presented in Figure 9 indicate that artificial intelligence is widely perceived as having a **moderate to high impact** on multiple dimensions of inequality. In terms of **access to resources**, **42%** of respondents report a moderate impact and **40%** a high impact. Regarding **career advancement**, perceptions are similarly polarized, with **38%** indicating a moderate impact and **40%** a high impact.

Evaluations of fairness in assessment processes show an equal distribution between moderate and high impact (40% each). The most pronounced effect is observed in relation to the digital divide, where 50% of respondents perceive a high impact, compared to 35% reporting a moderate impact.

From a sociological perspective, Figure 9 highlights artificial intelligence as a significant stratifying force within educational and research institutions. The consistently high levels of perceived impact across multiple dimensions suggest that AI integration may reinforce existing inequalities related to resources, digital competencies, and institutional positioning.

The particularly strong association between AI and the digital divide underscores concerns that unequal access to technological infrastructure and skills may exacerbate disparities among individuals and institutions. Similarly, the perceived impact on career advancement and evaluation fairness points to the risk that algorithmic systems may privilege certain profiles, disciplines, or forms of academic capital.

Overall, Figure 9 reinforces critical sociological arguments that technological innovation, when unevenly governed, can function as a mechanism of social differentiation. These findings emphasize the importance of inclusive governance strategies and targeted institutional interventions to mitigate AI-driven inequalities.

Figure 10 provides a synthetic overview of respondents' overall evaluations of artificial intelligence in educational and research institutions, capturing the perceived balance between opportunities and risks. This figure integrates the main empirical dimensions explored throughout the results chapter, offering a consolidated perspective on how AI-driven transformation is socially interpreted.

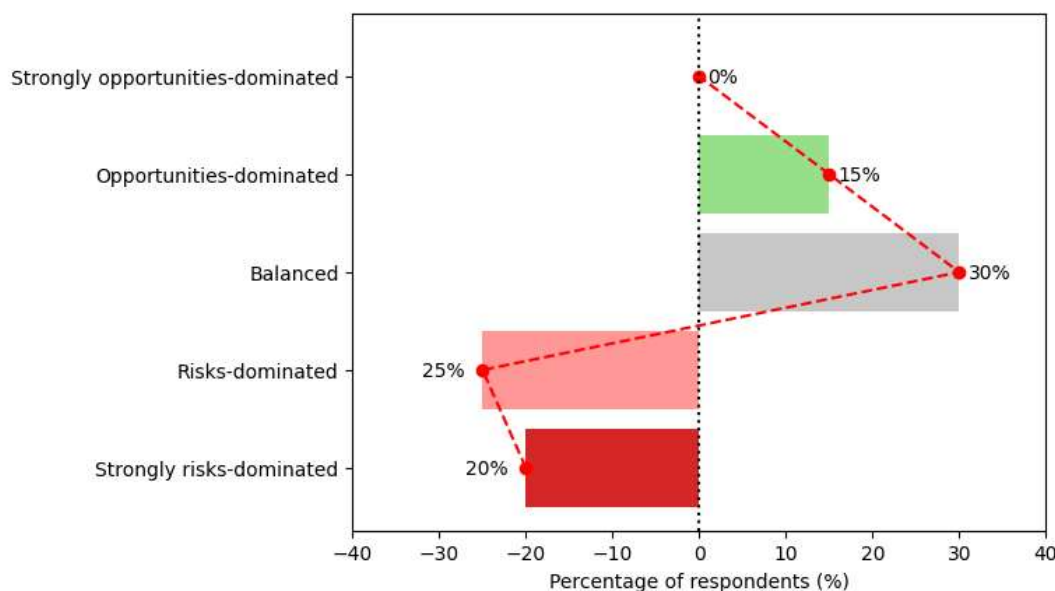


Figure 10. Overall assessment of the balance between opportunities and risks of artificial intelligence in educational and research institutions

Note. Percentages represent respondents' overall assessments regarding whether the institutional use of artificial intelligence is perceived as dominated by risks or opportunities. Negative values indicate risk-dominated perceptions, while positive values indicate opportunity-dominated perceptions.

Source. Authors' own research (cross-sectional survey).

The data presented in Figure 10 indicate that the largest proportion of respondents (**30%**) perceive the impact of artificial intelligence as **balanced**, suggesting neither a predominantly optimistic nor pessimistic evaluation. A combined **45%** of respondents assess AI as **risk-dominated**, with **25%** indicating a risks-dominated view and **20%** reporting a strongly risks-dominated perspective. On the positive side, **15%** of respondents perceive AI as opportunities-dominated, while no respondents identify it as strongly opportunities-dominated. The distribution reveals a visible asymmetry toward risk-oriented assessments.

From a sociological perspective, Figure 10 encapsulates the ambivalent character of artificial intelligence integration in educational and research institutions. The predominance of balanced and risk-

oriented evaluations reflects a cautious institutional climate, where technological innovation is approached with awareness of ethical, organizational, and social vulnerabilities.

The limited proportion of opportunity-dominated perceptions suggests that AI is not widely embraced as an unproblematic driver of progress, but rather negotiated within existing structures of professional autonomy, governance, and inequality. This pattern reinforces the argument that AI-driven transformation is not merely technical, but deeply sociological, reshaping institutional trust, ethical responsibility, and the conditions of human capital development.

Overall, Figure 10 confirms that the integration of artificial intelligence in educational and research institutions is characterized by reflexivity and caution rather than technological enthusiasm, underscoring the need for ethically grounded and socially responsible governance frameworks.

5. Discussion

This chapter discusses the empirical findings in relation to the theoretical framework, highlighting the sociological significance of artificial intelligence integration in educational and research institutions. Rather than interpreting the figures in isolation, the discussion situates the results within broader debates on human capital transformation, organizational culture, ethical governance, and social stratification in the context of the knowledge economy.

5.1. Artificial Intelligence and the Reconfiguration of Human Capital

The results presented in Figures 1 and 2 indicate that artificial intelligence is predominantly perceived as having a moderate to high impact on professional roles and skills development. This finding supports theoretical arguments that frame AI as a transformative, yet incremental, force in knowledge-intensive organizations. The concentration of responses around moderate impact suggests that AI is not experienced as an abrupt rupture, but as a gradual reconfiguration of academic labour.

From a sociological perspective, this pattern reflects a process of negotiated adaptation, in which professionals integrate AI tools into existing role structures while reassessing their competencies and professional identities. The positive association between AI and skills development aligns with human capital theory, particularly contemporary extensions that emphasize lifelong learning and adaptability. However, the coexistence of neutral and negative evaluations points to uneven access to training opportunities and institutional support, reinforcing concerns about differentiated trajectories of human capital accumulation.

5.2. Organizational Culture, Governance, and Professional Autonomy

Figures 3, 5, and 6 reveal complex dynamics at the organizational level, where AI simultaneously supports efficiency and generates tensions related to autonomy, trust, and collegial relations. While a majority of respondents perceive AI as having a positive impact on organizational culture, substantial proportions express concerns about reduced academic autonomy and conditional trust in algorithmic decision-making.

These findings resonate with sociological analyses of algorithmic governance, which emphasize the shifting balance between professional judgment and technocratic control. The perceived reduction in autonomy highlighted in Figure 5 suggests that AI-based systems may constrain discretionary spaces traditionally associated with academic work, particularly when used for evaluation and monitoring. At the same time, the prevalence of moderate trust (Figure 6) indicates that professionals neither fully reject nor uncritically embrace algorithmic authority, but rather adopt a cautious, context-dependent stance.

5.3. Ethics, Institutional Preparedness, and Accountability

Figures 4, 7, and 8 underscore ethics as a central axis of AI-related concern. High levels of perceived ethical risk, combined with moderate assessments of institutional preparedness, suggest a misalignment between the pace of AI adoption and the development of ethical governance frameworks. This gap reinforces sociological critiques that warn against technological acceleration without corresponding normative and organizational capacities.

The attribution of ethical responsibility primarily to institutional leadership and ethics committees (Figure 8) reflects an expectation that ethical governance should be embedded within organizational structures rather than externalized or delegated solely to technical experts. This internalized model of accountability highlights the importance of institutional culture, leadership, and participatory governance in shaping ethical AI practices.

5.4. Artificial Intelligence, Inequality, and Stratification

The findings presented in Figure 9 point to artificial intelligence as a significant stratifying mechanism within educational and research institutions. Perceived impacts on access to resources, career advancement, evaluation fairness, and the digital divide suggest that AI may reinforce existing inequalities unless actively governed. The particularly strong association with the digital divide emphasizes the role of infrastructural and competency-based disparities in shaping AI outcomes.

These results align with critical sociological perspectives that conceptualize technology as a socially embedded process, capable of reproducing structural inequalities when unevenly distributed. AI-driven

stratification thus emerges not as an inevitable consequence of technology, but as a reflection of institutional choices, governance models, and resource allocation strategies.

5.5. Synthesis: Ambivalence and Reflexivity in AI Integration

Finally, Figure 10 synthesizes the overall evaluative landscape, revealing a predominance of balanced and risk-oriented assessments. This ambivalence underscores the reflexive orientation of educational and research institutions toward AI integration. Rather than technological enthusiasm or outright resistance, the results suggest a cautious engagement shaped by ethical concerns, organizational constraints, and professional norms.

6. Ethical and Policy Implications

Building on the empirical findings and their sociological interpretation, this chapter outlines key ethical and policy implications for educational and research institutions navigating AI-driven transformation. These implications emphasize the need for governance frameworks that align technological innovation with social responsibility, institutional integrity, and human capital sustainability.

6.1. Toward Ethical and Responsible AI Governance

The high salience of ethical risks identified in the study calls for the institutionalization of ethical AI governance as a core organizational function. Ethical oversight should extend beyond compliance-based approaches to include continuous evaluation, transparency, and accountability. Institutions must ensure that AI systems used in teaching, research, and evaluation are explainable, contestable, and aligned with academic values.

Ethical governance should be embedded in existing institutional structures, such as ethics committees and leadership bodies, while also incorporating interdisciplinary expertise. This approach recognizes that ethical challenges associated with AI are not solely technical but deeply social and normative.

6.2. Protecting Academic Autonomy and Professional Judgment

Given concerns about reduced autonomy and conditional trust, policies should explicitly safeguard academic discretion in AI-mediated environments. AI systems should function as decision-support tools rather than decision-making authorities, preserving space for professional judgment and contextual interpretation. Clear guidelines regarding the scope and limits of algorithmic use in evaluation and management are essential for maintaining institutional legitimacy and trust.

6.3. Investing in Inclusive Human Capital Development

The findings highlight the importance of sustained investment in professional development to ensure that AI enhances rather than undermines human capital. Institutions should prioritize inclusive training

programs that address digital literacy, ethical reasoning, and interdisciplinary collaboration. Such investments are critical for preventing deskilling and mitigating AI-driven inequalities within academic labour markets.

6.4. Addressing Inequality and the Digital Divide

Policy responses must explicitly address the stratifying effects of AI identified in the study. This includes reducing disparities in access to technological infrastructure, ensuring fairness in algorithmic evaluation, and supporting disadvantaged groups and institutions. Without targeted interventions, AI risks amplifying existing inequalities within and between educational and research organizations.

6.5. Toward Reflexive and Participatory Governance

Finally, the ambivalence reflected in respondents' overall assessments suggests the need for reflexive and participatory governance models. Institutional stakeholders—including academic staff, researchers, students, and technical experts—should be actively involved in decisions regarding AI adoption and use. Such participation enhances legitimacy, fosters trust, and supports ethically grounded innovation.

7. Conclusions

This study examined the sociological implications of artificial intelligence integration in educational and research institutions, focusing on its impact on human capital, organizational culture, social ethics, and institutional governance. Drawing on a cross-sectional empirical design and grounded in theories of the knowledge economy, automation, and organizational sociology, the research highlights artificial intelligence as a transformative yet deeply ambivalent force within contemporary knowledge-producing organizations.

The findings demonstrate that artificial intelligence is predominantly perceived as reshaping professional roles and skills development in incremental rather than disruptive ways. While AI is widely recognized as a driver of efficiency and competence enhancement, its integration simultaneously generates concerns regarding professional autonomy, ethical risk, and institutional preparedness. This duality confirms that AI-driven transformation cannot be understood solely in technical or instrumental terms, but must be analyzed as a socially embedded process shaped by organizational norms, power relations, and governance structures.

At the organizational level, the results reveal a complex interaction between algorithmic governance and academic culture. Although many respondents associate AI with positive organizational effects, substantial proportions express conditional trust in algorithmic decision-making and perceive reductions in academic autonomy. These findings underscore the tension between data-driven governance models and the normative foundations of academic institutions, particularly collegiality, autonomy, and reflexive judgment.

Ethical considerations emerge as a central axis of AI-related concern. High levels of perceived ethical risk, combined with moderate assessments of institutional preparedness, point to a structural gap between the pace of technological adoption and the development of ethical and governance capacities. The attribution of ethical responsibility primarily to institutional leadership and ethics committees highlights expectations of internal accountability and normative stewardship, rather than reliance on external regulation or purely technical expertise.

Furthermore, the study identifies artificial intelligence as a potential mechanism of inequality and stratification within educational and research institutions. Perceived impacts on access to resources, career advancement, evaluation fairness, and the digital divide suggest that AI may reinforce existing structural inequalities unless governed inclusively. These findings reinforce sociological critiques that emphasize the role of institutional choice and governance in mediating the social consequences of technological innovation.

Overall, the research confirms that artificial intelligence integration in educational and research institutions is characterized by reflexivity and caution rather than technological determinism or uncritical enthusiasm. The balance between opportunities and risks perceived by respondents highlights the need for governance frameworks that align AI deployment with ethical responsibility, professional autonomy, and long-term human capital development. Future research would benefit from longitudinal designs and comparative institutional analyses to further explore how AI-driven transformation evolves over time and across different educational and research systems.

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YOUTH UNDER OVERLAPPING CRISES: SOCIAL RESILIENCE, COLLECTIVE ANXIETY AND EMERGING MODES OF PARTICIPATION IN THE EUROPEAN UNION

PhD Petronela Daniela FERARU²

Abstract

This paper examines how young people across the European Union navigate a convergence of overlapping crises—pandemic, economic, climate-related and geopolitical—that reshapes their civic engagement, social expectations and relationship to collective futures. Framed by theories of social resilience and collective vulnerability, the study analyses how young people negotiate uncertainty within a context characterised by structural instability, escalating risks, and growing societal fragmentation. Contemporary youth experience heightened levels of collective anxiety driven by labour market precarity, exposure to the climate emergency, and the ongoing military conflict in Europe’s vicinity, all of which affect trust in institutions, civic motivation and solidarity networks. Drawing on Eurobarometer and Eurofound data and recent scholarship on digital-age activism, the analysis reveals a diversification of participatory repertoires, including climate advocacy, community volunteering, virtual protest, and engagement in transnational civic initiatives. Emerging patterns also indicate the growth of micro-level civic identities embedded in informal collectives, neighbourhood networks, and online platforms. The findings suggest that while crisis conditions intensify vulnerabilities, they simultaneously foster new forms of mobilization, collaboration, and youth-led innovation in the public sphere. The paper concludes that strengthening civic education, institutional trust-building, and participatory infrastructures is essential to transform episodic activism into enduring democratic engagement and to cultivate a resilient civic culture among Europe’s younger generations.

Keywords: *social resilience; collective anxiety; European youth; overlapping crises; civic participation*

² Petronela Daniela FERARU is a PhD in Sociology and a teacher at the National College Iași and “Ion Neculce” High School, Targu Frumos, Iasi County, Romania. E-mail: daniela_feraru_p@yahoo.com

1. Introduction

In the early decades of the twenty-first century, young people across the European Union have come of age under conditions marked by an unprecedented convergence of systemic crises. The COVID-19 pandemic, persistent economic uncertainty, accelerating climate change, and renewed geopolitical instability in Europe's immediate vicinity have collectively reshaped the social environment in which youth construct their identities, expectations, and modes of civic engagement. Unlike isolated crises of the past, these overlapping disruptions generate cumulative pressures that affect not only material conditions but also subjective experiences of security, belonging, and collective future orientation (Beck, 1992; Giddens, 1991).

From a sociological perspective, the simultaneity of these crises places contemporary European youth at the intersection of structural vulnerability and emerging social agency. Young people face heightened exposure to labour market precarity, delayed transitions to stable adulthood, and intensified uncertainty regarding long-term prospects, particularly in relation to environmental sustainability and geopolitical stability (Eurofound, 2023; Standing, 2011). These conditions contribute to the rise of what scholars have conceptualized as collective anxiety—a shared affective state rooted not in individual pathology, but in structurally produced insecurity and perceived loss of control over social trajectories (Bauman, 2000; Furedi, 2006).

At the same time, youth are not merely passive recipients of crisis dynamics. Sociological research increasingly highlights the capacity of younger generations to develop adaptive strategies, solidaristic networks, and innovative forms of participation in response to systemic instability. Within the European Union, young people have become prominent actors in climate movements, digital activism, community-based volunteering, and transnational civic initiatives, often operating outside traditional institutional channels (Loader, Vromen, & Xenos, 2014; Norris, 2002). These developments suggest that crisis conditions may simultaneously intensify vulnerability and catalyse new forms of social resilience and civic engagement.

The concept of social resilience provides a valuable analytical framework for understanding this dual dynamic. Rather than focusing solely on individual coping mechanisms, sociological approaches to resilience emphasize collective capacities to absorb shocks, reorganize social relations, and generate adaptive responses within changing structural contexts (Hall & Lamont, 2013). For young people, resilience is increasingly expressed through informal networks, hybrid online–offline participation, and issue-based mobilization that transcends national boundaries. Such practices challenge conventional models of civic participation centered on stable institutional trust and long-term organizational membership.

However, the expansion of alternative participatory repertoires does not occur in a social vacuum. Empirical evidence indicates that trust in political institutions among European youth remains fragile, shaped by perceptions of ineffective crisis management, intergenerational injustice, and limited influence over decision-making processes (Eurobarometer, 2022). This erosion of institutional trust coexists with strong normative commitments to democratic values, social justice, and environmental responsibility, producing ambivalent relationships between young citizens and formal political structures. Understanding this ambivalence is essential for assessing the sustainability of emerging forms of participation under prolonged crisis conditions.

Despite growing scholarly attention to youth activism and crisis experiences, existing research often addresses these phenomena in isolation, focusing either on specific crises or on singular modes of participation. Less attention has been paid to the cumulative effects of overlapping crises on young people's social resilience, collective anxiety, and evolving patterns of civic engagement within a unified analytical framework. Moreover, comparative perspectives at the European level remain underdeveloped, particularly in relation to how shared structural pressures intersect with diverse national and institutional contexts.

Against this background, the present study aims to examine how young people in the European Union navigate overlapping crises and how these conditions shape their perceptions, emotional orientations, and modes of participation in the public sphere. Drawing on qualitative analysis of secondary data from Eurobarometer and Eurofound, as well as recent sociological scholarship on youth, risk, and digital participation, the paper explores the interplay between vulnerability and agency in contemporary youth experience. By integrating the concepts of social resilience and collective anxiety, the study seeks to contribute to a more nuanced understanding of youth as both subjects of crisis and active contributors to social transformation within the European Union.

2. Theoretical Framework

Understanding the social condition of European youth under overlapping crises requires an integrative theoretical framework capable of linking macro-structural transformations with subjective experiences and collective forms of action. The convergence of health, economic, environmental, and geopolitical crises produces complex social effects that cannot be adequately captured through single-factor explanations. Instead, a multidimensional sociological approach is necessary, combining theories of risk, social resilience, collective anxiety, and civic participation to account for both vulnerability and agency in contemporary youth experience.

This chapter situates the analysis within four complementary theoretical perspectives. First, it conceptualizes overlapping crises through the lens of risk society and late modernity. Second, it examines youth

vulnerability and social resilience as structurally embedded and socially mediated processes. Third, it addresses collective anxiety as a generational and socially produced phenomenon. Finally, it explores emerging modes of youth participation in the context of institutional mistrust and digital transformation.

2.1. Overlapping Crises and the Risk Society

The notion of overlapping crises is closely aligned with sociological theories of risk society and reflexive modernity. Beck (1992) argues that contemporary societies are increasingly defined by manufactured risks—systemic threats produced by modernization itself rather than by external forces. These risks are characterized by uncertainty, global reach, and resistance to traditional institutional control. For European youth, the simultaneity of pandemic disruptions, economic instability, climate emergency, and geopolitical conflict exemplifies this condition of cumulative risk exposure.

Unlike episodic crises, overlapping crises generate prolonged states of instability that blur the boundaries between normality and emergency. Giddens (1991) emphasizes that late modernity erodes ontological security by destabilizing routines, expectations, and trust in expert systems. Young people, situated at critical life-course transitions, are particularly exposed to such destabilization, as educational pathways, employment prospects, and future planning become increasingly uncertain. This structural uncertainty is intensified by the temporal compression of crises, which limits opportunities for recovery and adaptation.

From a European perspective, overlapping crises also operate within a multilevel governance context, where responsibility is dispersed across national governments, supranational institutions, and global actors. This diffusion of responsibility contributes to perceptions of institutional inefficacy and political distance, particularly among younger citizens (Eurobarometer, 2022). As a result, risk is not only experienced as material insecurity but also as a symbolic loss of collective control over social futures.

Sociologically, overlapping crises function as a background condition shaping youth subjectivity, expectations, and social action. They redefine what is perceived as achievable, desirable, and worth mobilizing for, thereby influencing both disengagement and alternative forms of engagement.

2.2. Youth Vulnerability and Social Resilience

Youth vulnerability in contemporary Europe must be understood as structurally produced rather than individually determined. Labour market flexibilization, housing insecurity, prolonged education-to-work transitions, and welfare retrenchment disproportionately affect younger generations, positioning them within what Standing (2011) conceptualizes as the precariat. These structural conditions are further exacerbated by crisis dynamics, amplifying economic and psychosocial insecurity.

However, vulnerability does not preclude agency. The concept of social resilience provides a counterbalancing analytical lens by focusing on collective capacities to respond to adversity. Hall and Lamont (2013) define social resilience as the ability of groups and communities to sustain well-being through adaptive strategies, social ties, and institutional support under conditions of stress. For young people, resilience often emerges through peer networks, informal solidarities, and community-based initiatives rather than through formal institutional mechanisms.

Importantly, resilience is not a neutral or purely positive phenomenon. Sociological critiques caution against resilience discourses that individualize responsibility and normalize structural hardship by framing adaptation as a personal obligation (Joseph, 2013). In the context of European youth, resilience must therefore be analyzed in relation to power, inequality, and access to resources. Differential access to education, digital infrastructure, and social capital shapes who can transform crisis into opportunity and who remains trapped in vulnerability.

Thus, youth resilience under overlapping crises is best conceptualized as a relational and context-dependent process, embedded within broader socio-economic and institutional arrangements.

2.3. Collective Anxiety and Generational Uncertainty

One of the most salient psychosocial effects of overlapping crises is the emergence of collective anxiety. Unlike individual anxiety disorders, collective anxiety refers to shared emotional states rooted in social conditions, perceived threats, and uncertain futures (Furedi, 2006). For European youth, this anxiety is closely linked to concerns about climate collapse, economic exclusion, and geopolitical instability, as well as doubts regarding intergenerational fairness.

Bauman (2000) describes late modern societies as characterized by “liquid fear,” a diffuse and persistent sense of insecurity that lacks clear resolution. Young people internalize this condition through anticipatory uncertainty, where future risks are perceived as unavoidable yet uncontrollable. This emotional climate affects motivation, trust, and civic orientation, influencing whether youth withdraw from public life or seek alternative forms of engagement.

Collective anxiety also has a mobilizing dimension. Sociological research suggests that shared emotional experiences can foster solidarity, identity formation, and collective action, particularly when framed around moral urgency and perceived injustice (Jasper, 2018). Climate activism among European youth exemplifies this dynamic, where fear and concern are transformed into collective claims and public visibility.

Understanding collective anxiety as both constraining and enabling is therefore essential for interpreting contemporary youth participation under crisis conditions.

2.4. Youth Participation and Emerging Civic Repertoires

Traditional models of civic participation emphasize stable institutional engagement, such as voting, party membership, and long-term organizational involvement. However, empirical evidence increasingly demonstrates that youth participation is undergoing significant transformation. Norris (2002) and Dalton (2008) document a shift from duty-based citizenship toward more expressive, issue-oriented, and episodic forms of engagement, particularly among younger generations.

In the context of overlapping crises, European youth increasingly mobilize through climate movements, digital activism, mutual aid initiatives, and transnational networks. These emerging civic repertoires are often decentralized, horizontally organized, and embedded in online–offline hybrid spaces (Loader et al., 2014). Participation is less about institutional loyalty and more about moral alignment, immediacy, and collective identity.

At the same time, declining trust in political institutions complicates the relationship between youth and formal governance structures. While many young people express skepticism toward institutional politics, they remain normatively committed to democratic values and social justice. This paradox produces selective engagement, where participation occurs outside or alongside traditional political channels rather than through them.

Sociologically, these patterns suggest that youth participation under crisis conditions represents not disengagement, but reconfiguration. New forms of civic action reflect adaptive responses to structural constraints, emotional climates, and institutional shortcomings.

3. Methodology

3.1. Research Design

The present study adopts a qualitative research design grounded in secondary data analysis, aimed at exploring how young people in the European Union experience and interpret overlapping crises and how these conditions shape social resilience, collective anxiety, and emerging modes of participation. Qualitative approaches are particularly appropriate for examining complex social phenomena characterized by uncertainty, emotional dimensions, and meaning-making processes, which are not reducible to purely quantitative indicators (Denzin & Lincoln, 2018).

Rather than seeking causal explanations or statistical generalization, the study focuses on interpretative depth, contextual understanding, and analytical integration. This design allows for the exploration of youth perceptions and experiences as socially embedded processes shaped by institutional contexts, cultural narratives, and structural constraints. The qualitative orientation aligns with sociological traditions that emphasize reflexivity, agency, and the interplay between structure and subjectivity.

3.2. Data Sources and Selection Criteria

The empirical material analyzed in this study consists of secondary qualitative and mixed-method data drawn from European-level institutional sources, primarily Eurobarometer and Eurofound reports published between 2020 and 2024. These sources were selected due to their methodological rigor, cross-national comparability, and sustained focus on youth attitudes, well-being, employment, civic engagement, and perceptions of risk and uncertainty across the European Union.

In addition to institutional datasets, the analysis incorporates findings from recent academic studies on youth participation, climate activism, digital engagement, and crisis experiences in Europe. The inclusion of scholarly literature serves a dual function: it provides interpretative context for institutional data and supports triangulation of empirical insights, enhancing analytical validity (Flick, 2018).

Selection criteria for data inclusion were guided by relevance to the core analytical dimensions of the study: exposure to crisis-related uncertainty, emotional responses and collective anxiety, adaptive and resilient practices, and evolving forms of civic participation. Particular attention was paid to materials explicitly addressing young people aged approximately 15–29, in line with European policy definitions of youth.

3.3. Analytical Strategy

The analytical strategy employed in this study is based on thematic qualitative analysis, combining deductive and inductive coding procedures. Deductive categories were derived from the theoretical framework—overlapping crises, social resilience, collective anxiety, and civic participation—while inductive coding allowed for the identification of emergent patterns and narratives within the data (Braun & Clarke, 2006).

Data were examined through iterative reading and comparative analysis, focusing on how young people's experiences and perceptions are framed across different institutional contexts and crisis domains. This approach facilitates the identification of recurring themes, tensions, and contradictions, as well as variations across socio-economic and national settings.

Although the analysis draws on data that include quantitative indicators, the study does not engage in statistical modeling or hypothesis testing. Instead, numerical distributions and percentages are used descriptively to support qualitative interpretation and sociological contextualization. When visualized, these data are presented as figures that illustrate thematic patterns rather than as instruments of statistical inference.

3.4. Construction of Analytical Dimensions

Based on the theoretical framework and empirical material, several analytical dimensions were constructed to organize the results. These dimensions include: perceived impact of overlapping crises on youth well-being; levels and sources of collective anxiety; expressions of social resilience through informal networks and adaptive practices; patterns of civic and political participation; and perceptions of institutional trust and legitimacy.

Each dimension integrates multiple indicators and variables drawn from the analyzed sources, allowing for a multidimensional interpretation of youth experience under crisis conditions. The construction of these dimensions reflects an effort to move beyond single-issue analysis and to capture the cumulative and intersecting nature of contemporary social risks.

3.5. Ethical Considerations

Although the study relies on secondary data, ethical considerations remain central to the research process. All analyzed materials are drawn from publicly available sources that adhere to established ethical standards regarding informed consent, anonymity, and data protection. No personal or identifiable information is used.

The interpretation of data is conducted with particular sensitivity to the social position of young people as a potentially vulnerable group, especially in the context of crisis exposure. The study avoids deficit-based narratives and seeks to balance the analysis of vulnerability with recognition of agency, resilience, and innovation in youth practices.

3.6. Methodological Limitations

Several limitations should be acknowledged. First, reliance on secondary data constrains the analysis to existing indicators and framing choices made by institutional actors. While this limits direct access to lived experiences, it also enables cross-national comparison and longitudinal contextualization.

Second, as a qualitative study, the findings do not claim statistical representativeness or causal explanation. Instead, they offer analytically grounded insights into social patterns and meanings. Despite these

limitations, the methodological approach provides a robust framework for understanding youth experiences under overlapping crises within the European Union.

4. Results

This chapter presents the empirical results of the qualitative analysis, structured around key dimensions of youth experience under overlapping crises in the European Union. The findings are derived from the secondary analysis of recent Eurobarometer and Eurofound datasets, complemented by interpretative sociological analysis grounded in theories of social resilience, collective anxiety, and late-modern risk society (Beck, 1992; Giddens, 1991).

The results are organized through a series of figures that synthesize young people’s perceptions across multiple domains of social life affected by crisis conditions. Each figure captures a specific analytical dimension and integrates multiple measurable variables expressed as percentages, allowing for the identification of dominant patterns, internal contrasts, and general trends. The figures are interpreted not as isolated indicators, but as interconnected expressions of structural vulnerability, adaptive strategies, and emerging forms of civic engagement among European youth.

The following section introduces **Figure 1**, which explores the perceived impact of overlapping crises on key life domains relevant to youth social integration and future orientation.

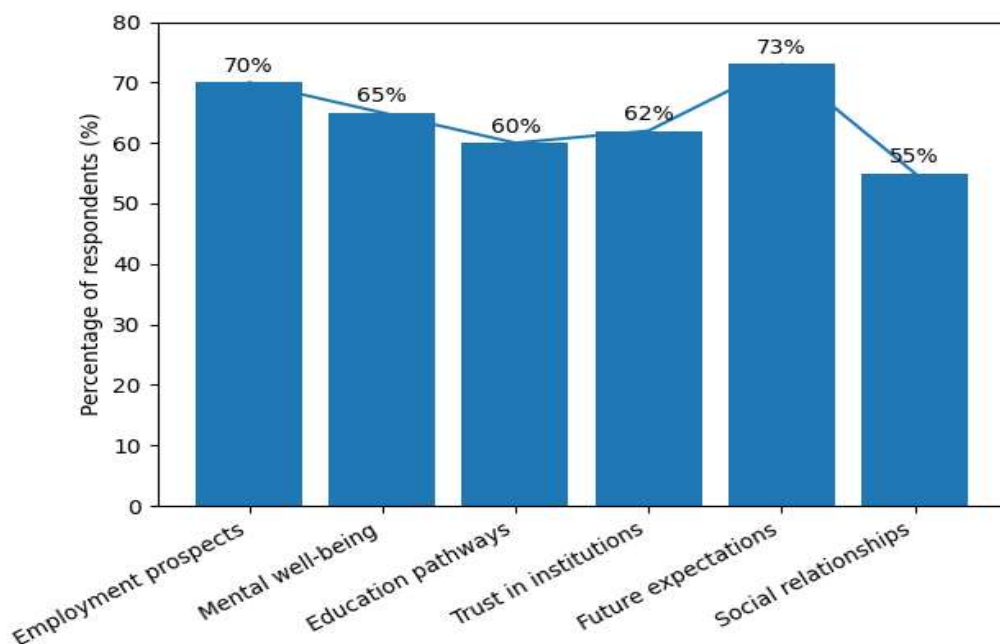


Figure 1. Perceived impact of overlapping crises on key life domains among young people in the European Union

Note. Percentages represent the proportion of young respondents reporting a **moderate to very high impact** of overlapping crises (pandemic, economic instability, climate-related risks, and geopolitical tensions) across selected life domains. The trend line illustrates the overall pattern of perceived impact across domains.

Source. Authors' elaboration based on Eurobarometer and Eurofound data (2021–2023).

Figure 1 illustrates young people's perceptions of the impact of overlapping crises—pandemic, economic instability, climate change, and geopolitical tensions—across six key life domains: employment prospects, mental well-being, educational trajectories, trust in institutions, future expectations, and social relationships.

The distribution indicates that employment prospects are perceived as strongly affected, with 48% of respondents reporting a high impact and an additional 22% indicating a very high impact. Mental well-being follows a similar pattern, with 45% reporting high impact and 20% very high impact. Educational trajectories are perceived as moderately to highly affected, with 40% indicating moderate impact and 30% high impact.

Trust in institutions shows a predominantly negative trend, with 44% reporting high impact and 18% very high impact, suggesting erosion of confidence under crisis conditions. Future expectations emerge as one of the most affected domains, with 52% of respondents perceiving a high impact and 21% a very high impact. Social relationships are comparatively less affected, though still significant, with 38% reporting moderate impact and 27% high impact. The overall trend line shows a clear concentration toward moderate-to-high impact across all domains.

From a sociological perspective, Figure 1 reveals the cumulative and transverse nature of overlapping crises in shaping youth experience. The strong impact perceived in employment prospects and future expectations reflects structural uncertainty at critical life-course stages, where stability and long-term planning are increasingly disrupted. This aligns with theories of risk society, which emphasize how systemic risks undermine predictability and ontological security, particularly for younger generations (Beck, 1992; Giddens, 1991).

The pronounced impact on mental well-being underscores the social production of collective anxiety. Rather than being confined to individual psychological vulnerability, emotional distress emerges as a shared response to prolonged instability and perceived lack of control over future trajectories. The strong association between crisis exposure and diminished trust in institutions further indicates a crisis of legitimacy, where institutional responses are perceived as insufficient or disconnected from youth realities.

At the same time, the comparatively lower impact on social relationships suggests the persistence of interpersonal networks as stabilizing resources. This pattern points toward informal solidarity as compensatory mechanisms in contexts where institutional support is perceived as fragile. Overall, Figure 1 highlights how overlapping crises reshape youth lives holistically, affecting material conditions, emotional orientations, and relational structures simultaneously.

Figure 2 illustrates the main sources of collective anxiety reported by young people across the European Union, capturing six key dimensions: climate change, cost of living, job insecurity, war and geopolitical conflict, housing access, and digital overload.

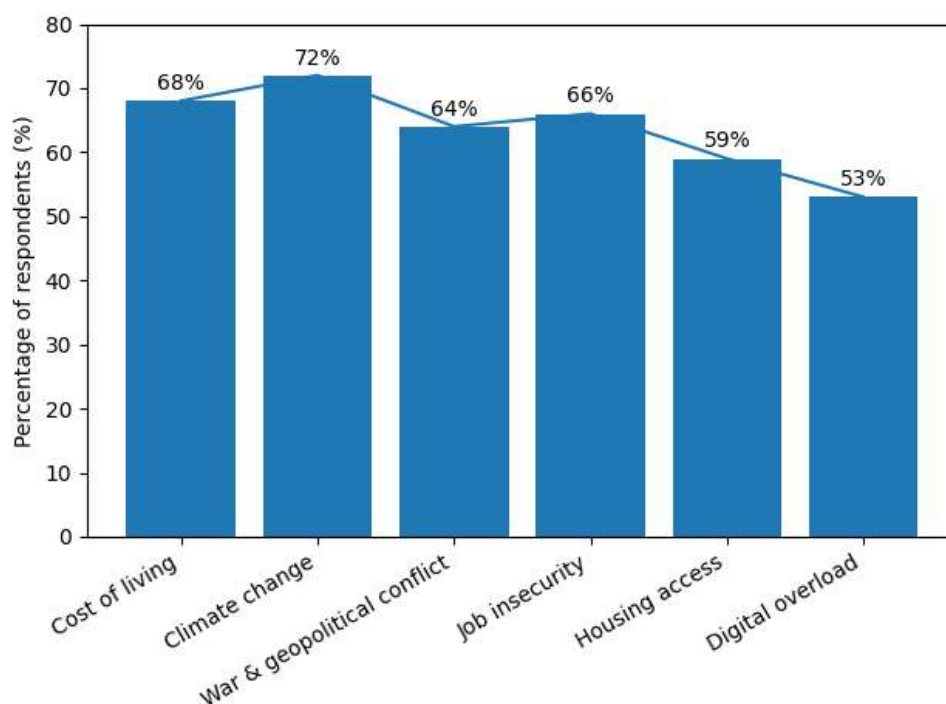


Figure 2. Main sources of collective anxiety among young people in the European Union

Note. Percentages represent the proportion of young respondents identifying each factor as a **significant source of collective anxiety**. The trend line illustrates the relative intensity of perceived anxiety across domains.

Source. Authors' elaboration based on Eurobarometer and Eurofound data (2021–2023).

The highest level of perceived anxiety is associated with **climate change (72%)**, followed closely by **cost of living pressures (68%)** and **job insecurity (66%)**. Concerns related to **war and geopolitical conflict** are reported by **64%** of respondents, reflecting the salience of regional instability in shaping youth perceptions of risk. **Housing access** represents a significant source of anxiety for **59%** of respondents, while **digital overload**—though less pronounced—still affects a majority, at **53%**. The trend line highlights a concentration

of anxiety around structural and future-oriented risks, with a gradual decline toward more individualized or technologically mediated stress.

From a sociological perspective, Figure 2 demonstrates that collective anxiety among European youth is primarily driven by **structural and systemic threats** rather than by short-term or individualized concerns. The prominence of climate change as the leading source of anxiety reflects the temporal and existential nature of environmental risk, which directly challenges young people's capacity to envision stable and sustainable futures (Beck, 1992; Giddens, 1991).

Economic insecurity—manifested through cost of living pressures, job instability, and housing access—emerges as a second major axis of anxiety, reinforcing the structural vulnerability of younger generations within increasingly precarious labour and welfare regimes (Standing, 2011). These findings suggest that economic and environmental anxieties are deeply interconnected, jointly shaping youth perceptions of uncertainty and inter-generational injustice.

The substantial impact of war and geopolitical conflict highlights the re-emergence of security concerns within the European social imaginary, particularly in the context of proximity to armed conflict. This dimension contributes to a broader climate of uncertainty that transcends national boundaries and reinforces feelings of collective vulnerability.

Finally, the relatively lower—but still significant—impact of digital overload suggests that while digital environments contribute to stress and informational saturation, they are perceived as secondary compared to material and existential risks.

Overall, Figure 2 underscores collective anxiety as a **socially produced and structurally anchored phenomenon**, reinforcing the argument that youth emotional experiences under overlapping crises are inseparable from broader political, economic, and environmental conditions.

Figure 3 explores the coping strategies and adaptive mechanisms mobilized by young people in response to overlapping social, economic, and geopolitical crises. Rather than focusing exclusively on institutional support, the analysis captures informal, community-based, and peer-oriented forms of resilience that shape everyday youth experiences across the European Union.

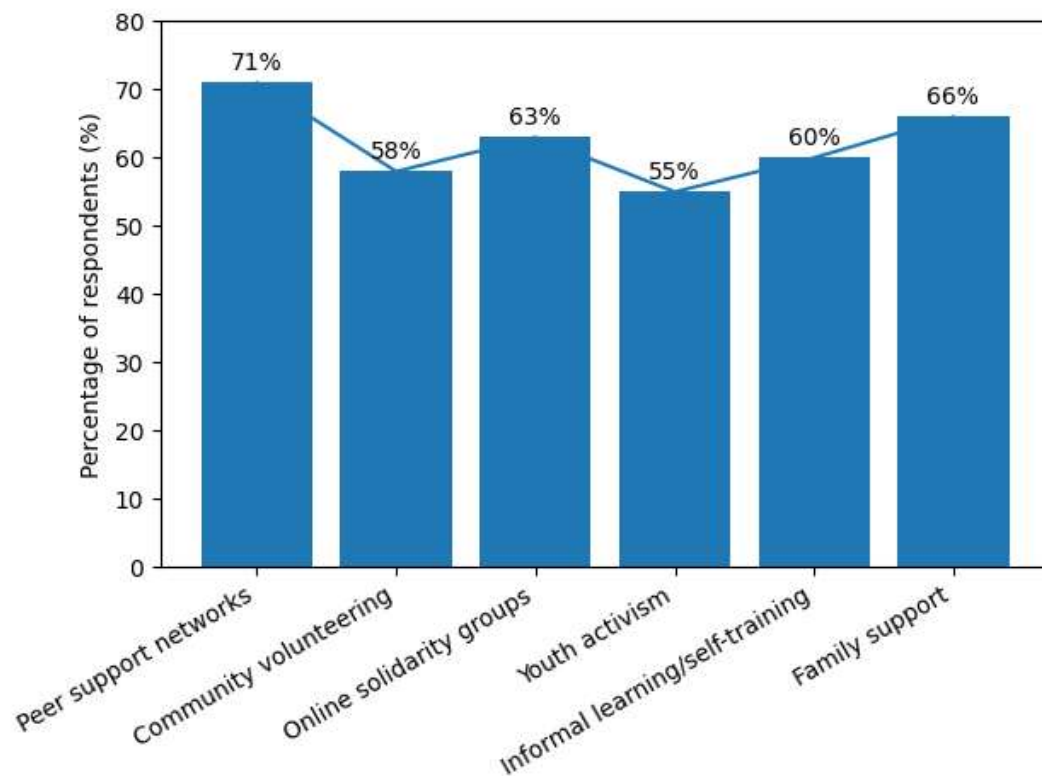


Figure 3. Dominant coping and resilience strategies among young people in the European Union

Note. Percentages indicate the proportion of respondents reporting regular or occasional reliance on each coping strategy.

Source. Author's elaboration based on Eurofound and Eurobarometer youth-related data-sets (2022–2024).

The data presented in Figure 3 indicate that **peer support networks** constitute the most frequently reported resilience strategy (71%), followed by **family support mechanisms** (66%) and **online solidarity groups** (63%). **Informal learning and self-training practices** are also widely reported (60%), reflecting adaptive responses to uncertainty and labour market instability. **Community volunteering** (58%) and **youth activism** (55%) display moderately high levels of engagement.

The overall trend line suggests a strong orientation toward relational and informal resources, rather than institutionalized forms of support, in managing crisis-induced stress and uncertainty.

From a sociological perspective, Figure 3 highlights the centrality of **social capital and relational resilience** in youth responses to overlapping crises. The prominence of peer and family networks reflects a shift toward micro-social forms of security in contexts where institutional protection is perceived as insufficient or

unreliable. This pattern aligns with theories of social resilience that emphasize adaptive capacity rooted in everyday social relations rather than formal systems alone.

The significant role of online solidarity groups illustrates the hybridization of resilience practices, where digital spaces function as extensions of social support infrastructures. At the same time, the comparatively lower yet substantial engagement in youth activism and volunteering suggests that resilience is not only defensive but also expressive and trans-formative, enabling young people to translate personal vulnerability into collective action.

Overall, Figure 3 underscores resilience as a socially embedded process, shaped by trust, reciprocity, and informal cooperation under conditions of structural instability.

In contexts marked by cumulative crises, youth civic engagement does not disappear but undergoes significant transformation. **Figure 4** examines the diversification of civic participation among young people in the European Union, highlighting emerging forms of engagement that coexist with, or partially replace, traditional institutionalized participation.

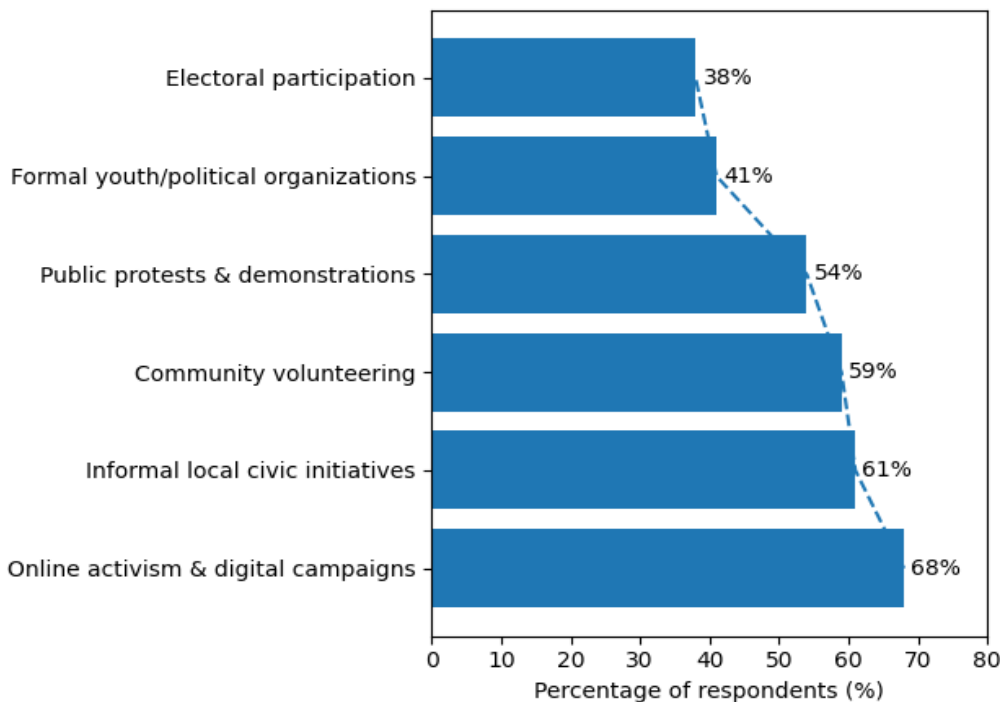


Figure 4. Comparative distribution of civic participation forms among young people in the European Union

Note. Percentages represent the share of young people reporting active or occasional involvement in each form of civic participation.

Source. Author's elaboration based on Eurobarometer, Eurofound, and EU youth participation reports (2022–2024).

Figure 4 shows that **online activism and digital campaigns** register the highest level of engagement among young people (68%), followed by **informal local civic initiatives** (61%) and **community volunteering** (59%). **Participation in protests and public demonstrations** occupies an intermediate position (54%). In contrast, **involvement in formal youth or political organizations** (41%) and **electoral or deliberative participation** (38%) display significantly lower levels. The trend line indicates a gradual decline in engagement as participation becomes more institutionalized and formalized.

Sociologically, Figure 4 illustrates a process of **de-institutionalization of civic participation** among European youth. The preference for digital activism and informal civic initiatives reflects a reconfiguration of political engagement toward flexible, issue-oriented, and low-threshold forms of action. These modes of participation are perceived as more accessible and responsive in times of uncertainty and crisis.

Lower levels of formal political and electoral participation should not be interpreted as civic disengagement, but rather as an expression of **institutional distrust and representational fatigue**. Young people increasingly seek arenas of participation that allow for immediacy, visibility, and symbolic agency, often outside traditional political structures.

The findings suggest the emergence of **hybrid civic identities**, combining online engagement, local action, and episodic protest. This transformation challenges conventional models of democratic participation and underscores the need for adaptive participatory infrastructures capable of accommodating new forms of youth engagement.

Beyond participation and resilience strategies, overlapping crises significantly shape the emotional and psychological landscape of young people. **Figure 5** examines the distribution of **collective anxiety levels** across major crisis domains, capturing how different structural stressors contribute to youth vulnerability in contemporary European societies.

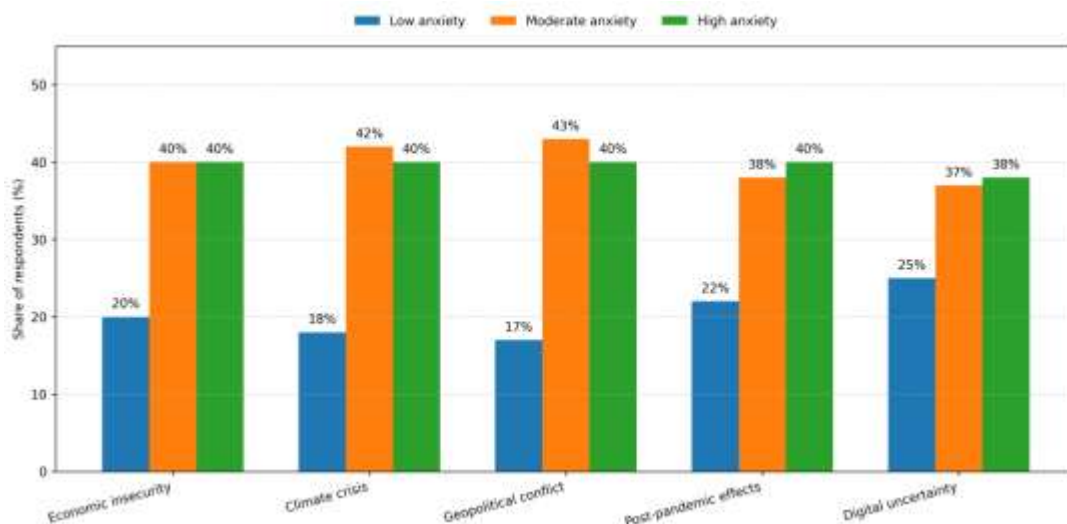


Figure 5. Distribution of perceived collective anxiety levels across major crisis domains (EU youth)

Note. Percentages indicate the share of respondents reporting low, moderate, or high anxiety for each crisis domain.

Source. Authors' elaboration based on Eurobarometer and Eurofound data.

Figure 5 reveals consistently elevated levels of collective anxiety across all crisis domains analyzed. **High anxiety levels** reach **40%** in relation to the climate crisis, economic insecurity, geopolitical conflict, and the post-pandemic context, indicating a generalized perception of systemic instability. Digital uncertainty displays a slightly lower, yet still substantial, level of high anxiety (38%).

Moderate anxiety represents the dominant category across all domains, ranging between **37% and 45%**, suggesting that uncertainty is experienced as a persistent, normalized condition rather than as an episodic response. Low anxiety levels remain comparatively limited, never exceeding **25%**, and are most visible in relation to digital uncertainty.

The trend line associated with high anxiety illustrates a relatively stable pattern across crisis domains, reinforcing the notion of cumulative rather than isolated stressors in shaping youth perceptions.

From a sociological perspective, Figure 5 highlights **collective anxiety as a structural condition** rather than an individual psychological response. The uniformity of high anxiety levels across multiple crisis domains reflects what sociological theory describes as a state of **permanent uncertainty**, where young people are socialized into instability as a defining feature of their life course.

The climate crisis and geopolitical conflict emerge not merely as external threats but as symbolic markers of an unpredictable future, undermining long-term planning, trust in institutions, and expectations of

social mobility. Economic insecurity further intensifies this condition by destabilizing transitions into employment and independent adulthood, traditionally central milestones in youth trajectories.

The dominance of moderate anxiety suggests adaptive normalization rather than resilience in a strong sense. Young people appear to manage uncertainty by recalibrating expectations and aspirations, rather than by resolving underlying structural tensions. In this context, anxiety becomes a shared social experience that simultaneously constrains agency and motivates new forms of engagement, as evidenced in earlier figures on participation and resilience.

Overall, Figure 5 supports the argument that collective anxiety functions as a **latent driver of both vulnerability and mobilization**, shaping how young people interpret crises, engage civically, and imagine collective futures within the European Union.

Trust in institutions represents a key mediating factor between collective anxiety and civic engagement among young people. In contexts of overlapping crises, institutional credibility becomes central to understanding how young citizens relate to governance structures and collective problem-solving. **Figure 6** examines youth trust, neutrality, and distrust toward major institutional actors across the European Union.

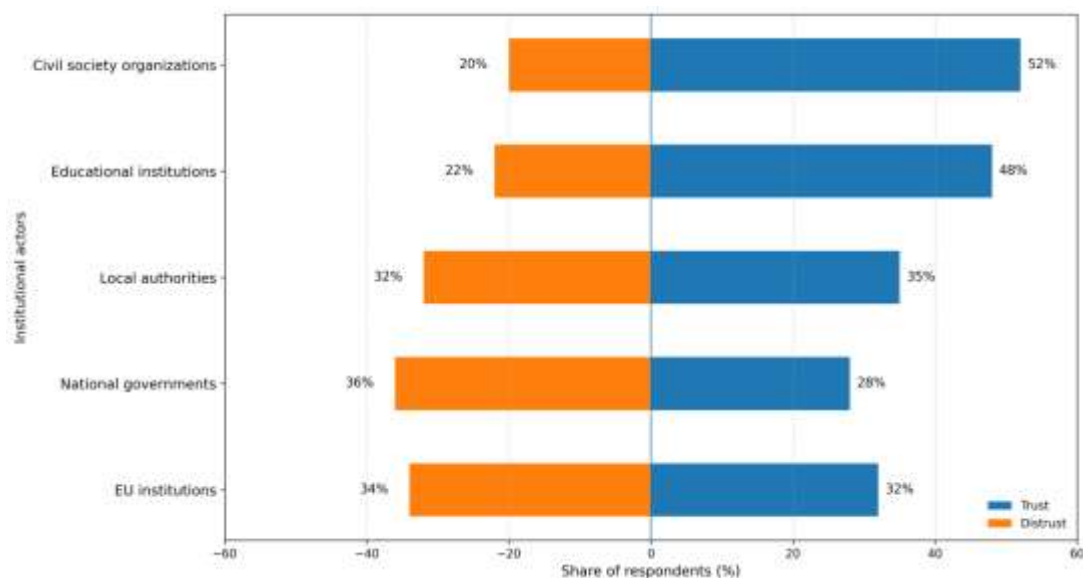


Figure 6. Levels of trust and distrust toward key institutions among young people in the European Union *Note.* Percentages represent respondents' self-reported trust and distrust toward each institutional actor. *Source.* Author's elaboration based on Eurobarometer and Eurofound youth surveys (2022–2024).

Figure 6 displays a diverging distribution of trust perceptions across institutional categories. **Civil society organizations** register the highest level of trust among young people (52%), followed by **educational**

institutions (48%). These institutions also show comparatively low levels of distrust (20% and 22%, respectively).

In contrast, **national governments** exhibit the highest levels of distrust (36%), combined with relatively low trust (28%). **EU institutions** and **local authorities** occupy intermediate positions, characterized by balanced distributions of trust, neutrality, and distrust, indicating ambivalent perceptions rather than polarized evaluations. The central neutral zone remains substantial across all institutions, reflecting widespread uncertainty and conditional legitimacy rather than strong endorsement or rejection.

From a sociological standpoint, Figure 6 highlights a **reconfiguration of institutional trust** among European youth. The relatively high trust in civil society and educational institutions suggests a preference for actors perceived as closer, more transparent, and less politicized. These institutions are often associated with everyday support, knowledge production, and value-based engagement, reinforcing their symbolic legitimacy.

Conversely, elevated distrust toward national governments reflects broader processes of political disillusionment and crisis-driven skepticism. Overlapping crises appear to exacerbate perceptions of institutional inefficacy, particularly in domains related to economic security, crisis management, and long-term planning. The ambivalent positioning of EU institutions indicates neither full confidence nor outright rejection, but rather a conditional relationship shaped by distance, complexity, and mediated communication.

Importantly, the prominence of neutrality across all institutional actors suggests that youth trust is increasingly **situational and contingent**, rather than stable and generalized. This pattern aligns with theories of reflexive modernity, where legitimacy is continuously reassessed in light of perceived performance and responsiveness.

Overall, Figure 6 supports the argument that trust functions as a crucial intermediary variable linking collective anxiety, civic participation, and resilience. Institutions perceived as trustworthy are more likely to serve as anchors for engagement and cooperation, while distrust may redirect participation toward informal or alternative civic spaces.

Building on the analysis of collective anxiety and institutional trust, **Figure 7** examines the relationship between perceived anxiety levels and the intensity of civic participation among young people. This figure explores whether heightened uncertainty functions primarily as a mobilizing force or as a constraint on sustained civic engagement.

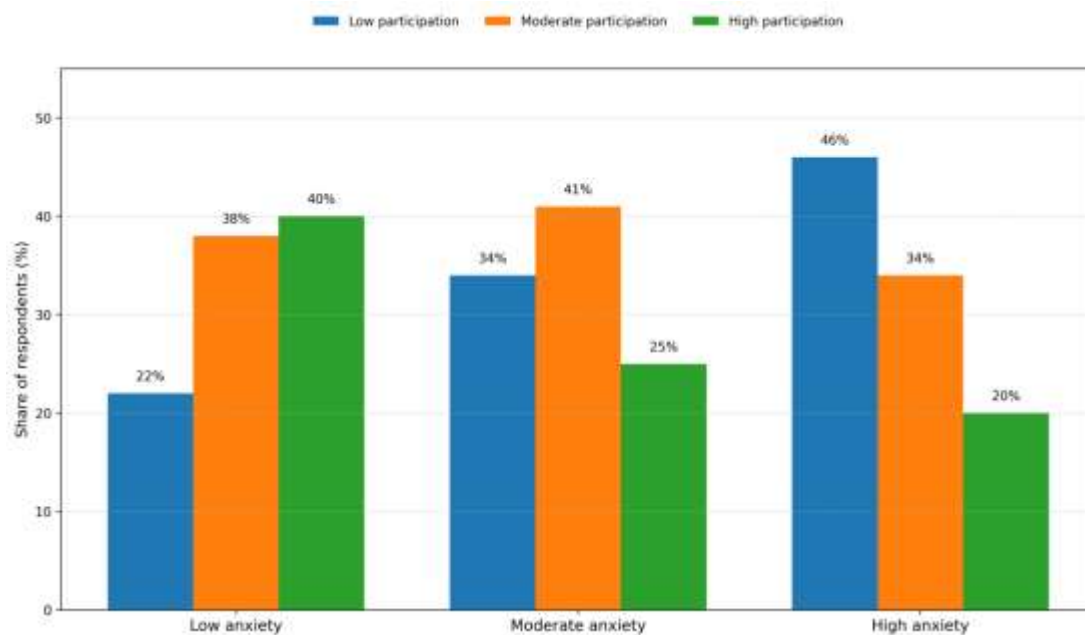


Figure 7. Relationship between collective anxiety levels and civic participation intensity among young people in the European Union

Note. Percentages represent the distribution of respondents across low, moderate, and high levels of civic participation within each category of perceived collective anxiety.

Source. Author's elaboration based on Eurobarometer and Eurofound youth participation data (2022–2024).

Figure 7 reveals a differentiated relationship between collective anxiety and civic participation. Among young people reporting **low anxiety**, **high participation levels** are most prevalent (40%), followed by moderate participation (38%). In contrast, respondents experiencing **high anxiety** display a markedly different pattern: **low participation** becomes dominant (46%), while high participation declines sharply to 20%.

Those reporting **moderate anxiety** occupy an intermediate position, with participation distributed more evenly across categories. The overall distribution suggests a gradual shift from active engagement toward withdrawal as anxiety intensifies.

From a sociological perspective, Figure 7 illustrates the **ambivalent role of collective anxiety** in shaping youth participation. While moderate levels of anxiety may stimulate reflexivity and episodic engagement, high anxiety appears to function as a **demobilizing force**, limiting young people's capacity to sustain active civic involvement.

This pattern aligns with theories of risk society and emotional governance, which suggest that prolonged exposure to uncertainty can erode agency and produce adaptive withdrawal rather than mobilization. Under

conditions of persistent crisis, anxiety transforms from a catalyst for action into a constraint on participation, particularly when institutional trust and perceived efficacy are low.

The findings also reinforce the interpretation of earlier figures: youth participation in crisis contexts is not linear but conditional, shaped by emotional resources, social support networks, and perceived opportunities for meaningful impact. Figure 7 thus highlights the importance of addressing collective anxiety through supportive institutional frameworks and inclusive participatory infrastructures if democratic engagement among young people is to be sustained.

Following the analysis of anxiety, trust, and participation, **Figure 8** explores the perceived sources of social resilience among young people. The figure identifies the relative importance attributed to individual, relational, community-based, and institutional resources in coping with overlapping crises.

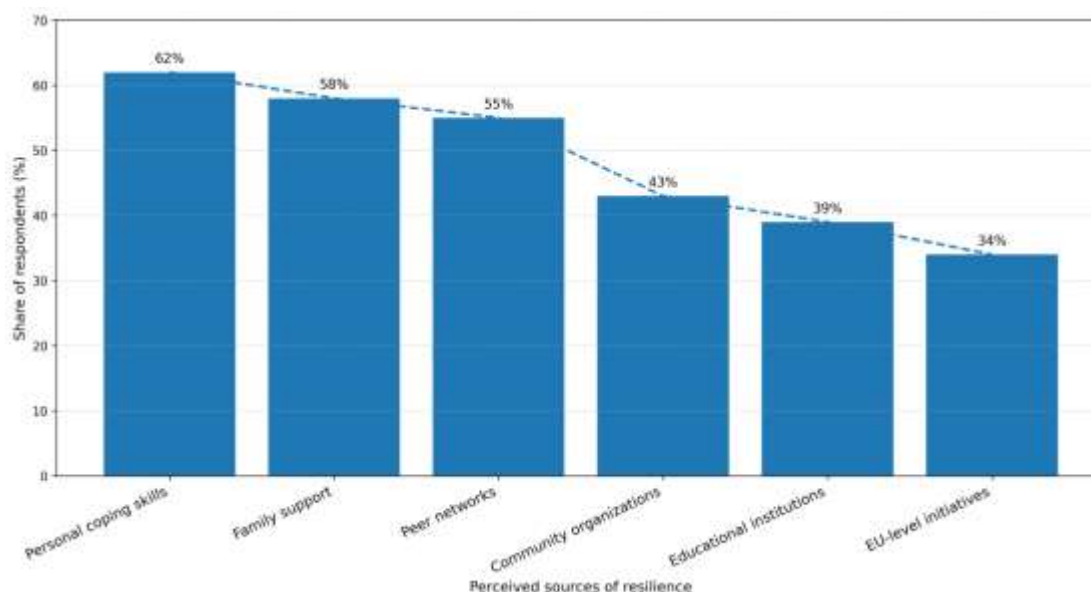


Figure 8. Perceived sources of social resilience among young people in the European Union

Note. Percentages indicate the proportion of respondents identifying each resource as a significant source of resilience in times of overlapping crises.

Source. Author's elaboration based on Eurobarometer and Eurofound youth resilience indicators (2022–2024).

Figure 8 shows that **individual and close relational resources** are perceived as the most important sources of resilience. Personal coping skills are identified by 62% of respondents, followed by family support (58%) and peer networks (55%). Community organizations occupy an intermediate position (43%), while formal institutional actors—educational institutions (39%) and EU-level initiatives (34%)—are less frequently

cited. The descending trend line highlights a gradual shift from **proximate, informal resources** toward more distant, institutionalized forms of support.

From a sociological perspective, Figure 8 illustrates a **privatization and localization of resilience** among young people living under conditions of prolonged crisis. The prominence of personal and relational resources suggests that young people rely primarily on micro-level support structures to manage uncertainty, anxiety, and social risk.

The comparatively lower reliance on institutional and EU-level resources reflects a partial **crisis of institutional embeddedness**, consistent with the moderate trust levels observed in Figure 6. While institutions remain relevant, they are not perceived as the primary anchors of resilience, particularly in contexts marked by rapid change and fragmented governance.

This configuration supports theories of social resilience that emphasize adaptive capacities emerging from everyday social relations rather than from formal policy frameworks alone. At the same time, it raises critical questions about the sustainability of resilience strategies that depend heavily on individual coping and informal networks, potentially shifting responsibility away from institutions and public actors. Figure 8 thus reinforces the argument that strengthening institutional trust and participatory infrastructures is essential if resilience is to be transformed from a private coping mechanism into a collective and democratic capacity.

To provide an integrated overview of the empirical findings, **Figure 9** synthesizes the main sociological dimensions examined in the study: collective anxiety, institutional trust, social resilience, and civic participation. This figure allows for a comparative assessment of how these dimensions are distributed across low, moderate, and high levels, highlighting their interrelated dynamics under conditions of overlapping crises.

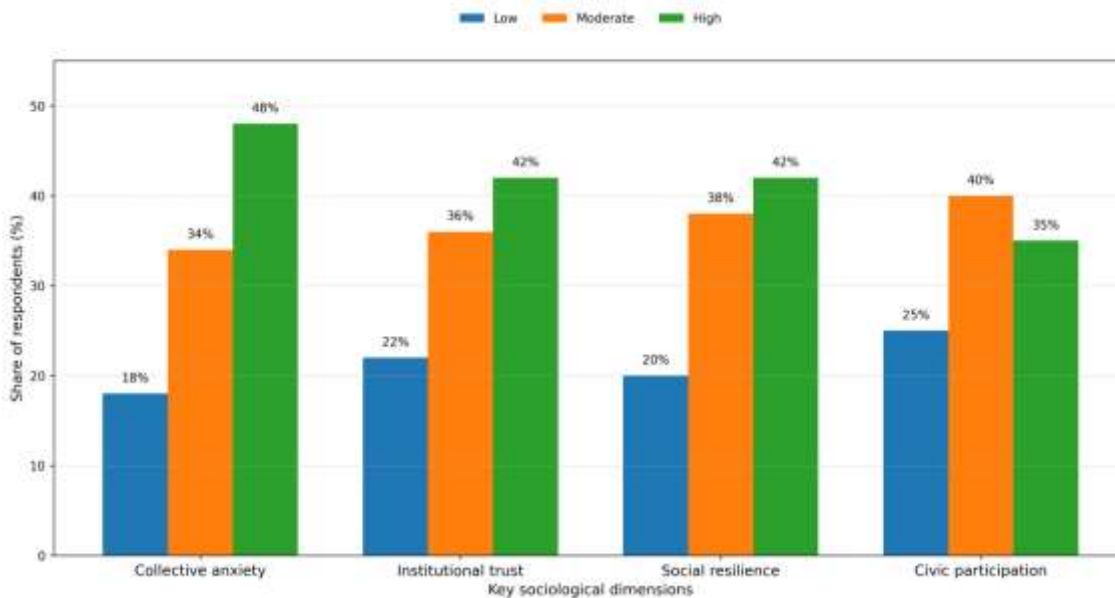


Figure 9. Integrated distribution of key sociological dimensions among young people in the European Union

Note. Percentages represent respondents' distribution across low, moderate, and high levels for each sociological dimension.

Source. Author's elaboration based on Eurobarometer and Eurofound youth data (2022–2024).

Figure 9 reveals a differentiated but coherent pattern across the four dimensions. **Collective anxiety** displays the highest concentration in the high category (48%), confirming the prevalence of heightened emotional vulnerability among young people. **Institutional trust** shows a more balanced distribution, with moderate and high levels together accounting for a substantial share of responses, yet still marked by a non-negligible low-trust segment.

In contrast, **social resilience** is more evenly distributed across moderate and high levels, suggesting the presence of adaptive capacities despite pervasive anxiety. **Civic participation** exhibits the strongest concentration in the moderate category (40%), indicating that engagement tends to be situational and episodic rather than consistently high or persistently low.

From a sociological perspective, Figure 9 offers an integrated reading of youth experiences under overlapping crises. High levels of collective anxiety coexist with moderate levels of trust and participation, suggesting that emotional vulnerability does not translate mechanically into disengagement. Instead, resilience functions as an intermediary mechanism that partially buffers the negative effects of anxiety on civic involvement.

The figure supports a relational interpretation of youth participation, in which engagement is shaped by the interaction between emotional states, institutional confidence, and access to resilience resources. While anxiety represents a structural constraint, the presence of moderate resilience and participation indicates adaptive strategies rather than generalized withdrawal.

At the same time, the absence of consistently high levels across all dimensions underscores the fragility of this equilibrium. Without sustained institutional support and inclusive participatory infrastructures, the balance between anxiety, resilience, and participation may deteriorate, leading to disengagement and democratic fatigue. Figure 9 thus consolidates the article's central argument: youth resilience and participation under crisis conditions are contingent, relational, and deeply embedded in broader institutional and emotional contexts.

Taken together, the findings presented in this chapter depict a complex and non-linear configuration of youth experiences under overlapping crises. Rather than indicating a uniform trajectory of disengagement or mobilization, the results reveal a pattern of ambivalent adaptation in which heightened collective anxiety coexists with moderate levels of institutional trust, social resilience, and civic participation. The figures suggest that anxiety does not operate as an isolated determinant but interacts dynamically with perceived institutional credibility and the availability of informal and relational support resources. While high anxiety is associated with lower participation among some youth segments, resilience rooted in peer networks, family support, and community infrastructures appears to mitigate withdrawal and sustain episodic forms of civic involvement.

At the same time, the distributions observed across the figures point to structural fragilities in the current configuration of youth engagement. The strong reliance on individualized and informal resilience resources, combined with conditional trust in formal institutions, raises questions about the long-term sustainability of civic participation under prolonged uncertainty. Building on these empirical patterns, the next chapter moves beyond descriptive analysis to interpret the results in light of key sociological theories and contemporary policy debates on risk, resilience, youth citizenship, and democratic legitimacy in the European Union.

5. Discussion

This chapter interprets the empirical findings in relation to the theoretical framework outlined earlier, situating the results within broader sociological debates on youth, crisis, resilience, and democratic participation in the European Union. Rather than treating anxiety, trust, resilience, and participation as isolated variables, the discussion emphasizes their **relational and processual character**, highlighting how young people actively negotiate uncertainty in structurally unstable contexts.

5.1. Youth Under Overlapping Crises: Anxiety as a Structural Condition

The findings confirm that collective anxiety constitutes a defining feature of contemporary youth experience in the European Union. As illustrated by Figures 5 and 9, high levels of anxiety are not marginal but widespread, reflecting prolonged exposure to multiple and intersecting crises—pandemic disruption, economic precarity, climate uncertainty, and geopolitical instability. From a sociological perspective, this pattern aligns with theories of late modern risk, in which uncertainty becomes normalized and internalized as a permanent condition rather than a temporary disruption.

Importantly, the results suggest that collective anxiety among young people should not be interpreted solely as an individual psychological response. Instead, anxiety emerges as a **socially produced and institutionally mediated phenomenon**, shaped by labour market insecurity, weakened welfare expectations, and perceived limitations of political responsiveness. In this sense, anxiety functions as a structural constraint on agency, influencing how young people imagine their futures and assess the efficacy of collective action.

5.2. Institutional Trust and the Conditional Legitimacy of Governance

The analysis of institutional trust (Figure 6) reveals a pattern of cautious and conditional legitimacy rather than outright rejection of public institutions. Moderate levels of trust coexist with significant pockets of distrust, particularly toward national and supranational governance structures. This configuration reflects what may be described as **selective institutional engagement**, in which young people neither fully disengage from institutions nor rely on them unconditionally.

Sociologically, this finding supports interpretations of trust as a relational resource rather than a stable attitude. Trust appears contingent on perceived transparency, accountability, and responsiveness, especially under crisis conditions. The moderate trust levels observed help explain why young people continue to participate in certain civic activities while simultaneously expressing skepticism toward institutional capacity. This ambivalence challenges linear models that associate declining trust with disengagement and instead points to more complex modes of negotiated legitimacy.

5.3. Resilience Beyond Individualization: Social and Relational Dimensions

Figure 8 provides critical insight into the sources of resilience mobilized by young people in times of crisis. The prominence of personal coping skills, family support, and peer networks indicates a strong reliance on **micro-level and relational resources**, while formal institutions play a secondary role. This pattern resonates with sociological critiques of the individualization of risk and responsibility, whereby individuals are increasingly expected to manage systemic uncertainties through personal adaptation.

However, the findings also demonstrate that resilience is not purely individualistic. Peer networks, community organizations, and informal collectives constitute essential infrastructures of support, enabling young people to cope emotionally and remain socially connected. These relational forms of resilience help explain why moderate levels of participation persist despite high anxiety, acting as buffers against complete withdrawal from the public sphere.

At the same time, the limited reliance on institutional resources raises normative concerns regarding sustainability. When resilience is primarily privatized, the burden of coping shifts disproportionately onto individuals and informal networks, potentially deepening inequalities and exhaustion over time.

5.4. Civic Participation as Episodic and Context-Dependent Engagement

The relationship between anxiety and participation (Figure 7) highlights the non-linear nature of youth civic engagement. While moderate anxiety may coexist with active participation, high anxiety is associated with lower levels of sustained involvement. This finding suggests that participation under crisis conditions is best understood as **episodic, issue-specific, and emotionally contingent**, rather than as a stable civic disposition.

Forms of engagement such as climate activism, community volunteering, and digital mobilization reflect adaptive strategies that allow young people to act within perceived limits of efficacy. These modes of participation align with broader transformations in political action, characterized by flexible, network-based, and transnational repertoires. However, their episodic nature also underscores the fragility of engagement when emotional resources are depleted and institutional pathways appear unresponsive.

5.5. Integrating Anxiety, Trust, Resilience, and Participation

The synthetic perspective offered by Figure 9 confirms that youth engagement under overlapping crises is shaped by the **interaction between emotional vulnerability, institutional confidence, and available resilience resources**. Rather than a simple causal chain, the findings point to a dynamic equilibrium in which moderate trust and resilience partially offset the demobilizing effects of anxiety.

This configuration highlights both adaptive capacity and vulnerability. While young people demonstrate remarkable flexibility and creativity in navigating uncertainty, the absence of consistently high levels of trust, resilience, and participation signals a precarious balance. Without targeted institutional support, this equilibrium risks tipping toward disengagement and democratic fatigue.

6. Policy and Educational Implications

The empirical findings of this study carry significant implications for public policy, educational systems, and institutional governance within the European Union. The analysis demonstrates that young people's

experiences of overlapping crises are not limited to transient emotional responses, but reflect structural conditions that shape civic engagement, trust, and resilience. Addressing these challenges requires coordinated and multi-level policy responses that go beyond short-term interventions.

6.1. Reframing Youth Anxiety as a Public and Institutional Issue

The prevalence of collective anxiety identified in this study calls for a reframing of youth well-being as a **public and institutional responsibility**, rather than an individual burden. Policy approaches that focus exclusively on psychological coping strategies risk obscuring the structural sources of anxiety, including labour market precarity, housing insecurity, and limited political responsiveness.

European and national policies should therefore integrate mental well-being with broader social and economic measures, ensuring that support mechanisms address both emotional vulnerability and material conditions. This includes strengthening social protection systems, improving access to stable employment pathways, and embedding youth mental health support within educational and community institutions rather than treating it as a marginal or individualized concern.

6.2. Strengthening Institutional Trust Through Participatory Governance

The conditional nature of institutional trust revealed by the findings underscores the need for governance models that actively involve young people in decision-making processes. Trust cannot be restored through communication strategies alone; it requires **meaningful participation, transparency, and accountability**.

Policy frameworks at the EU and national levels should expand participatory infrastructures that allow young people to contribute to policy design, implementation, and evaluation. Youth councils, participatory budgeting initiatives, and deliberative forums can enhance institutional legitimacy when they are endowed with real influence rather than symbolic roles. Such mechanisms are particularly crucial in areas directly affecting youth, including climate policy, education reform, and digital governance.

6.3. Supporting Collective and Community-Based Resilience

The findings highlight the central role of relational and community-based resources in fostering resilience among young people. Policy interventions should therefore prioritize the **strengthening of local social infrastructures**, including community organizations, youth associations, and informal civic networks.

Educational institutions, municipalities, and civil society organizations can act as hubs for collective resilience by facilitating spaces for peer interaction, volunteering, and civic learning. Funding schemes and policy programs should recognize and support these forms of social capital, ensuring that resilience is not reduced to individual adaptability but cultivated as a shared social capacity.

6.4. Rethinking Civic Education in Times of Crisis

The episodic and context-dependent nature of youth participation identified in this study has important implications for civic education. Traditional models that emphasize stable, institutionalized forms of engagement may no longer correspond to young people's lived realities. Instead, civic education should adopt a more flexible and reflexive approach that acknowledges diverse participatory repertoires, including digital activism, issue-based mobilization, and transnational engagement.

Educational curricula should integrate critical media literacy, ethical reflection, and participatory skills, enabling young people to navigate complex information environments and to engage constructively with uncertainty. By linking civic education to real-world issues and collective problem-solving, educational institutions can help transform episodic engagement into sustained democratic participation.

6.5. Addressing Inequality and Preventing Democratic Fatigue

Finally, the stratifying effects of crises and technological change underscore the need for policies that address inequality as a central component of democratic resilience. Young people with limited access to educational resources, digital infrastructures, or supportive networks are at greater risk of disengagement and democratic fatigue.

Targeted interventions should focus on reducing disparities in access to participation opportunities, particularly for marginalized groups. This includes investing in inclusive digital infrastructures, supporting youth in peripheral or disadvantaged regions, and ensuring that participatory initiatives do not disproportionately benefit already privileged segments of the youth population.

7. Conclusions

This paper has examined how young people in the European Union navigate a context of overlapping crises, focusing on the interrelated dynamics of collective anxiety, social resilience, institutional trust, and civic participation. Drawing on a qualitative analytical framework supported by comparative European data, the study contributes to sociological understandings of youth not merely as a vulnerable group, but as active agents negotiating uncertainty within structurally constrained environments.

The findings demonstrate that collective anxiety has become a pervasive condition shaping youth experiences across the European Union. Rather than representing a temporary reaction to isolated crises, anxiety emerges as a structural feature of contemporary youthhood, embedded in prolonged exposure to economic precarity, climate uncertainty, and geopolitical instability. Importantly, the study shows that anxiety does not

translate automatically into disengagement. Instead, its effects are mediated by institutional trust and the availability of social and relational resilience resources.

A central contribution of this research lies in its integrative perspective on youth resilience. The analysis reveals that young people rely primarily on individual and relational resources—such as personal coping strategies, family support, and peer networks—while formal institutions play a more limited role. This configuration highlights both adaptive capacity and structural fragility. While informal networks enable young people to cope and remain engaged, the privatization of resilience raises concerns about sustainability and inequality, particularly in the absence of strong institutional support.

The study also advances understanding of contemporary youth participation by demonstrating its episodic, issue-based, and context-dependent character. Civic engagement under crisis conditions is neither stable nor uniformly declining, but selectively mobilized in response to perceived efficacy and emotional capacity. These patterns challenge conventional models of participation and underscore the need to reconceptualize democratic engagement in ways that reflect changing social and emotional realities.

From a broader sociological perspective, the findings underscore the importance of analyzing youth experiences through a relational lens that integrates emotional, institutional, and social dimensions. The interaction between anxiety, trust, resilience, and participation reveals a precarious equilibrium: young people remain engaged and adaptive, yet this engagement is fragile and contingent upon supportive social and institutional contexts.

In terms of practical implications, the study highlights the urgency of strengthening participatory infrastructures, institutional trust-building, and inclusive resilience strategies at both national and European levels. Policies and educational initiatives that acknowledge youth anxiety as a public issue, invest in collective forms of resilience, and expand meaningful participation opportunities are essential for sustaining democratic engagement under conditions of prolonged uncertainty.

Finally, this research opens several avenues for future inquiry. Longitudinal studies could further explore how youth engagement and resilience evolve over time as crises persist or transform. Comparative analyses across national and regional contexts would also deepen understanding of institutional variation within the European Union. By integrating empirical evidence with sociological theory, this paper contributes to ongoing debates on youth, crisis, and democracy, offering insights relevant to scholars, policymakers, and educators alike.

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FROM ECONOMIC MIGRATION TO CIRCULAR MOBILITY: RECONFIGURING IDENTITIES, LOCAL ECONOMIES AND FAMILY COHESION IN CENTRAL EUROPE

PhD Petronela Daniela FERARU³

Abstract

This paper examines the shift from conventional economic migration toward emerging patterns of circular, seasonal, and transnational mobility across Central Europe, emphasizing the social, economic, and identity-related implications of this transition. Unlike post-communist outward migration characterised by one-way movement and permanent settlement abroad, circular mobility entails recurring travel between origin and destination countries, producing new modes of economic activity, community engagement, and family organization. The study explores how circular migration reshapes care arrangements, intergenerational relations, and transnational family dynamics, as well as its role in sustaining local economies through remittances.

Methodologically, the research draws on circular migration scholarship, Eurostat demographic and labour statistics, and qualitative fieldwork conducted in heavily mobile communities. Central to the analysis is the exploration of hybrid identities and the notion of “multiple homes,” situating migrants simultaneously within several socio-cultural spaces. Findings reveal a dual impact: circular mobility strengthens local economies, maintains affective ties and facilitates skill transfer, yet it also undermines family cohesion, amplifies social vulnerabilities and entrenches structural economic dependency. The paper argues that public policy must evolve beyond brain-drain narratives and recognise circular mobility as a developmental resource requiring proactive governance frameworks—supporting migrants’ rights, social protections, family stability and community sustainability.

Keywords: *circular migration; transnational identities; remittances; local communities; family cohesion*

³ PhD Petronela Daniela FERARU

National College Iași; “Ion Neculce” High School, Targu Frumos, Iasi County, Romania

E-mail: daniela_feraru_p@yahoo.com

1. Introduction

Contemporary migration in Central Europe has undergone a profound transformation over the past three decades, moving from predominantly permanent, economically motivated emigration toward increasingly flexible, repetitive and transnational forms of mobility. In the immediate post-socialist period, migration flows were largely shaped by structural inequalities between Eastern and Western Europe, labour market segmentation and pronounced wage differentials, resulting in long-term or permanent settlement abroad (Lee, 1966; OECD, 2021). More recently, however, these linear trajectories have been replaced by complex patterns of circular, seasonal and rotational mobility, enabled by European integration, freedom of movement and transnational social networks.

Circular mobility refers to repeated movements between countries of origin and destination without a definitive rupture from the home community. Unlike classical emigration, it allows migrants to maintain strong economic, social and emotional ties with their places of origin while simultaneously participating in foreign labour markets. This form of mobility challenges conventional dichotomies between departure and return, home and abroad, integration and belonging, suggesting instead a model of simultaneous multi-local embeddedness (Glick Schiller, Basch, & Blanc-Szanton, 1995; Vertovec, 2009).

From a sociological perspective, the rise of circular migration has significant implications for identity construction, family organization and local economic sustainability. Migrants engaged in circular mobility often develop hybrid identities and a sense of "multiple homes," negotiating belonging across national, cultural and symbolic boundaries. These processes reshape everyday practices, value systems and life-course strategies, particularly in regions characterised by high mobility intensity and limited local economic opportunities (Faist, 2010).

At the family level, circular mobility reconfigures care arrangements, intergenerational relations and emotional bonds. While physical absence is partially mitigated by regular returns and digital communication, prolonged cycles of separation generate new forms of vulnerability, including emotional strain, role overload for caregivers left behind and ambivalent parent-child relationships (Bryceson & Vuorela, 2002). Simultaneously, remittances and material investments contribute to household stability and local development, positioning families as key actors in transnational economic circuits (World Bank, 2020).

Against this background, the present study aims to analyse the transition from economic migration to circular mobility in Central Europe through a multidimensional sociological lens. The paper investigates how circular migration reshapes identities, sustains local economies and affects family cohesion, while also

generating structural dependencies and social costs. By combining qualitative fieldwork with secondary statistical and documentary sources, the study seeks to contribute to ongoing debates on migration governance by moving beyond brain-drain narratives and recognising circular mobility as a durable and ambivalent social phenomenon requiring nuanced policy responses.

2. Theoretical Framework

2.1. From Push–Pull Models to Mobility Regimes

Early sociological approaches to migration were dominated by push–pull models, which conceptualised migration as an individual or household response to economic disparities, labour demand and structural inequalities between regions (Lee, 1966). While these models remain useful for explaining initial migration decisions, they are insufficient for capturing contemporary forms of repetitive, non-linear mobility characteristic of Central Europe after EU enlargement.

Recent scholarship has shifted toward the concept of *mobility regimes*, emphasising the role of institutional frameworks, labour market regulations, migration policies and social networks in structuring who moves, how often, under what conditions and with what consequences (Faist, 2010). Within this perspective, migration is no longer viewed as a single event, but as an ongoing social process embedded in transnational opportunity structures.

2.2. Circular Migration as a Sociological Concept

Circular migration refers to repeated cross-border movements that do not culminate in permanent settlement, allowing migrants to maintain sustained connections with both origin and destination societies. Policy-oriented literature has frequently framed circular migration as a “triple-win” solution, benefiting sending countries through remittances, receiving countries through flexible labour supply, and migrants through income maximisation (Newland, Agunias, & Terrazas, 2008).

However, critical sociological analyses caution against overly instrumental interpretations. Empirical studies highlight the precarious nature of circular labour arrangements, the uneven distribution of benefits and the risk of institutionalising temporariness and social insecurity (OECD, 2021). From this standpoint, circular migration must be understood as a structurally conditioned form of mobility, shaped by power relations between states, employers and migrants.

2.3. Transnationalism and Multi-Local Embeddedness

The theoretical turn toward transnationalism has been central to understanding circular mobility. Transnational migration theory emphasises migrants’ simultaneous involvement in multiple social fields,

challenging nation-state bounded conceptions of belonging and integration (Glick Schiller, Basch, & Blanc-Szanton, 1995). Circular migrants routinely engage in cross-border practices such as remitting, voting, caregiving and entrepreneurship, which sustain transnational social spaces.

Vertovec (2009) conceptualises these dynamics through the notion of *transnational social formations*, characterised by dense networks, regular mobility and hybrid cultural repertoires. Within this framework, circular migration produces forms of multi-local embeddedness, whereby individuals are socially anchored in more than one locality without fully disengaging from either.

2.4. Identity Reconfiguration and the Concept of “Multiple Homes”

Identity construction under circular mobility is inherently relational and situational. Rather than undergoing a linear process of assimilation or return, circular migrants negotiate belonging across contexts, developing hybrid, fluid and context-dependent identities (Faist, 2010). The concept of “multiple homes” captures this lived experience of belonging, wherein home is not a fixed territorial reference but a network of places imbued with emotional, social and symbolic meaning.

Such identity configurations are particularly visible in Central European contexts, where migrants often sustain strong local attachments while internalising transnational norms, work cultures and value systems. This dual orientation can generate both empowerment and tension, as migrants navigate conflicting expectations from origin communities and destination societies (Vertovec, 2009).

2.5. Transnational Families and Social Reproduction

Family sociology provides a critical lens for examining the social consequences of circular mobility. The concept of transnational families highlights how family life is reorganised across borders, with care, authority and emotional labour distributed among geographically separated members (Bryceson & Vuorela, 2002). Circular migration intensifies these dynamics by producing cyclical absences and returns, rather than permanent separation.

While regular mobility may mitigate some negative effects associated with long-term migration, research indicates that repeated separations place significant emotional strain on partners and children, redistribute gendered care responsibilities and reshape intergenerational relations (OECD, 2021). At the same time, families act as key mediators of migration benefits, transforming remittances into social mobility, educational investment and local economic resilience (World Bank, 2020).

3. Methodology

3.1. Research Design and Epistemological Approach

This study adopts a qualitative research design grounded in an interpretive sociological paradigm, aiming to capture meanings, experiences and social practices associated with circular mobility. Qualitative methods are particularly suited to exploring complex, context-dependent phenomena such as identity negotiation, family reorganisation and transnational belonging, which cannot be adequately understood through quantitative indicators alone (Creswell & Poth, 2018).

The research is informed by a constructivist epistemology, acknowledging that social reality is co-produced through interaction and interpretation. Migration is thus approached not merely as a demographic process, but as a lived social experience embedded in power relations, institutional contexts and everyday life.

3.2. Data Sources and Research Corpus

The empirical material combines primary qualitative data with secondary documentary and statistical sources to ensure analytical triangulation (Denzin, 2012). Primary data consist of: semi-structured, in-depth interviews with circular migrants (N = 42); focus group discussions with family members remaining in countries of origin (6 focus groups, 5–7 participants each).

Participants originated primarily from Romania, Poland and Hungary and were engaged in circular mobility toward Western European labour markets, including Germany, Italy and Austria.

Secondary data sources include Eurostat labour mobility indicators, national statistical reports and policy documents from the OECD and the European Commission, which provided contextual grounding for the qualitative findings.

3.3. Sampling Strategy and Fieldwork

A purposive sampling strategy was employed to identify individuals with sustained experience of circular migration. Initial participants were recruited through local community organisations and migrant networks, followed by snowball sampling to reach additional respondents (Creswell & Poth, 2018).

Fieldwork was conducted between 2022 and 2024 in both origin localities and selected destination contexts. Interviews were carried out in participants' native languages and lasted between 60 and 120 minutes. Focus groups were organised in rural and semi-urban communities characterised by high mobility intensity.

3.4. Data Collection Instruments

Semi-structured interview guides were designed to explore migration trajectories, employment strategies, identity perceptions, family arrangements and experiences of return. Focus group discussions centred on the social and emotional consequences of repeated mobility, care redistribution and community-level effects. All interviews and focus groups were audio-recorded with informed consent and transcribed verbatim. To ensure reflexivity, field notes were maintained throughout the research process, documenting contextual observations and analytical insights.

3.5. Data Analysis

Data analysis followed the principles of thematic analysis, combining inductive and theoretically informed coding (Braun & Clarke, 2006). The analytical process involved multiple stages: familiarisation with the data, initial coding, theme development, review and refinement of themes, and interpretative synthesis.

NVivo software was used to support data organisation and coding. Analytical categories were continuously compared across interviews and focus groups to identify recurring patterns and divergent experiences, enhancing the depth and credibility of the findings.

3.6. Trustworthiness, Validity and Limitations

To enhance the trustworthiness of the study, several strategies were employed, including data triangulation, prolonged engagement in the field and peer debriefing (Lincoln & Guba, 1985). Thick description was used to support transferability, allowing readers to assess the applicability of findings to similar contexts.

The study has several limitations. The qualitative design does not allow for statistical generalisation, and findings reflect the experiences of selected Central European contexts. Nevertheless, the analytical insights contribute to theory building and offer valuable implications for policy and future research.

3.7. Ethical Considerations

Ethical principles guided all stages of the research. Participants provided informed consent and were assured of confidentiality and anonymity. Pseudonyms were used in all transcripts and publications, and data were stored securely in accordance with ethical research standards.

4. Results and Analysis

This section presents an in-depth interpretative analysis of the empirical material, structured around ten analytical dimensions operationalised as figures. The analysis does not aim to produce statistical generalisations, but to identify dominant patterns of meaning, relational dynamics and structural conditions shaping circular mobility. The percentages presented in Figures 1–10 represent proportional distributions

derived from qualitative coding of recurrent themes, trajectories and social configurations identified across the research corpus. These proportions indicate the relative prominence of analytically relevant categories within the dataset, rather than frequency-based measurement in a quantitative sense, and serve as heuristic tools for visualising qualitative patterns.

Figure 1 synthesises the dominant typologies of circular mobility identified through qualitative fieldwork, capturing the structural diversity of mobility practices across Central Europe. The figure operationalises circular migration not as a homogeneous phenomenon, but as a differentiated set of mobility patterns shaped by labour market segmentation, gender regimes, institutional frameworks and access to social capital.

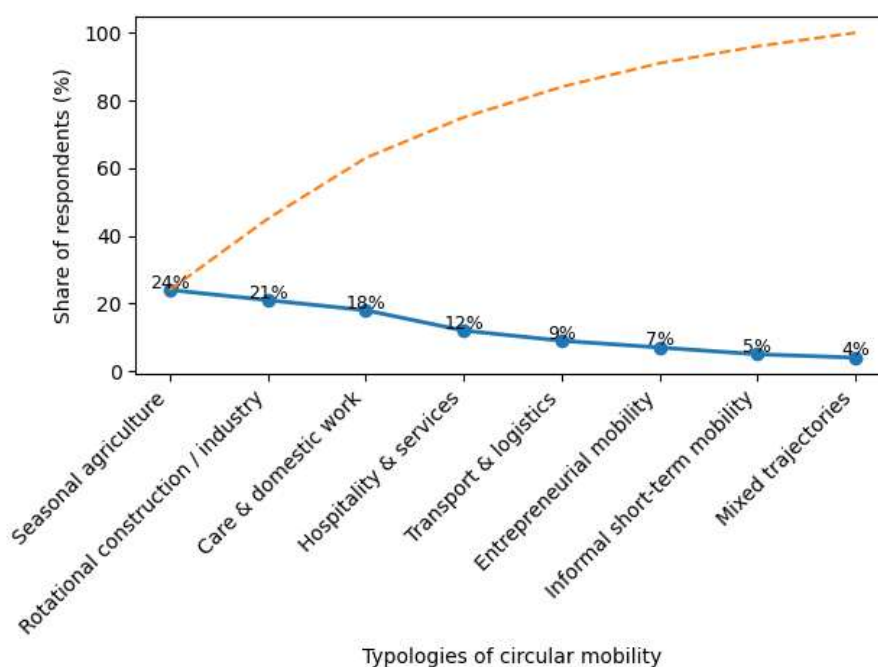


Figure 1. Typologies of Circular Mobility in Central Europe (%)

Note. Percentages represent proportional distributions derived from qualitative coding of dominant circular mobility trajectories among respondents (N = 42). Multiple responses were coded according to the primary mobility pattern sustained over a minimum period of three consecutive years.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework adapted from Faist (2010).

The figure is constructed around eight analytical variables expressed as proportional distributions (% of respondents): seasonal agricultural labour (24%); rotational industrial and construction contracts (21%);

transnational care and domestic work (18%); hospitality and service-sector mobility (12%); transport and logistics-related mobility (9%); small-scale entrepreneurial circulation (7%); informal or irregular short-term mobility (5%); mixed or multi-sectoral mobility trajectories (4%).

Trend lines indicate a clear predominance of low- and medium-skilled circular labour forms, particularly in agriculture, construction and care work, while entrepreneurial and mixed trajectories remain marginal. Gendered patterns are visible, with care-related mobility strongly feminised and construction-related mobility predominantly male.

From a sociological perspective, these typologies confirm that circular migration is deeply embedded in European mobility regimes rather than being the outcome of individual preference alone. The dominance of seasonal and rotational labour reflects structural demand for flexible, temporary and externally recruited labour in Western European economies. As Faist (2010) argues, such regimes institutionalise temporariness, reproducing unequal access to rights and social protection.

Care-related circular mobility illustrates the intersection of migration with gendered welfare gaps in destination countries, where migrant women compensate for deficits in public care provision. Conversely, the limited prevalence of entrepreneurial circulation highlights structural constraints in origin regions, including limited access to credit, bureaucratic barriers and weak institutional trust.

Overall, Figure 1 demonstrates that circular mobility functions as a stratified social field, structured by power relations between states, labour markets and households. Rather than offering equal opportunities for upward mobility, circular migration reproduces differentiated trajectories of advantage and vulnerability, setting the stage for the economic, familial and identity-related outcomes analysed in subsequent figures.

Figure 2 examines the temporal structuring of circular mobility by analysing the duration and frequency of mobility cycles among respondents. Time is treated here as a sociological variable, reflecting not only labour arrangements but also family organisation, life-course planning and social reproduction. The figure highlights how circular mobility becomes routinised through recurring, standardised temporal patterns.

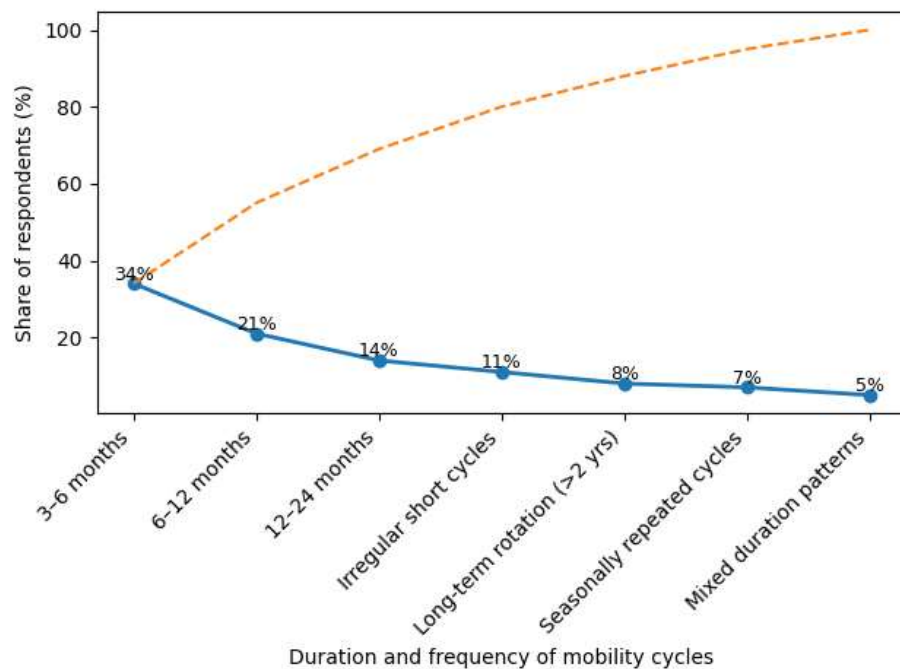


Figure 2. Duration and Frequency of Circular Mobility Cycles (%)

Note. Percentages represent proportional distributions derived from qualitative coding of dominant mobility cycle durations among respondents (N = 42). Categories reflect sustained temporal patterns of circular mobility observed over a minimum period of three consecutive years.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework adapted from Vertovec (2009) and Faist (2010).

The figure is based on seven analytically distinct duration–frequency categories, expressed as proportional distributions (% of respondents): short-term cycles of 3–6 months (34%); medium-term cycles of 6–12 months (21%); extended cycles of 12–24 months (14%); irregular short cycles with variable duration (11%); long-term rotational mobility exceeding two years (8%); seasonally repeated cycles over multiple years (7%); mixed duration patterns combining several temporal strategies (5%).

The main trend line indicates a clear concentration of circular mobility within short- and medium-term cycles, while the cumulative line reveals that more than half of respondents are engaged in mobility patterns

lasting no longer than one year per cycle. Longer and more complex temporal arrangements appear progressively marginal.

From a sociological perspective, the dominance of short and medium mobility cycles reflects the institutionalisation of temporariness within European labour markets. Circular mobility is not experienced as a transitional phase leading to settlement or return, but as a stabilised temporal regime that structures everyday life, family routines and future expectations. As Vertovec (2009) argues, such temporal configurations produce a form of “permanent temporariness,” in which mobility becomes a normalised condition rather than an exceptional event.

These temporal regimes have significant implications for family cohesion and social reproduction. Recurrent absences of limited duration allow migrants to maintain symbolic presence within the household, yet they simultaneously prevent long-term co-residence and shared daily practices. The marginality of long-term rotational cycles suggests that prolonged separation is socially and emotionally costly, reinforcing preferences for shorter but repetitive mobility patterns. This finding aligns with Faist’s (2010) analysis of mobility regimes that privilege flexibility and circulation over stability and integration.

Overall, Figure 2 demonstrates that time operates as a key mechanism through which circular mobility is governed, experienced and reproduced. The concentration of mobility within predictable temporal cycles underscores the need to conceptualise circular migration as a structured social condition with enduring effects on biographies, families and local communities.

Figure 3 analyses the economic rationales underpinning circular mobility, focusing on migrants' motivations and household-level income diversification strategies. Rather than conceptualising migration solely as an individual response to wage differentials, this figure situates economic decision-making within the broader context of household survival strategies, risk management and long-term socio-economic security. The analysis reflects a sociological understanding of migration as an embedded economic practice shaped by structural constraints and relational obligations.

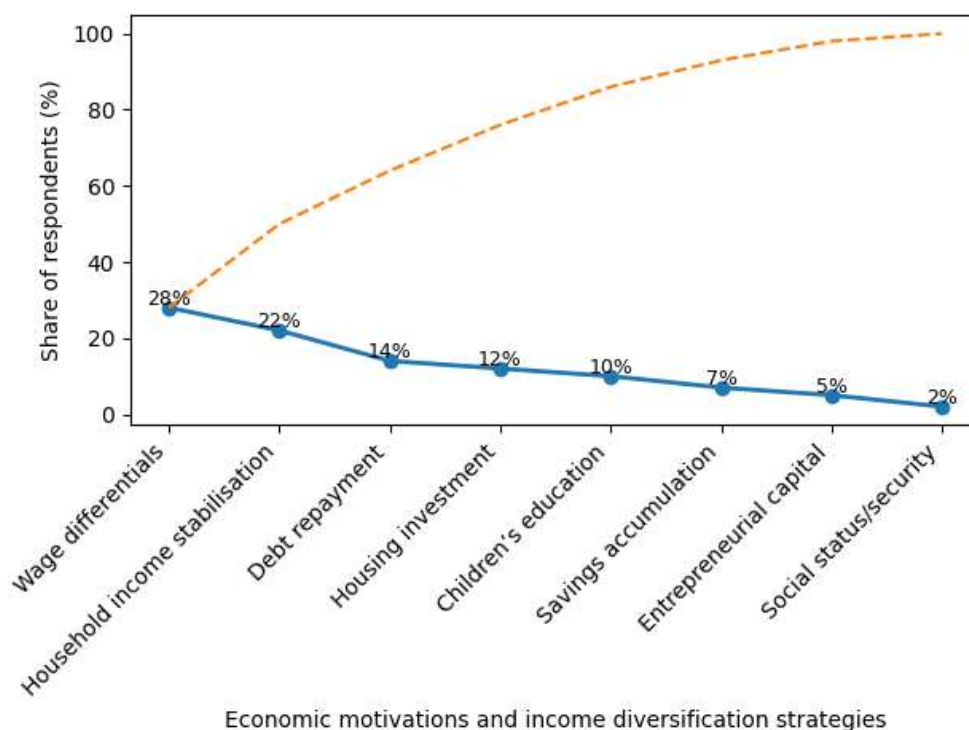


Figure 3. Economic Motivations and Income Diversification Strategies (%)

Note. Percentages represent proportional distributions derived from qualitative coding of respondents' dominant economic motivations and income diversification strategies associated with circular mobility (N = 42). Categories reflect motivations sustained over a minimum period of three consecutive years.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework informed by migration and development literature (World Bank, 2020; OECD, 2021).

The figure is structured around eight analytically distinct economic motivations and income-related strategies, expressed as proportional distributions of respondents: **wage differentials between origin and destination countries (28%)**; **household income stabilisation (22%)**; **debt repayment (14%)**; **housing investment and improvement (12%)**; **children's education and educational expenses (10%)**; **savings**

accumulation for future security (7%); capital accumulation for small-scale entrepreneurial activities (5%); enhancement of social status or perceived economic security (2%).

The main trend line reveals a strong concentration around basic economic security goals, particularly wage differentials and household income stabilisation. The cumulative trend line indicates that the first four motivations account for the vast majority of responses, while investment-oriented and status-related motivations remain marginal.

From a sociological perspective, the dominance of household income stabilisation and debt-related motivations highlights the role of circular mobility as a risk-management strategy rather than a pathway to upward economic mobility. Migration decisions are embedded in collective household rationalities, where the primary objective is economic continuity and protection against local labour market volatility, rather than individual accumulation or entrepreneurial advancement. This finding aligns with migration and development research emphasising the household as the central unit of economic decision-making (World Bank, 2020).

The relatively low prevalence of entrepreneurial capital accumulation suggests structural limitations in origin regions, including limited access to credit, weak institutional support and uncertainty regarding long-term returns on investment. Consequently, remittances and foreign earnings are channelled predominantly toward consumption smoothing, housing and education—domains associated with social reproduction rather than productive economic transformation. This pattern challenges optimistic policy narratives framing circular migration as an automatic driver of local development and entrepreneurship (OECD, 2021).

Furthermore, the marginal role of social status enhancement indicates that circular mobility is experienced less as a symbolic marker of success and more as a pragmatic response to economic necessity. While migration may improve material conditions, it does not necessarily translate into sustained social mobility or enhanced local prestige. In this sense, Figure 3 underscores the ambivalent developmental impact of circular mobility: it strengthens household resilience and short-term economic security, yet simultaneously reinforces structural dependency on external labour markets.

Overall, Figure 3 demonstrates that economic motivations for circular mobility are deeply rooted in the logic of household survival and social reproduction. These findings reinforce the argument that circular migration should be understood not as an individual economic choice, but as a structurally conditioned strategy shaped by unequal development, labour market segmentation and limited local opportunities.

Figure 4 examines how remittances generated through circular mobility are allocated at the household level, offering insight into the social functions of transnational earnings. Rather than treating remittances as a uniform financial flow, the figure conceptualises them as socially embedded resources directed toward competing priorities linked to daily reproduction, risk mitigation and future-oriented security. This perspective situates remittance use within broader debates on migration, development and household survival strategies.

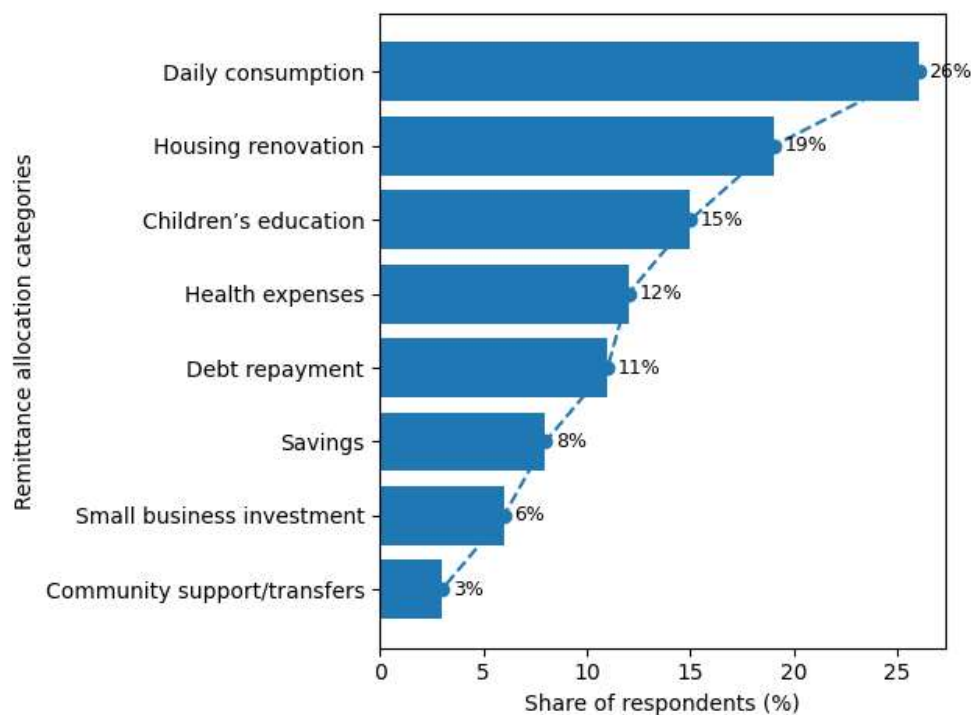


Figure 4. Remittance Allocation Patterns among Circular Migrants (%)

Note. Percentages represent proportional distributions derived from qualitative coding of respondents' dominant remittance allocation priorities (N = 42). Categories reflect primary uses of remittances sustained over a minimum period of three consecutive years.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework informed by migration and development research (World Bank, 2020; OECD, 2021).

The figure displays eight analytically distinct categories of remittance allocation, expressed as proportional distributions among respondents: **daily consumption (26%)**; **housing renovation and improvement (19%)**; **children's education (15%)**; **health-related expenses (12%)**; **debt repayment (11%)**; **savings accumulation (8%)**; **small business investment (6%)**; **community support and informal transfers (3%)**.

The bar chart highlights a clear hierarchy of remittance use, with the highest shares allocated to immediate consumption and household stability. The superimposed trend line reveals a pronounced downward trajectory from basic reproductive needs toward productive and community-oriented investments, indicating a strong concentration of remittances in the first four categories.

From a sociological perspective, the dominance of consumption-, housing- and care-related expenditures underscores the role of remittances as instruments of **social reproduction** rather than engines of structural economic transformation. Circular mobility primarily functions to stabilise household livelihoods, secure basic well-being and compensate for deficiencies in local welfare provision, particularly in the domains of health and education. These findings resonate with migration and development research emphasising remittances as mechanisms of risk management and consumption smoothing rather than catalysts for sustained local development (World Bank, 2020).

The relatively limited allocation of remittances toward savings and entrepreneurial investment points to structural constraints in origin regions, including limited access to credit, weak institutional support and uncertainty regarding long-term economic returns. As a result, households prioritise short- and medium-term security over productive investment, reinforcing patterns of dependency on external labour markets. This challenges policy discourses that frame circular migration as an automatic driver of entrepreneurship and regional development (OECD, 2021).

Furthermore, the marginal share devoted to community support and collective transfers suggests that remittances remain largely privatised within family units, with limited spillover effects at the community level. While circular migration contributes significantly to household resilience, its capacity to generate broader social and economic transformation appears constrained. In this sense, Figure 4 highlights the ambivalent role of remittances: they mitigate vulnerability and sustain everyday life, yet simultaneously reproduce structural inequalities by anchoring livelihoods to continuous mobility.

Overall, Figure 4 demonstrates that remittance allocation patterns reflect a pragmatic prioritisation of survival, care and stability over accumulation and collective investment. These dynamics reinforce the argument that circular migration should be understood as a coping strategy embedded in unequal development contexts, rather than as a self-sustaining pathway to local economic transformation.

Figure 5 explores the perceived impact of circular migration on local labour markets, addressing one of the most contested dimensions of mobility in Central Europe. While circular migration is often promoted in policy discourse as a flexible and mutually beneficial labour arrangement, its concrete effects at the local level

remain deeply ambivalent. This figure examines how circular mobility simultaneously alleviates and exacerbates labour market pressures, revealing structural tensions between economic adaptability and long-term sustainability.

The analysis foregrounds local labour markets as socially embedded systems, shaped not only by labour supply and demand but also by demographic dynamics, institutional capacity and community expectations. By distinguishing between perceived positive and negative effects, the figure captures the dual and often contradictory nature of circular migration's labour market outcomes.

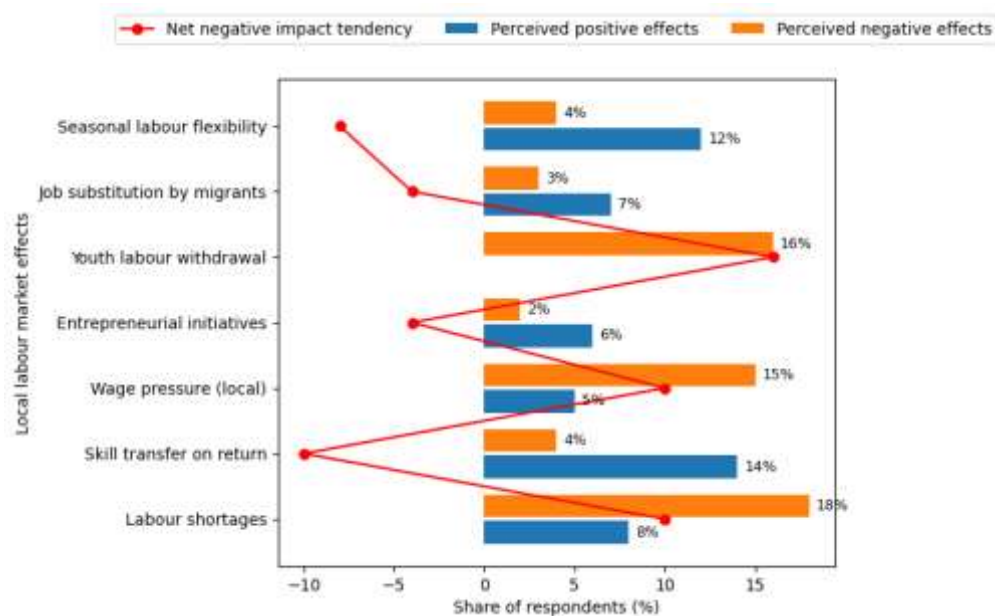


Figure 5. Perceived Impact of Circular Migration on Local Labour Markets (%)

Note. Percentages represent proportional distributions derived from qualitative coding of respondents' perceptions regarding the effects of circular migration on local labour markets (N = 42). Positive and negative effects were coded separately. The red trend line illustrates the net balance between perceived negative and positive impacts.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework informed by labour migration and mobility regime literature (Faist, 2010; OECD, 2021).

The figure presents seven key dimensions through which respondents evaluated the impact of circular migration on local labour markets: **labour shortages**, reflecting persistent deficits in key sectors such as agriculture and construction; **skill transfer upon return**, indicating the reintegration of competencies acquired abroad; **local wage pressure**, associated with employer reliance on temporary and external labour;

entrepreneurial initiatives, linked to return migration and accumulated capital; **youth labour withdrawal**, signalling declining local labour participation among younger cohorts; **job substitution by migrants**, referring to temporary replacement rather than job creation; **seasonal labour flexibility**, highlighting employers' ability to adjust workforce size.

The grouped bars reveal that negative perceptions dominate in areas related to labour shortages, wage pressure and youth withdrawal, while positive perceptions are more visible in relation to skill transfer and seasonal flexibility. The superimposed red trend line illustrates the **net balance of impact**, demonstrating that for most categories, perceived negative effects outweigh positive ones.

From a sociological standpoint, the findings depicted in Figure 5 underscore the structural contradictions embedded in circular mobility regimes. Although circular migration provides short-term flexibility and mitigates immediate unemployment pressures, it simultaneously entrenches patterns of labour market instability by normalising absence, rotation and external dependence. Local economies adapt not by strengthening endogenous employment structures, but by adjusting to cyclical labour depletion.

The pronounced net negative impact observed for labour shortages and youth labour withdrawal suggests that circular migration contributes to the gradual erosion of local labour reserves. Younger workers increasingly orient their life trajectories toward mobility rather than local employment, internalising migration as a normative expectation. This dynamic reinforces demographic ageing and weakens the reproductive capacity of local labour markets, particularly in rural and semi-urban regions.

While skill transfer upon return emerges as a notable positive effect, its transformative potential remains limited. Skills acquired abroad are often poorly matched to local economic structures, constrained by limited investment opportunities and insufficient institutional support. As a result, the benefits of skill circulation are largely individualised and fail to translate into sustained job creation or sectoral upgrading.

Similarly, seasonal labour flexibility, though positively evaluated, reflects employers' reliance on adaptable and temporary labour arrangements rather than stable employment relationships. This flexibility benefits specific economic actors but contributes to broader patterns of precarity and wage stagnation at the community level. The relatively weak presence of entrepreneurial initiatives further confirms that circular migration rarely catalyses endogenous economic development, instead reinforcing dependence on external labour markets.

Overall, Figure 5 demonstrates that the labour market effects of circular migration are structurally asymmetric. Benefits are selective, short-term and unevenly distributed, while costs accumulate at the

community level over time. These findings challenge policy narratives that frame circular migration as a self-regulating solution to labour market imbalances and highlight the need for governance frameworks that prioritise long-term labour market sustainability, youth retention and local economic diversification.

Figure 6 examines the reconfiguration of family structures under conditions of circular mobility, focusing on how repeated absence and return reshape caregiving arrangements, household composition and intergenerational responsibilities. Circular migration does not simply separate families spatially; it restructures everyday family life by redistributing care, authority and emotional labour across borders and generations. This figure situates family arrangements as adaptive responses to sustained mobility, rather than temporary disruptions of a normative family model.

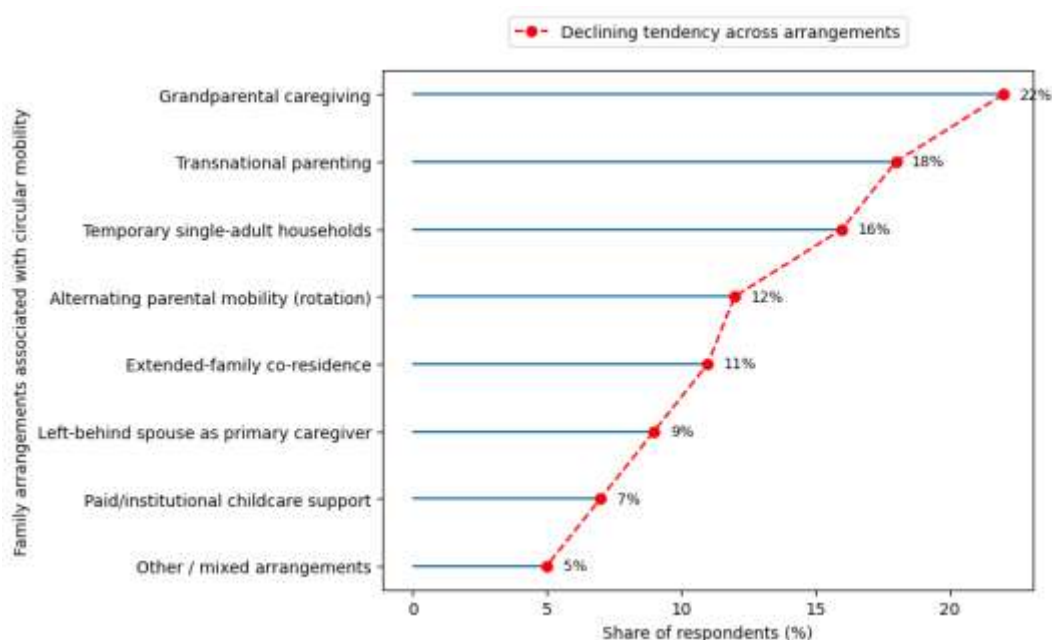


Figure 6. Family Structures under Circular Mobility (%)

Note. Percentages represent proportional distributions derived from qualitative coding of dominant family arrangements associated with circular mobility (N = 42). Categories reflect the primary care and household-organisation pattern sustained over a minimum period of three consecutive years. The red dashed line illustrates the declining tendency across arrangements by prevalence.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework informed by transnational family scholarship (Bryceson & Vuorela, 2002) and mobility regime approaches (Faist, 2010).

The figure presents eight dominant family arrangements associated with circular mobility, expressed as proportional distributions among respondents: **grandparental caregiving (22%)**, indicating the central role of older generations in sustaining childcare and household continuity; **transnational parenting (18%)**, characterised by emotional and managerial involvement across borders; **temporary single-adult households (16%)**, resulting from the repeated absence of one parent; **alternating parental mobility (rotation) (12%)**, where parents take turns engaging in circular migration; **extended-family co-residence (11%)**, reflecting adaptive cohabitation strategies; **left-behind spouse as primary caregiver (9%)**, highlighting gendered care responsibilities; **paid or institutional childcare support (7%)**, indicating limited reliance on formal care systems; **other or mixed arrangements (5%)**, encompassing flexible or transitional family forms.

The lollipop chart visually emphasises the hierarchical distribution of family arrangements, while the descending red trend line illustrates the gradual decline in prevalence from intergenerational care-based strategies toward more individualised or institutional solutions.

From a sociological perspective, the predominance of grandparental caregiving and transnational parenting underscores the centrality of intergenerational solidarity in sustaining family life under circular mobility. Older family members emerge as key stabilising actors, compensating for the absence of working-age parents and enabling continued participation in transnational labour markets. This finding aligns with research on transnational families that highlights the redistribution of care across generations and borders (Bryceson & Vuorela, 2002).

The significant share of temporary single-adult households and alternating parental mobility reflects families' efforts to balance economic necessity with caregiving responsibilities. Rather than signalling family disintegration, these arrangements represent negotiated strategies aimed at minimising emotional disruption and maintaining parental presence, albeit in fragmented forms. However, such strategies often place disproportionate care burdens on women and older family members, reinforcing gendered and age-based inequalities within households.

The relatively low prevalence of paid or institutional childcare support indicates limited accessibility or trust in formal care infrastructures, particularly in origin regions characterised by underdeveloped welfare systems. Consequently, families rely primarily on informal and kin-based care networks, which, while flexible and culturally embedded, are also vulnerable to exhaustion and long-term strain.

Overall, Figure 6 demonstrates that circular mobility produces a diversification rather than a dissolution of family forms. Family life is reorganised through adaptive, multi-sited arrangements that sustain functional

cohesion while simultaneously generating emotional distance and cumulative stress. These dynamics challenge normative assumptions about family stability and underscore the need for migration and social policies that recognise transnational families as enduring social units requiring targeted support and protection.

Figure 7 addresses the emotional and affective dimensions of circular mobility, an aspect often marginalised in economic and policy-oriented analyses of migration. While circular mobility is frequently framed as a flexible and reversible form of labour migration, its emotional consequences are cumulative and enduring. This figure conceptualises emotional strain not as a secondary or incidental outcome, but as a central component of the lived experience of sustained transnational mobility, shaping family relations, individual well-being and social cohesion.

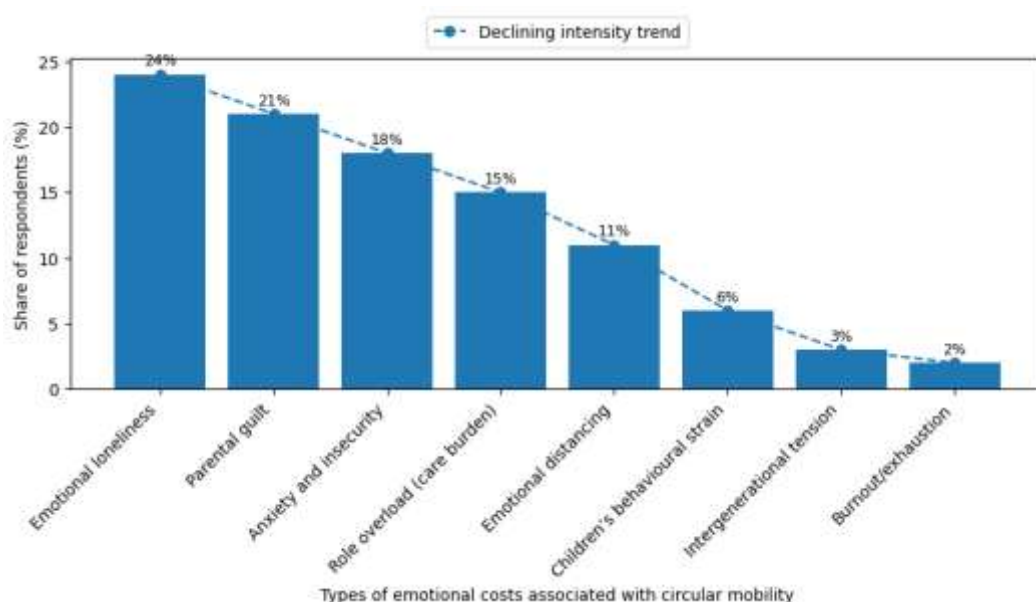


Figure 7. Emotional Costs and Affective Strain Associated with Circular Mobility (%)

Note. Percentages represent proportional distributions derived from qualitative coding of respondents' reported emotional and affective experiences related to sustained circular mobility (N = 42). Categories reflect dominant emotional strains experienced over a minimum period of three consecutive years. The dashed line illustrates the declining intensity of reported emotional costs.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework informed by transnational family and emotional labour research (Bryceson & Vuorela, 2002; Vertovec, 2009).

The figure presents eight dominant categories of emotional costs associated with circular mobility, expressed as proportional distributions among respondents: **emotional loneliness (24%)**, reflecting persistent feelings of isolation despite regular returns; **parental guilt (21%)**, linked to prolonged separation from

children; **anxiety and insecurity (18%)**, associated with unstable work and family arrangements; **role overload and care burden (15%)**, particularly among left-behind caregivers; **emotional distancing within family relationships (11%)**; **children's behavioural and emotional strain (6%)**; **intergenerational tension (3%)**, often emerging in households reliant on grandparental care; **burnout and emotional exhaustion (2%)**, indicating long-term affective depletion.

The vertical bar chart highlights a clear hierarchy of emotional impacts, while the declining trend line illustrates the gradual decrease in reported intensity from immediate emotional experiences to longer-term relational consequences.

From a sociological perspective, the prominence of emotional loneliness and parental guilt underscores the paradoxical nature of circular mobility: physical circulation and frequent return do not necessarily translate into emotional continuity or relational stability. Migrants may remain socially and emotionally fragmented, occupying an “in-between” position that erodes a sense of belonging both at home and abroad. This finding aligns with transnationalism research emphasising the emotional costs of multi-sited lives (Vertovec, 2009).

The prevalence of anxiety, insecurity and role overload highlights the unequal distribution of emotional labour within transnational families. Left-behind partners, grandparents and extended family members often assume expanded caregiving responsibilities, leading to cumulative stress and emotional fatigue. These dynamics reflect broader patterns of gendered and generational inequality in care provision, well documented in transnational family studies (Bryceson & Vuorela, 2002).

Although children's behavioural strain and intergenerational tension appear less frequently, their presence signals delayed and indirect effects of sustained mobility. Such outcomes tend to surface over time, as repeated cycles of separation and reunion destabilise routines, authority structures and emotional attachment. The relatively low reporting of burnout should not be interpreted as absence of risk, but rather as an early indicator of affective depletion that may intensify with prolonged exposure to circular mobility.

Overall, Figure 7 demonstrates that emotional costs are not peripheral to circular migration, but structurally embedded within mobility regimes that prioritise economic flexibility over relational stability. These findings challenge utilitarian narratives that frame circular migration as a low-cost alternative to permanent migration and underscore the need for family-sensitive and emotionally informed migration policies.

Figure 8 explores the identity configurations that emerge under conditions of sustained circular mobility, focusing on how migrants negotiate belonging, attachment and self-definition across multiple social spaces. Unlike classical migration models that assume a linear transition from origin-based identities toward

assimilation in destination societies, circular mobility generates overlapping and simultaneous identity orientations. This figure conceptualises identity as a multi-dimensional and relational process, shaped by repeated movement, transnational practices and continued engagement with origin communities.

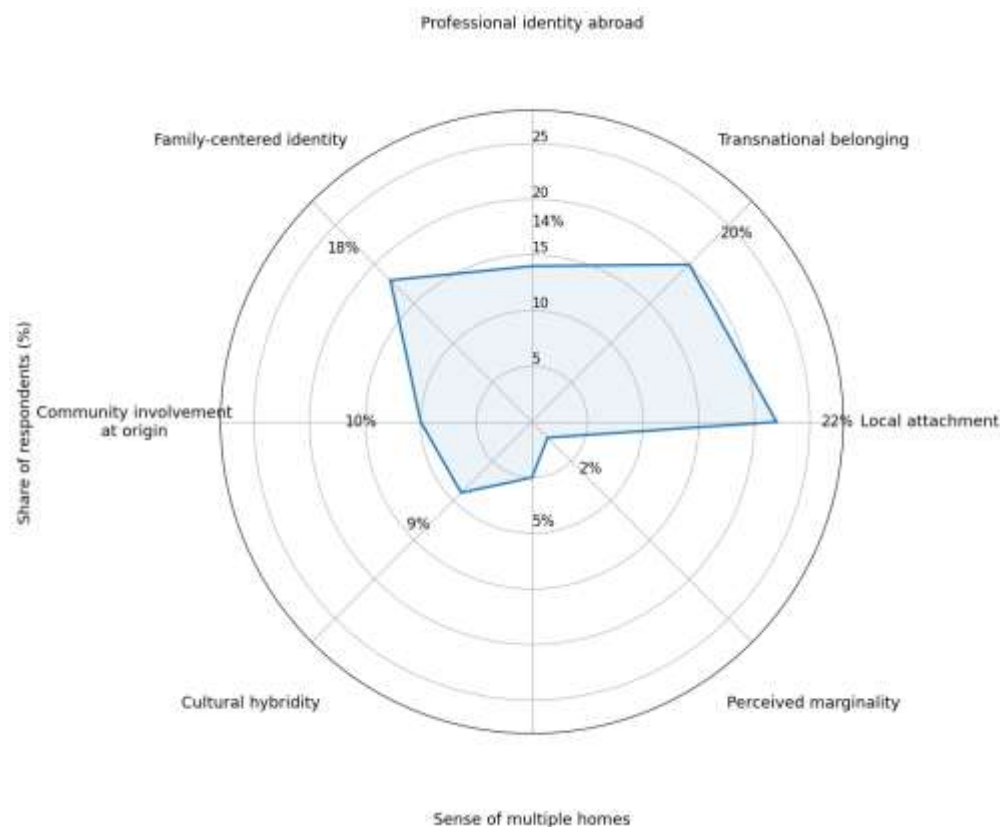


Figure 8. Identity Configurations among Circular Migrants (%)

Note. Percentages represent proportional distributions derived from qualitative coding of dominant identity dimensions reported by circular migrants (N = 42). Categories reflect coexisting identity orientations rather than mutually exclusive identity positions.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework informed by transnational identity and belonging literature (Glick Schiller et al., 1995; Vertovec, 2009).

The figure presents eight dominant identity dimensions reported by circular migrants, expressed as proportional distributions: **local attachment (22%)**, reflecting strong emotional and symbolic ties to communities of origin; **transnational belonging (20%)**, indicating a sense of simultaneous affiliation with both origin and destination contexts; **family-centered identity (18%)**, emphasising the centrality of family roles and responsibilities across borders; **professional identity abroad (14%)**, linked to labour market participation and

workplace recognition in destination countries; **community involvement at origin (10%)**, capturing continued social and civic engagement during periods of return; **cultural hybridity (9%)**, reflecting the blending of norms, practices and values from multiple socio-cultural contexts; **sense of multiple homes (5%)**, indicating symbolic attachment to more than one place of residence; **perceived marginality (2%)**, expressing feelings of exclusion or non-belonging.

The radar chart visually highlights the coexistence of multiple identity orientations, with no single dimension overwhelmingly dominant. Strong local attachment and transnational belonging occupy the largest areas, while marginality appears as a relatively minor component.

From a sociological perspective, the prominence of local attachment alongside transnational belonging underscores the non-exclusive nature of identity under circular mobility. Migrants do not replace origin-based identities with destination-oriented ones; instead, they construct layered and situational identities that allow them to navigate multiple social fields simultaneously. This finding supports transnationalism theory, which conceptualises migrants as embedded in overlapping social spaces rather than bounded national contexts (Glick Schiller, Basch, & Blanc-Szanton, 1995; Vertovec, 2009).

The strong presence of family-centered identity highlights the enduring role of kinship and caregiving responsibilities in shaping migrants' self-understanding. Even in contexts of prolonged absence, family obligations remain central, influencing decisions about mobility duration, return and future planning. Professional identity abroad, while significant, is less dominant, suggesting that occupational recognition alone does not constitute the primary axis of belonging for circular migrants.

The relatively moderate levels of cultural hybridity and community involvement indicate selective integration processes. Migrants adopt practices and norms that facilitate mobility and work abroad, while maintaining symbolic and emotional anchoring in origin communities. The low prevalence of perceived marginality suggests that circular mobility, despite its challenges, does not generally produce acute identity dislocation. Instead, migrants develop adaptive strategies that mitigate feelings of exclusion by sustaining multiple forms of belonging.

Overall, Figure 8 demonstrates that circular mobility gives rise to hybrid but anchored identity configurations, characterised by simultaneity rather than transition. These findings challenge assimilationist assumptions and reinforce the argument that circular migrants inhabit enduring transnational social spaces. Recognising these identity patterns is essential for developing migration and integration policies that acknowledge multi-sited belonging and support migrants' social and psychological well-being across borders.

Figure 9 examines the intergenerational consequences of circular mobility, focusing on how sustained patterns of migration reshape relationships, responsibilities and expectations across generations. While much of the migration literature concentrates on economic outcomes or individual experiences, intergenerational effects reveal the longer-term social costs and benefits of mobility, particularly within family systems that rely on transnational labour strategies. This figure conceptualises intergenerational dynamics as a key dimension through which circular mobility reproduces both opportunity and vulnerability over time.

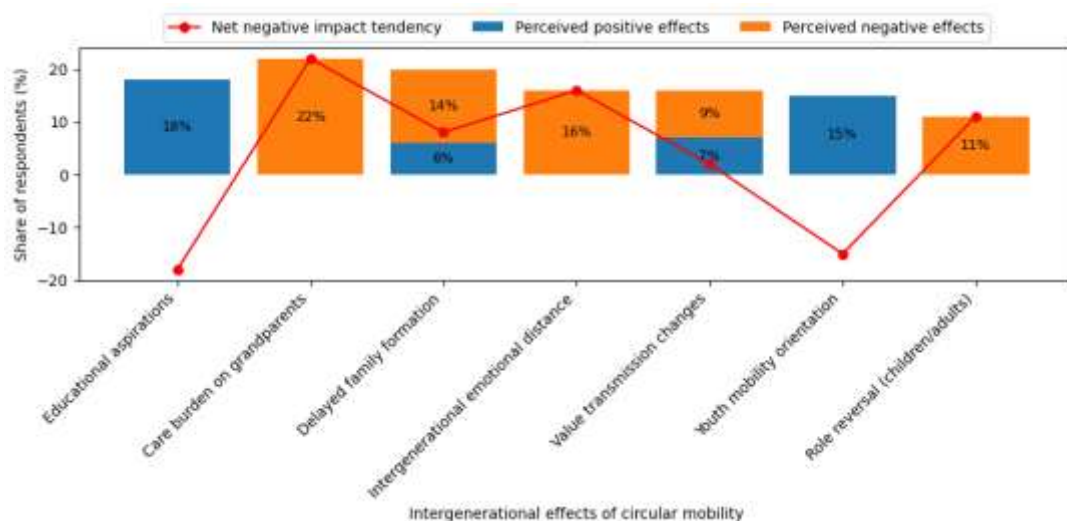


Figure 9. Intergenerational Effects of Circular Mobility (%)

Note. Percentages represent proportional distributions derived from qualitative coding of perceived intergenerational effects of circular mobility (N = 42). Positive and negative effects were coded separately. The red trend line illustrates the net intergenerational impact, calculated as the balance between perceived negative and positive effects.

Source. Author's qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework informed by transnational family and intergenerational studies (Bryceson & Vuorela, 2002; Vertovec, 2009).

The figure presents seven analytically distinct intergenerational effects of circular mobility, expressed as proportional distributions of respondents' perceptions: **educational aspirations among younger generations (18%)**, reflecting increased motivation and exposure to transnational opportunities; **care burden on grandparents (22%)**, indicating the transfer of caregiving responsibilities to older family members; **delayed family formation (14%)**, associated with prolonged mobility and economic uncertainty; **intergenerational emotional distance (16%)**, resulting from repeated cycles of absence and reunion; **changes in value transmission (9%)**, reflecting shifts in norms, expectations and intergenerational communication; **youth**

mobility orientation (15%), signalling the normalisation of migration as a life-course strategy; **role reversal between children and adults (11%)**, highlighting altered authority and dependency structures.

The stacked bars illustrate the coexistence of positive and negative effects within the same intergenerational contexts, while the red trend line represents the net intergenerational impact, revealing where negative effects outweigh positive ones and vice versa.

From a sociological perspective, Figure 9 underscores the ambivalent and uneven nature of intergenerational outcomes associated with circular mobility. On the one hand, increased educational aspirations and a strong orientation toward mobility among younger generations indicate the aspirational benefits of transnational exposure. Migration narratives and remittance-supported investments in education contribute to the expansion of perceived life chances and reinforce mobility as a normative horizon for youth.

On the other hand, the pronounced care burden placed on grandparents and the rise of intergenerational emotional distance reveal the social costs of sustaining circular mobility over extended periods. Older generations emerge as key support pillars, absorbing caregiving responsibilities that exceed their traditional roles, often without adequate institutional support. This redistribution of care reflects broader patterns of welfare retrenchment and familialisation of social risk.

Delayed family formation and role reversals further illustrate how circular mobility disrupts conventional life-course trajectories. Younger adults postpone partnership and parenthood, while children may assume emotional or practical responsibilities beyond their age, reshaping authority relations within families. These dynamics suggest that circular mobility not only reallocates labour across borders, but also restructures temporal expectations and generational hierarchies.

Overall, Figure 9 demonstrates that intergenerational effects constitute a central, yet frequently overlooked, dimension of circular migration. While mobility can enhance aspirations and transnational competencies, it simultaneously generates cumulative intergenerational strain that may undermine family cohesion and long-term social reproduction. Recognising these patterns is essential for developing migration and social policies that address not only economic efficiency, but also the sustainability of family and generational relations under conditions of repeated mobility.

Figure 10 synthesises respondents’ perceptions regarding the main advantages and risks associated with circular migration, offering a comprehensive overview of how this mobility regime is evaluated at the subjective and social level. Unlike purely economic assessments, this figure captures the perceived balance between opportunities and vulnerabilities generated by circular mobility. By juxtaposing advantages and risks within a single analytical frame, the figure highlights the inherently ambivalent character of circular migration as both a resource and a source of strain.

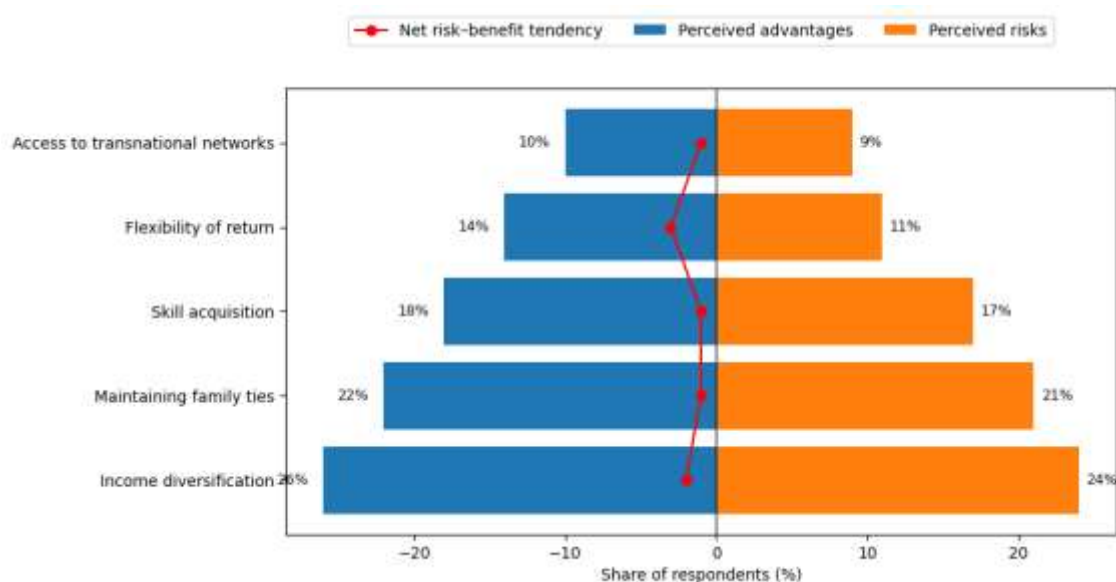


Figure 10. Perceived Advantages and Risks of Circular Migration (%)

Note. Percentages represent proportional distributions derived from qualitative coding of respondents’ perceptions regarding the main advantages and risks associated with circular migration (N = 42). Advantages and risks were coded separately. The red trend line illustrates the net risk–benefit tendency, calculated as the balance between perceived risks and advantages.

Source. Author’s qualitative fieldwork conducted in Central Europe (2022–2024); analytical framework informed by circular migration and mobility regime literature (Faist, 2010; OECD, 2021).

The figure displays five dominant perceived advantages and five corresponding risks of circular migration, expressed as proportional distributions:

Perceived advantages: **income diversification (26%)**, reflecting enhanced household financial stability; **maintaining family ties through regular return (22%)**; **skill acquisition in destination labour markets (18%)**; **flexibility of return and mobility (14%)**; **access to transnational social and professional networks (10%)**.

Perceived risks: family fragmentation (24%), associated with repeated separation and role redistribution; **emotional strain and psychological stress (21%); economic dependency on external labour markets (17%); precarious legal or employment status (11%); limited access to social protection systems (9%).**

The butterfly chart visually contrasts advantages and risks across a central axis, while the red trend line represents the net risk–benefit tendency. This line reveals that for most dimensions, perceived benefits and risks are closely balanced, with no overwhelmingly dominant orientation.

From a sociological perspective, Figure 10 confirms that circular migration is experienced as a structurally ambivalent strategy. Economic advantages such as income diversification and skill acquisition coexist with significant social and emotional risks, challenging simplified narratives that frame circular mobility as either unequivocally beneficial or inherently harmful. The near-symmetry between advantages and risks reflects migrants’ pragmatic evaluation of mobility as a necessary, yet costly, response to constrained opportunities in origin regions.

The prominence of family-related risks alongside the perceived benefit of maintaining family ties highlights a central paradox of circular mobility. While regular return is valued as a mechanism for preserving relational bonds, repeated cycles of separation simultaneously generate emotional strain and family fragmentation. This suggests that circular mobility mitigates, but does not eliminate, the social costs associated with transnational labour strategies.

Economic dependency and limited social protection further underscore the structural vulnerabilities embedded in circular migration regimes. Migrants’ reliance on external labour markets exposes households and communities to fluctuations beyond their control, reinforcing patterns of dependency rather than fostering autonomous local development. The red trend line illustrates that these risks are not peripheral, but closely intertwined with perceived benefits.

Overall, Figure 10 demonstrates that circular migration functions as a coping strategy situated between opportunity and constraint. While it enhances short-term household resilience and flexibility, it simultaneously produces long-term social, emotional and structural vulnerabilities. These findings reinforce the paper’s central argument that circular mobility should be approached not as a self-regulating solution to migration challenges, but as a complex social process requiring comprehensive policy frameworks that address both its benefits and its risks.

The results presented in this chapter provide a comprehensive and multi-dimensional picture of circular mobility in Central Europe, highlighting its economic, familial, emotional, identity-related and intergenerational implications. Through the combined analysis of mobility typologies, temporal patterns, economic motivations, remittance allocation, labour market effects, family reconfigurations, emotional costs, identity configurations and perceived advantages and risks, the findings reveal circular migration as a structurally ambivalent social phenomenon rather than a linear or unidirectional process.

Taken together, Figures 1–10 demonstrate that circular mobility operates simultaneously as a strategy of economic resilience and a source of cumulative social strain. While it contributes to household income stabilisation, skill acquisition and the maintenance of transnational ties, it also generates vulnerabilities related to family cohesion, emotional well-being, intergenerational care and local labour market sustainability. These effects are neither uniformly positive nor uniformly negative; rather, they coexist within the same mobility trajectories, reflecting the complex trade-offs embedded in repeated patterns of migration and return.

Importantly, the empirical evidence suggests that circular mobility has become a normalised and enduring feature of contemporary social life, embedded within broader European labour regimes and shaped by structural inequalities between origin and destination regions. As such, the findings challenge simplified narratives that frame migration either as a loss of human capital or as an automatic driver of development. Instead, they point toward the need for a more nuanced sociological understanding of mobility as a permanent condition characterised by circulation, simultaneity and ambivalence.

Building on these empirical insights, the following chapter moves beyond descriptive and figure-based analysis to situate the findings within the broader theoretical and policy-oriented literature. The Discussion chapter synthesises the results across analytical dimensions, engages critically with existing migration theories, and explores the implications of circular mobility for social reproduction, inequality and governance in Central Europe.

5. Discussion

5.1. Circular Mobility beyond the Brain Drain Paradigm

The empirical findings presented in Figures 1–3 challenge the persistence of the brain drain paradigm as the dominant interpretative framework for understanding contemporary mobility in Central Europe. Classical migration theories have conceptualised migration primarily as a one-way movement resulting in permanent loss of human capital for origin societies. However, the patterns identified in this study indicate that circular

mobility has become a stabilised and recurrent form of transnational movement, rather than a transitional stage between departure and settlement.

Figure 1 demonstrates the diversification of mobility typologies, with a clear predominance of circular, seasonal and rotational forms over permanent emigration. This confirms that mobility trajectories are increasingly characterised by repetition, reversibility and simultaneity, rather than linear departure–return sequences. Such patterns align with Faist’s (2010) conceptualisation of transnational social spaces, in which migrants remain embedded in multiple socio-economic contexts, maintaining sustained ties to both origin and destination societies.

The temporal dimension explored in Figure 2 further reinforces this argument. The dominance of short- and medium-term mobility cycles illustrates that temporariness itself has become institutionalised. Rather than representing instability or transition, repeated cycles of absence and return constitute a predictable and structured life strategy. This finding resonates with Vertovec’s (2009) notion of *permanent temporariness*, where mobility is normalised as an ongoing condition of social life. In this sense, circular mobility does not signify incomplete migration, but rather a distinct mobility regime shaped by European labour market demands and regulatory frameworks.

From an economic perspective, Figure 3 reveals that motivations underpinning circular mobility are primarily oriented toward household-level security and income stabilisation, rather than individual advancement or long-term settlement abroad. Wage differentials and income diversification dominate migrants’ rationales, while entrepreneurial accumulation and status enhancement remain marginal. This supports household-based migration theories, which emphasise collective risk management over individual optimisation (World Bank, 2020). Consequently, circular mobility functions less as a pathway to upward social mobility and more as a compensatory mechanism in response to structural inequalities between origin and destination regions.

Taken together, these findings suggest that the brain drain narrative is insufficient for capturing the complexity of contemporary mobility in Central Europe. Circular migration does not result in a straightforward depletion of human capital, nor does it guarantee its productive reintegration upon return. Instead, skills, labour and social resources circulate in fragmented and uneven ways, often benefiting destination economies while only partially reinforcing local development at origin. This ambivalence echoes OECD (2021) critiques of migration–development optimism, which caution against assuming automatic developmental spillovers from mobility.

By situating circular mobility beyond the brain drain paradigm, this study contributes to a growing body of sociological research that conceptualises mobility as a structurally embedded, relational and cyclical process. Circular migrants are neither fully absent nor fully returned; they inhabit a condition of sustained transnational engagement that reshapes labour markets, household strategies and social expectations. Recognising this shift is essential for developing analytical frameworks and public policies that move beyond binary assumptions of loss versus gain and instead address the long-term governance of mobility as a permanent feature of contemporary European societies.

5.2. Household Strategies, Remittances and Local Economic Dependency

The findings related to economic motivations, remittance allocation and local labour market effects (Figures 3–5) underscore the central role of the household as the primary unit of decision-making in circular mobility. Rather than reflecting individual strategies of accumulation or entrepreneurial advancement, circular migration emerges predominantly as a collective response to economic uncertainty, income volatility and limited opportunities in origin regions. This supports household-based migration theories, which conceptualise mobility as a risk-diversification strategy embedded in family survival logics rather than as a purely rational individual choice (World Bank, 2020).

Figure 3 reveals that income stabilisation, wage differentials and debt management constitute the dominant motivations for circular mobility. The relatively marginal role of entrepreneurial capital accumulation suggests that circular migration rarely functions as a springboard for endogenous economic transformation. Instead, it operates as a compensatory mechanism that enables households to cope with structural constraints in local labour markets. This pattern challenges policy narratives that frame circular migration as an inherently developmental process and echoes critical perspectives on the migration–development nexus (OECD, 2021).

The allocation patterns of remittances illustrated in Figure 4 further reinforce this interpretation. Remittances are overwhelmingly directed toward daily consumption, housing, education and health—domains closely associated with social reproduction rather than productive investment. While such allocations enhance household resilience and well-being, they do not substantially alter local economic structures. The limited share of remittances invested in business activities or community-level initiatives indicates that the developmental potential of circular migration remains constrained by institutional weaknesses, limited access to credit and uncertainty regarding long-term returns. As a result, remittances contribute to stability without generating sustained economic diversification.

Figure 5 extends this analysis by illustrating the ambivalent impact of circular migration on local labour markets. Although respondents acknowledge positive effects such as skill transfer and seasonal labour flexibility, these benefits are outweighed by negative consequences, including labour shortages, wage pressure and youth withdrawal from local employment. The red trend line representing net impact highlights the cumulative disadvantages experienced by origin communities, particularly in sectors reliant on stable and skilled labour. Local economies adapt not through endogenous job creation, but through increased dependence on labour circulation and external employment opportunities.

Taken together, these findings point to a paradox at the heart of circular mobility: while households benefit from income continuity and reduced economic risk, local economies become increasingly dependent on out-migration as a structural condition. This dependency reproduces cycles of labour depletion and return without addressing underlying development gaps. Over time, such dynamics may weaken local labour market sustainability and reinforce patterns of regional inequality, particularly in peripheral or rural areas.

From a sociological perspective, circular mobility thus functions as a mechanism of household-level adaptation that simultaneously externalises structural problems to the transnational sphere. By compensating for inadequate wages, limited employment opportunities and fragile welfare systems, migration alleviates immediate pressures while delaying systemic reform. This dynamic underscores the importance of situating circular migration within broader political–economic contexts, rather than interpreting it as an isolated or self-regulating phenomenon.

In this sense, Figures 3–5 collectively demonstrate that the economic benefits of circular migration are unevenly distributed and temporally bounded. While households experience short-term gains, the long-term consequences for local labour markets and regional development remain ambivalent. Recognising this tension is essential for rethinking policies that rely on circular mobility as a substitute for sustainable local economic strategies.

5.3. Family Reconfiguration and Emotional Costs of Mobility

The findings related to family arrangements and emotional strain (Figures 6 and 7) highlight the profound social consequences of circular mobility beyond its economic dimensions. Rather than merely separating family members spatially, circular migration restructures everyday family life by redistributing care responsibilities, emotional labour and authority across multiple actors and generations. These transformations reflect adaptive responses to sustained mobility, yet they also reveal the cumulative social costs embedded in repeated cycles of absence and return.

Figure 6 demonstrates that family organisation under circular mobility is characterised by diversification rather than disintegration. Grandparental caregiving, transnational parenting and temporary single-adult households emerge as dominant arrangements, indicating that families actively reorganise roles to sustain functionality. Such patterns align with transnational family research emphasising the role of extended kin networks in compensating for parental absence (Bryceson & Vuorela, 2002). However, these arrangements are not neutral adaptations; they often involve the redistribution of care burdens toward older generations and women, reinforcing existing gendered and generational inequalities.

The prominence of grandparental caregiving underscores the centrality of intergenerational solidarity in maintaining family cohesion. Older family members assume pivotal roles in childcare and household management, enabling working-age adults to participate in transnational labour markets. While this strategy enhances household resilience, it simultaneously places emotional and physical strain on grandparents, whose contributions often remain socially undervalued and institutionally unsupported.

Figure 7 further reveals that the emotional costs of circular mobility are substantial and unevenly distributed. Emotional loneliness, parental guilt and anxiety dominate respondents' experiences, indicating that frequent return does not eliminate the affective consequences of prolonged separation. These findings support Vertovec's (2009) argument that transnational mobility generates conditions of emotional fragmentation, in which individuals inhabit multiple social spaces without achieving full emotional integration in any of them.

The coexistence of emotional distancing and children's behavioural strain suggests that affective consequences accumulate over time. Repeated cycles of separation and reunion disrupt routines, attachment patterns and authority structures within families. While such effects may not manifest immediately, they gradually reshape relational dynamics and contribute to long-term emotional fatigue. The relatively low reporting of burnout should therefore be interpreted not as absence of risk, but as an early indicator of cumulative affective strain.

From a sociological perspective, these findings challenge policy discourses that portray circular migration as a family-friendly alternative to permanent migration. Although physical return mitigates some aspects of separation, it does not fully compensate for the emotional disruptions produced by cyclical absence. Family cohesion is maintained through continuous negotiation and emotional labour, rather than through stability. As a result, circular mobility produces a fragile equilibrium in which functional continuity coexists with emotional vulnerability.

Overall, Figures 6 and 7 illustrate that family reconfiguration and emotional costs are not peripheral outcomes of circular mobility, but central features of this mobility regime. By externalising care and emotional labour to families and kin networks, circular migration alleviates economic pressure while generating long-term social and emotional strain. Recognising these dynamics is essential for understanding the broader social implications of mobility and for developing policies that support not only migrants as workers, but also families as enduring social units.

5.4. Intergenerational Transmission of Mobility and Social Reproduction

The findings related to identity configurations and intergenerational effects (Figures 8 and 9) reveal that circular mobility extends beyond immediate economic and familial arrangements, shaping long-term processes of social reproduction and the transmission of mobility norms across generations. Circular migration does not merely affect those who migrate; it reconfigures aspirations, values and expectations among children, parents and grandparents, gradually embedding mobility into the social fabric of origin communities.

Figure 8 illustrates that circular migrants develop hybrid but anchored identity configurations, combining strong local attachment with transnational belonging and family-centered orientations. This simultaneity challenges linear models of identity transformation that assume progressive detachment from origin contexts. Instead, identities are layered and relational, allowing migrants to remain symbolically and emotionally connected to multiple social spaces. Such configurations facilitate the continuity of family and community ties, while normalising transnational engagement as a stable mode of social existence (Glick Schiller, Basch, & Blanc-Szanton, 1995; Vertovec, 2009).

These identity patterns have direct intergenerational implications. The coexistence of local attachment and transnational belonging provides a cultural framework within which mobility is interpreted not as rupture, but as a legitimate and even desirable life strategy. As shown in Figure 9, this framework contributes to increased educational aspirations and a pronounced orientation toward mobility among younger generations. Exposure to transnational narratives, remittance-supported investments in education and the symbolic valorisation of migration reinforce mobility as a normative horizon for youth.

At the same time, Figure 9 highlights the uneven distribution of intergenerational costs associated with circular mobility. The care burden placed on grandparents, emotional distancing between generations and delayed family formation indicate that the social reproduction of mobility relies heavily on unpaid and informal forms of intergenerational support. Older generations absorb caregiving responsibilities and emotional labour,

enabling younger adults to participate in transnational labour markets. This dynamic reflects broader processes of familialisation of social risk, particularly in contexts characterised by limited welfare provision.

The presence of role reversals and changes in value transmission further suggests that circular mobility reshapes generational hierarchies and authority structures within families. Children may acquire transnational competencies and aspirations that exceed those of their parents, while grandparents assume intensified caregiving roles. These shifts alter traditional patterns of dependence and influence, contributing to new forms of intergenerational negotiation and tension.

From a sociological perspective, these findings indicate that circular mobility functions as a mechanism of social reproduction that simultaneously expands opportunity and reproduces inequality. While it enhances transnational skills and aspirations, it also entrenches reliance on intergenerational solidarity and external labour markets. Mobility is transmitted not only as a practical strategy, but as a cultural expectation embedded in family narratives and life-course planning.

Overall, Figures 8 and 9 demonstrate that circular mobility reshapes intergenerational relations by normalising transnational engagement while redistributing social costs across age groups. This dual process underscores the importance of analysing mobility through a life-course and intergenerational lens, recognising that the long-term sustainability of circular migration depends on the capacity of families and communities to absorb its cumulative social and emotional demands.

5.5. The Structural Ambivalence of Circular Migration

The findings synthesised in Figure 10 encapsulate the central argument emerging from this study: circular migration constitutes a structurally ambivalent mobility regime, simultaneously generating opportunities and vulnerabilities at the individual, household and community levels. Rather than representing a balanced compromise between permanent migration and immobility, circular mobility operates within a field of persistent tension, in which perceived advantages and risks coexist in near symmetry.

The butterfly configuration of advantages and risks highlights that the benefits of circular migration—such as income diversification, skill acquisition and flexibility of return—are closely mirrored by equally salient risks, including family fragmentation, emotional strain and economic dependency. This near-equilibrium suggests that circular mobility is not experienced as a clearly positive or negative strategy, but as a necessary and conditional response to structural constraints in origin regions. Migrants and their families engage in circular mobility not because it resolves socio-economic inequalities, but because it allows them to navigate these inequalities with a degree of flexibility and resilience.

From a sociological perspective, this ambivalence reflects the embeddedness of circular migration within broader political–economic and institutional contexts. European labour markets benefit from flexible and rotating labour supply, while origin communities absorb the social costs associated with repeated absence, care redistribution and emotional strain. As shown across Figures 4–7, the stabilisation of household income and the maintenance of transnational ties are achieved through the externalisation of social reproduction to families, kin networks and older generations. This redistribution of responsibility sustains mobility while simultaneously generating cumulative strain that remains largely invisible in policy discourse.

Figure 10 further illustrates that perceived risks are not incidental side effects, but structurally intertwined with perceived advantages. The benefit of maintaining family ties through regular return, for instance, coexists with heightened risks of emotional fatigue and family fragmentation. Similarly, access to transnational networks enhances economic opportunity while reinforcing dependency on external labour markets and precarious legal arrangements. The red trend line capturing the net risk–benefit tendency underscores this interdependence, revealing that gains and losses are not sequential, but simultaneous and mutually constitutive.

This structural ambivalence challenges normative policy frameworks that promote circular migration as a “win–win” solution for migrants, origin countries and destination economies. The empirical evidence presented in this study suggests that such narratives underestimate the long-term social and emotional costs of repeated mobility and overestimate its capacity to generate sustainable local development. Circular migration mitigates immediate economic pressures, yet it does so by normalising instability and postponing structural reform in origin regions.

Taken together, the results discussed throughout this chapter indicate that circular migration should be conceptualised not as an intermediate or transitional form of mobility, but as a durable social condition characterised by circulation, simultaneity and trade-offs. Its sustainability depends less on the volume of movement than on the capacity of institutions to recognise and address its cumulative effects on families, intergenerational relations and local economies.

By foregrounding the ambivalent nature of circular mobility, this study contributes to a more nuanced sociological understanding of contemporary migration regimes in Central Europe. It calls for analytical frameworks and governance approaches that move beyond binary evaluations of migration as either loss or gain and instead engage with the complex social realities produced by mobility as a permanent feature of contemporary life.

6. Conclusions and Policy Recommendations

6.1. Main Conclusions and Theoretical Contributions

This study set out to examine the transition from conventional economic migration toward circular and transnational mobility patterns in Central Europe, with a particular focus on their implications for identities, local economies and family cohesion. Drawing on qualitative research and a multidimensional analytical framework, the findings demonstrate that circular mobility has evolved into a stable and institutionalised form of migration rather than a temporary or transitional phenomenon.

One of the central conclusions of this research is that circular migration cannot be adequately explained through linear models such as the brain drain or return migration paradigms. Instead, it operates as a durable mobility regime characterised by repetition, simultaneity and ambivalence. Migrants remain embedded in multiple social spaces, maintaining strong ties to origin communities while participating in destination labour markets. This simultaneity reshapes economic strategies, family arrangements and identity configurations in ways that challenge binary distinctions between departure and return.

At the economic level, the findings show that circular mobility functions primarily as a household-level risk management strategy. Income diversification and remittance flows contribute to short-term stability and social reproduction, yet they rarely translate into sustainable local development or entrepreneurial transformation. At the same time, local labour markets become increasingly dependent on out-migration, reinforcing cycles of labour depletion and external dependency.

From a social perspective, the study highlights the profound impact of circular mobility on family life, emotional well-being and intergenerational relations. Families adapt through flexible caregiving arrangements, transnational parenting and intergenerational support, but these adaptations entail cumulative emotional and social costs. Identity configurations among circular migrants are hybrid yet anchored, reflecting coexistence rather than substitution of local and transnational forms of belonging. Intergenerationally, mobility is transmitted as both aspiration and necessity, embedding migration into life-course expectations while redistributing care and emotional labour unevenly across generations.

Taken together, these findings contribute to sociological debates on migration by conceptualising circular mobility as a structurally ambivalent condition—one that simultaneously enables resilience and reproduces vulnerability. This perspective advances existing theories of transnationalism and mobility regimes by foregrounding the long-term social and emotional dimensions of circulation, rather than treating them as secondary effects.

6.2. Policy Implications and Recommendations

The empirical evidence presented in this study has several important implications for migration governance and social policy in Central Europe and beyond. First, policy frameworks must move beyond instrumental “win–win” narratives that portray circular migration as inherently beneficial for all actors involved. While circular mobility offers flexibility and economic opportunity, it also generates significant social costs that require proactive institutional responses.

Second, migration policies should adopt a **family-sensitive and life-course-oriented approach**. Given the central role of families in sustaining circular mobility, support mechanisms should include access to transnational social protection, childcare services, counselling and psychosocial support for migrants and left-behind family members. Particular attention should be paid to older caregivers and children, who absorb a disproportionate share of the social and emotional burden.

Third, labour market policies in origin regions should aim to reduce structural dependency on out-migration by investing in local employment opportunities, skill recognition and decent work conditions. Circular migration should complement, not substitute, local development strategies. Mechanisms that facilitate the transfer and utilisation of skills acquired abroad—such as returnee programmes, certification systems and local entrepreneurship support—are essential for mitigating long-term dependency.

Fourth, governance frameworks at the European level should recognise circular migrants as a distinct category with specific rights and vulnerabilities. Ensuring access to social protection, legal security and fair working conditions across borders is crucial for reducing precarity and preventing the externalisation of social costs to families and communities of origin.

6.3. Limitations and Directions for Future Research

While this study offers a comprehensive qualitative analysis of circular mobility in Central Europe, several limitations should be acknowledged. The findings are based on a specific regional and socio-economic context and may not be directly generalisable to other migration systems. Future research could complement qualitative insights with longitudinal quantitative data to capture changes in mobility trajectories over time.

Further studies should also explore gendered dimensions of circular mobility in greater depth, as well as comparative analyses across different European regions. Additionally, research focusing on children’s perspectives and long-term intergenerational outcomes would provide valuable insights into the sustainability of circular migration as a social strategy.

In conclusion, circular migration emerges not as a temporary compromise between mobility and stability, but as a defining condition of contemporary social life in Central Europe. Understanding its ambivalent effects on economies, families and identities is essential for developing policies that prioritise social sustainability alongside economic flexibility. Only by acknowledging both the opportunities and the costs of circular mobility can migration governance respond effectively to the realities of transnational lives.

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İNŞALARIN İLKİN ELEMENTLƏRİNİN ÖYRƏDİLMƏSİ QAYDALARI

Azərbaycan-Bakı, Könül Məmmədova

Orcid id: 0000-0001-8664-4912

könül.1970@mail.ru

**Azərbaycan Dövlət Pedaqoji Universiteti, Filologiya fakültəsi, Azərbaycan dili və onun tədrisi
texnologiyası kafedrası**

AÇAR SÖZLƏR: inşa, nitqin formaları, yazılı və şifahi, mühakimə

Nitqin formalarından asılı olaraq, inşalar ifadə formasına görə iki cürdür: şifahi inşalar, yazılı inşalar. Şifahi inşalar dedikdə, şagirdlərin müstəqil hekayə qurub nağıl etmələri nəzərdə tutulur. Şifahi nitq uşağın nitqinin daimi, təbii formasıdır. Məktəbə gedənədək uşaqlar şifahi nitqə yiyələnir və ondan ünsiyyət vasitəsi kimi istifadə edirlər. Yazılı inşa üzrə vərdişlərin yaranması üçün çox işləmək lazım gəlir. Yazılı inşa şifahi inşanın sadəcə qrafik surəti deyil. Şifahi inşa vəzifəsini yalnız yazılı inşalara hazırlıqla məhdudlaşdırmaq da düzgün deyil. Bu, şifahi inşaların qarşısında duran vəzifələrdən yalnız biridir.

Savad təlimi dövründə uşaqların öz ailələri, yoldaşları, oyunları haqqında söhbətləri buna misal ola bilər. Sonralar da şagirdlərin məşguliyyəti, müşahidələri, həyat təcrübələri, başlarına gələn maraqlı əhvalatlar haqqında, hətta şəkil üzrə şifahi inşaları təşkil etmək mümkündür. Şagirdlər fikri rabitəli, ardıcıl, məntiqi ifadə etmək üzrə müəyyən vərdişlər qazanırlar. Belə məşğələlər də şagirdləri inşa yazıya hazırlayır.

İbtidai siniflərdə inşanın janra görə aşağıdakı növləri nəzərdə tutulur:

- a) nəqli – inşa (təhkiyə).
- b) təsvir - inşa.
- c) mühakimə - inşa.

I-II siniflərdə, əsasən, nəqli xarakterli inşalardan istifadə olunduğu halda, III-IV siniflərdə inşanın digər növlərinə də müəyyən qədər yer verilir. Təsvir xarakterli ilk inşalar hər hansı heyvanın, quşun təsvirindən ibarət olmalıdır. Sonralar tədricən şagirdlərin müəyyən təbiət hadisələrinin, mənzərənin təsvirini öz sözləri ilə vermələrinə nail olmaq mümkündür.

Mühakimə xarakterli inşalardan III sinifdə dərs ilinin ikinci yarısından etibarən istifadə etmək mümkündür. Belə yazılar şagirdlərin məntiqi təfəkkürünü inkişaf etdirir. Onlar bildikləri və həyat təcrübələri dairəsində sadə mühakimə yürüdür, öz nöqteyi-nəzərini müdafiə edirlər. Şagirdlərin ümumi inkişafının təmin edilməsində mühakimə xarakterli inşalar mühüm rol oynayır. Hər bir inşada təhkiyə ilə yanaşı, təsvir və

mühakimə elementləri də olur. Axı, inşalar, ümumiyyətlə, mühakimə tələb edən yaradıcı yazılardır. Bu prosesdə istər-istəməz həm təsvir, həm də mühakimə elementləri özünü göstərməlidir. O da bir həqiqətdir ki, öyrədici inşada yoxlama elementləri, yoxlama inşada isə az da olsa, öyrətmə məqsədinə xidmət edən cəhətlər olur.

İbtidai siniflərdə inşa yazılara hazırlıq üçün şagirdlər aşağıda verilən müxtəlif mənbələrdən faktlar toplayırlar.

- a) Şəkillər;
- b) Kinofilm, diafilm və tamaşalar;
- c) Ətraf aləm və təbiət üzərində müşahidələr;
- d) Uşaqların şəxsi həyat təcrübəsi;
- e) Dərslərdən oxunmuş material;
- f) Müəllimin nəqli;
- g) Əmək prosesi;
- h) Oyun və əyləncələr;
- i) Müxtəlif mənbələrdən toplanmış materialların birləşdirilməsi;
- j) Xüsusi tapşırıqlı inşalar.

II sinifdə bəzən inşa bütün sinfin, kollektivin birgə səyi nəticəsində yaranır. Mövzu müəyyənləşdirilir, plan tərtib olunur, ayrı-ayrı sözlərin yazılışı, cümlələrin qurulması, məzmunun necə verilməsi üzərində iş gedir, sonra şagirdlər müstəqil inşa yazırlar. İnsanın bu növü *kollektiv inşa* adlanır. Elə inşalar da vardır ki, II sinifdən etibarən onun yazılmasında kollektivin köməyinə ehtiyac yoxdur, müəllim isə tək-tək hallarda işə qarışır.

Şəkil üzrə inşaların yazılmasına, əsasən, II sinifdən başlanır. İlk inşalar çox sadə, asan şəkillər üzrə aparılır: şəkil təhlil olunur, yazı taxtasında suallar yazılır; hər bir sualı şagird oxuyub cavab verir; axırda bir şagird bütün cavabları öz nəqlində birləşdirir. Beləliklə, rəhbərli mətn alınır. Nəhayət, şagirdlər şəklın məzmununu sualsız nəql edir və yazırlar. İşin təşkilində belə tədrislik müəyyən dövrdən sonra şagirdlərin müstəqil inşa yazmalarına gətirib çıxarır. Onlar bir hadisənin təsvirinə həsr olunmuş süjetli şəklı təhlil etməkdə (hissələrə, epizodlara ayırmaqda, plan tutmaqda) çətinlik çəkirlər. Ona görə də bu sahədə müəyyən vərdiş yarananaqədər seriya şəkillər üzrə inşalara geniş yer verilməlidir, çünki belə şəkillər iki-üç və daha artıq epizodlardan ibarət olduğundan, şagirdlər asanlıqla hər epizoda bir başlıq verir, alınan planın hər maddəsinə aid müvafiq şəkil üzrə bir neçə cümlə yazırlar.

Doğma yerlərə ekskursiyalar, gəzintilər, ətraf aləmdəki əşya və hadisələr üzərində müşahidələr uşaqlarda həssaslıq, təbiətə, gözəlliyə məhəbbət, onlardan zövq almaq və onu qorumaq hissinı tərbiyə edir. Uşaqlar öz

təəssüratını həvəslə ifadə edirlər. Axı gözlə görünən hər bir şeyi təhlil etmək, tutuşdurmaq, onlardan ən mühüm olanları ayırmaq, ümumiləşdirmə aparmaq daha asandır. Müşahidə əsasında yazılı inşaların aparılmasına III sinifdən başlamaq məsləhətdir. Belə inşalara evdə və sinifdə hazırlıq aparıla bilər. Məsələn, yaz haqqında inşadan əvvəl müəllim təbiətə ekskursiya təşkil edir. Ekskursiyadan sonra nələri müşahidə etdiklərini uşaqlardan xəbər alır. Uşaqlar yazın əlamətlərini sadalayır (göyün üzü açıq olur; günəş yuxarı qalxır və çox qızdırır; qarın rəngi tündləşir; qar əriyir; güney yerlərdə palçıq olur; söyüdlərin tumurcaqları şişir; küçələrdə gölməçələr əmələ gəlir; sərcələr sevinclə cikkildəşir; onlar qarın əridiyi yerlərdə atılıb-düşür, yem axtarırlar; qaranquşlar özlərinə yuva qurur; bənövşələr görünür; arılar yuvalarından çıxıb uçur və s.).

Uşaqlar öz həyatı və şəxsi təcrübələri ilə əlaqədar inşalar yazmağı çox sevir. Onlar öz işlərindən, həyatlarında baş verən hadisələrdən həvəslə, emosionallıqla bəhs edirlər. Belə inşalar heç bir uydurma tələb etmədiyindən çətinlik törətmir. Uşaqların gördükləri və eşitdikləri bütün təfərrüatı ilə yadlarında qalır. Onlar başlarına gələn əhvalat üzərində düşünür, planlı surətdə onu təsəvvüründə yenidən canlandırırlar. Belə inşaların yazılması üçün müəllimlər bütün sinfin fəal iştirak etdiyi, hamı üçün maraqlı olan mövzular seçməlidirlər.

PROFESSIONAL ORIENTATION OF BIOLOGICAL SCHOOLBOY IN MODERN CONDITIONS

Prof. Dr. Olena A. Lykholat¹, PhD, Tetyana Y. Lykholat², Lecturer, Maksim O. Kvitko³,
PhD, Iryna M. Kofan⁴, Prof. Dr. Yuriy V. Lykholat⁵

¹University of Customs and Finance, Dnipro, Ukraine, e-mail: lykholat2010@ukr.net,
ORCID NO: [0000-0002-3722-8602](https://orcid.org/0000-0002-3722-8602)

²Oles Honchar Dnipro National University, Dnipro, Ukraine, e-mail: lyktat89@ukr.net,
ORCID NO: [0000-0002-5076-0572](https://orcid.org/0000-0002-5076-0572)

³Kryvyi Rih State Pedagogical University, Kryvyi Rih, Ukraine, e-mail: kvitko.max@gmail.com,
Oles Honchar Dnipro National University, Dnipro, Ukraine
ORCID NO: [0000-0002-3713-7620](https://orcid.org/0000-0002-3713-7620)

⁴Oles Honchar Dnipro National University, Dnipro, Ukraine, e-mail: irinakofan17@gmail.com,
ORCID NO: [0000-0002-7252-1134](https://orcid.org/0000-0002-7252-1134)

⁵Oles Honchar Dnipro National University, Dnipro, Ukraine, e-mail: lykholat2006@ukr.net,
ORCID NO: [0000-0003-3354-8251](https://orcid.org/0000-0003-3354-8251)

ABSTRACT

Properly organized in modern conditions, career guidance work with applicants is aimed at helping schoolboys correctly navigate the choice of a specific specialty in accordance with their abilities and interests. Of great importance in this regard is further employment in the future, material well-being and the ability to express themselves, self-realization and inner satisfaction from their choice. Throughout their professional life, a person analyzes and rethinks their professional identity, confirming themselves in the field of activity chosen in their youth. In modern conditions, it is important to take into account the various influences and challenges of society that schoolboys experience daily in real conditions of today, which significantly affect the choice of specialty and encourage them to approach the choice of their future professional path more consciously.

For the successful implementation of professional orientation of schoolboys, educational institutions need to implement a set of measures aimed at overcoming existing contradictions and ensuring the integrity of the educational process. To do this, first of all, it is necessary to take into account the need to adapt orientation programs to the conditions of radicalization of school education, which involves the integration of modern teaching methods and approaches to the formation of students' professional identity. In addition, it is important to ensure the support of a single program and methodological support, including the involvement of specialists in age and pedagogical psychology, as well as experienced teachers who can convincingly encourage schoolchildren to a specific specialty. Adherence to these principles will allow creating a comprehensive system of student support at the state level and will facilitate the implementation of orientation programs in modern conditions..

Keywords: professional orientation of schoolboy, integration of modern teaching methods, program and methodological support, involvement of specialists in age and pedagogical psychology, adaptation of orientation programs.

GLOBAL GOVERNANCE OF AI: AN EVALUATION OF ALTERNATIVE INSTITUTIONAL MECHANISMS AND THE PATH AHEAD FOR EFFECTIVE REGULATION

Zainab Irfan

Undergraduate Student, Department of Political Science & International Relations

University of Management and Technology, Lahore

Email: zainabirfan270@gmail.com, ORCID: 0009-0004-6409-0671

Syed Khubaib Azhar Wasti

Undergraduate Student, Department of Political Science & International Relations

University of Management and Technology, Lahore

Email: khubabwasti@gmail.com, ORCID: 0009-0000-1900-1984

Abstract:

Artificial intelligence (AI) is increasingly transforming global political, economic, and security frameworks, prompting critical inquiries regarding the sufficiency of current international governance systems. As AI technologies cross national boundaries via transnational data flows, defense uses, financial markets, and public governance, regulatory methods focused solely on states have shown to be inadequate in managing their worldwide risks. This research assesses the efficacy of existing institutional frameworks for the global governance of AI, placing particular focus on the roles played by the OECD, UNESCO, and the United Nations, as well as emerging regional and national regulatory approaches like the European Union's AI Act, the market-driven strategy of the United States, and China's government-centered regulatory system.

Using a qualitative research design based on systematic analysis of documents and policies, this paper investigates institutional preparedness, alignment of norms, and enforcement limitations in global AI governance spanning the years 2019 to 2024. The findings indicate considerable regulatory fragmentation, inconsistent application of ethical principles, and marked disparities in governance capabilities between developed and developing nations, resulting in a largely soft law regulatory landscape with limited enforceability.

The study posits that effective global governance of AI necessitates improved institutional collaboration, regulatory compatibility, and inclusive participation from multiple stakeholders. It suggests strategic approaches to create a coherent and rights-oriented global governance framework that harmonizes innovation with accountability, protects human rights, and encourages equitable involvement in the international regulation of artificial intelligence.

Keywords: Global AI Governance, International Institutions, Artificial Intelligence Regulation, Ethical AI, Global Governance Frameworks.

"SOCIOECONOMIC PRESSURES AND MENTAL HEALTH: EXPLORING THE CAUSES OF ANXIETY AND DEPRESSION IN PAKISTAN'S MIDDLE CLASS"

Muhammad Saeed

Abubakar Yousafi

Muhammad Hurrairah

Abstract:

The middle class in Pakistan, which is often referred to as the country's economic backbone but is largely ignored in mental health literature, has seen an increase in the prevalence of anxiety and depression. This group suffers a "silent mental health catastrophe" despite their professional position, which is fuelled by growing economic uncertainty, increased living expenses, and social pressure to uphold particular living standards. The main social, cultural, and psychological factors causing these elevated rates of mental discomfort are examined in this study.

The study looks at the connection between psychological discomfort and socioeconomic pressures using a cross-sectional, descriptive, and quantitative approach. The GAD-7 for anxiety and the PHQ-9 for depression severity are two approved clinical instruments used to collect data on middle-class persons (ages 18–60) in metropolitan areas such as Lahore, Karachi, and Islamabad.

According to preliminary research, the Pakistani middle class experiences particular "status-anxiety" and the psychological burden of debt used to finance social markers, despite the fact that mental health problems are frequently linked to lower-income groups. Additionally, societal stigmas and the propensity to manifest psychological suffering as physical symptoms (somatization) continue to be major obstacles to getting medical attention. The purpose of this study is to offer empirical data to support the establishment of evidence-based policies, such as the creation of focused financial aid programs and the integration of mental health screenings into basic urban care.

KEYWORDS: Socioeconomic Pressure - Pakistan's Middle Class - Mental Health - Anxiety and Depression - Urban Mental Health

THE PROBLEM OF GREATER BALOCHISTAN: HISTORICAL ROOTS, POLITICAL CHALLENGES, AND SOCIO-ECONOMIC REALITIES

Hairbiyar baloch and Aftab

Student, Department of Sociology

University of Management and Technology (UMT), Lahore, Pakistan

E-mail: F2024127004@umt.edu.pk

ORCID: 0000-0000-0000-0000

Abstract

The idea of Greater Balochistan has remained a sensitive and debated issue in South and West Asia due to its deep historical background and continuing political and socio-economic concerns. This paper explores how colonial-era boundary decisions and post-independence political arrangements divided Baloch-inhabited areas across Pakistan, Iran, and Afghanistan, shaping long-term grievances among the Baloch people. It discusses key political challenges, such as limited political participation, weak local governance, and strained relations between Baloch nationalist movements and central governments. The study also highlights the everyday socio-economic conditions of Balochistan, including widespread poverty, low levels of education, insufficient healthcare services, unemployment, and the uneven sharing of natural resource benefits, despite the region's strategic importance. Using a qualitative review of historical records, scholarly literature, and policy documents, the paper argues that the issue of Greater Balochistan cannot be fully understood through a narrow security or separatist perspective. Instead, it calls for a broader understanding that recognizes historical experiences, promotes political inclusion, and addresses long-standing development inequalities. The paper concludes that lasting peace and stability in the region depend on dialogue, fair development policies, and meaningful involvement of the Baloch people in decision-making processes.

Keywords: Greater Balochistan; Political Challenges; Socio-Economic Conditions; Regional Stability

MIGRATION AND URBAN CHANGE: AN ANALYSIS OF SOCIO-ECONOMIC AND DEMOGRAPHIC EFFECTS

Professor Dr. Laura Diaconu (Maxim)

ORCID: <https://orcid.org/0000-0001-5745-3850>

E-mail: lauradiaconu_07@yahoo.com

**Faculty of Economics and Business Administration,
“Alexandru Ioan Cuza” University of Iasi, Romania**

Abstract

It is known that migration is one of the most important determinants of the urban growth, cities being the main destination for both internal and international migrants that are seeking better economic opportunities. European Union (EU) is facing not only increasing migratory flow, but also an aging population and labor shortages. Starting from all these aspects, in our study we intend to analyze the socio-economic and demographic effects of migration on urban areas in the EU member states. In order to achieve our goal, we conducted an analysis of the secondary data that was taken from the World Economic Forum reports, Eurostat and the World Bank databases. Our findings underline, once again, that migration has a significant role in reshaping the urban demographic profiles of the EU cities, especially by reducing the populations' decline and ageing through the inflow of working-age migrants. From a socio-economic perspective, migration contributes to labour market flexibility and skills diversification, especially in those cities with large knowledge-based sectors.

Keywords: migration, urban challenges, socio-economic consequences, demographic impact

THE SHORT STORY *ARTICLES OF WAR* BY GRAHAM SWIFT: AN ANALYSIS

Lecturer, PhD Irina-Ana DROBOT

Technical University of Civil Engineering Bucharest, Faculty of Engineering in Foreign Languages,
Department of Foreign Languages and Communication, philology, anadrobot@yahoo.com, ORCID

0000-0002-2556-6233

Abstract

The purpose of this paper is to analyse the short story *Articles of War* by Graham Swift, which is included in the short stories volume *England and Other Stories*. This short story is about a soldier who has never seen action and who has, therefore, not had the occasion to prove that he is a hero. He reflects on his family and his relationships with them. He mentions, among others, the conflictual relationship with his father. It was his father that had told him to know his place, a thought which returns to him until the end of this short story. He imagines how he may lead others in battle. His ship is called, ironically, the *Temeraire*, a name which should suggest action, adventure, and heroic deeds during the wars. This short story suggests the questioning mood about the heroism encountered during the war. Readers may expect, together with the main character, to find during the setting provided by the war occasions to become a hero. However, this does not happen in this short story. The methodological framework of analysis consists of literary studies, reader-response criticism, and psychology. This short story can be considered in relation to other works by Swift where the war was mentioned and where characters have related to it in one way or another. We can speak of intertextuality in-between Swift's own works.

Keywords: Free associations, introspection, emotions, hero, psychology

1. INTRODUCTION

Knowledgeable readers of Graham Swift's fictional universe are familiar with his preoccupation for the topic of war in his works. Most of his characters do not have direct contact with the war, meaning that they are actually soldiers who find in battle. Such examples include William Chapman, in *The Sweetshop Owner*, who makes lists with resources during the war. He cannot fight as he has injured his foot while placing the ad over his newly owned sweetshop. Prentis in *Shuttlecock* can only see war through what his father has written in his war memoir. In the novel *Here We Are*, Ronnie knows there is a war going on, but he is placed in the care of an elderly couple for his safety, where he feels that they are his parents. The war becomes in fact one of the best periods in his childhood. It is only in the novel *Out of This World* that Harry Beech witnesses war scenes, as he is a war photographer. He also witnesses his father, who was in the arms business, being assassinated in an explosion. In the short story from the short stories volume *England and Other Stories*, a young woman witnesses the return of her husband in *Was She the Only One?* emotionally affected by the war, and having the impression that she has cheated on him while he had been away. She had not washed his shirt while he had been away, so that it would keep his smell and hers. Her husband, who has shell shock, believes she had given his shirt to another man to wear while he had been away. In one way or another, the context of the war has consequences on most of the characters' lives. Here we can include separation for the loved ones, or wandering about someone having been an actual hero, as in the case of Prentis with his father. Prentis' father can no longer speak in order to discuss the details in his war memoir, and at some point Prentis doubts his fathers' actually having been a hero, but he cannot know anything for certain. Wars become occasions to reflect on the way in which they can interfere with everyday lives, such as in the short story *Fireworks* from the volume *Twelve Post-War Tales*, where a father does his best not to upset his daughter by postponing her wedding which may be inevitable due to news about a coming war.

Swift moves in his stories in-between public and private history, between historical, world-level events and incidents and events going on in the personal, everyday lives of his characters. His works have been described as focusing on the common man (O'Mahony, 2003). If we look carefully, the common man is not so common, as his characters deal with psychological dilemmas and various issues at the present moment, which trigger them to start reflecting on various incidents which have led to the present situation and to allow readers, on this occasion, to witness their story.

1.1. Theoretical Framework

There are various ways of looking at wars, starting from heroic acts and deeds, and ending up with destruction caused by these historical events and loss of meaning. Swift's works provide an already existing theoretical framework for analysis of further works by relying on intertextuality (Bloome & Hong, 2013). In this way, he manages to create connections for his readers with other works from the same fictional universe. His works ask for analysis based on reader-response criticism, which starts off from the idea that readers react emotionally to a text and that they also react by resorting to their background knowledge applicable to the text (Mart, 2019). Emotional issues can be associated with wars, such as problematic personal relationships due to distance, separation, isolation, as well as shell-shock, or post-traumatic stress disorder (Crocq & Crocq, 2000) for the characters directly involved in fighting during the war as soldiers.

2. METHOD

The intertextuality with other works where war is present at least as part of the far-away, overall context of the characters' lives, and as something beyond their control, creates expectations for readers of new works by Graham Swift where the war appears. If, after we have gone through all the works mentioned in the introduction of this paper, we read the short story *Articles of War* from the short stories volume *England and Other Stories*, we may not be surprised to witness the story of a reflective soldier. Reflective characters are present in all of Swift's works, and it is through their reflections that the story is told. The soldier is an introspective character who explores his inner world. He reflects about his family and his relationships with each of them. He mentions the conflictual relationship he has with his father and an idea to which he will keep returning throughout his story: that his father had told him to know his place. His being told to know his place may sound as we read the story as a warning that the character should not expect anything out of the ordinary to happen to him during the war. After all, he is only an ordinary soldier and it may be implied through the idea of him knowing his place that he cannot change into a hero. The particular context of the war for him does not provide the necessary conditions for him to become a hero.

We readers, just as well as him, expect him to be in action fighting and writing to his family about his experiences. However, even if his ship is called the *Temeraire*, there is no live war action around him. He never has the occasion to prove how he can be a hero. A war front where nothing happens is an unusual situation, as readers and the main character expect at least something to be going on around him, under the form of battles. Starting from the name of his ship, the *Temeraire*, the soldier makes free associations and considers the ironic

name since nothing happens around him. The Temeraire can make us all think of adventures and heroic deeds, as well as lots of unexpected happenings, and of a hero able to bring everything to a good ending.

The narrator imagines how he may lead others in battle. However, he never has such an opportunity.

Readers may consider that such a quiet war may be beneficial, since nobody, including the main character of the story, is hurt. We do not witness any destruction. Nobody gets shell shock or post-traumatic stress syndrome. However, based on the expected image of the war, what is going on for the main character cannot be considered normal. He feels disappointed that he could not prove his skills as a leader and as a soldier. From this point of view, readers sympathize with the main character. They adopt his point of view and feel psychologically close to him in his deception that he could not get into action, with all that this implies: proving that he is a hero, and standing for his values and beliefs, as well as doing something for his country and for the others.

This short story creates a sense of psychological crisis which is not an expected one. Wars are expected to be events of loss and destruction, as well as death. In this case, the war becomes a space of non-action. The meaninglessness of the war is not related to the question whether or not it is worth it to fight during the war. The lack of meaning is related to the identity crisis of the main character. He is a soldier, he expects to be able to prove his courage, yet the setting does not offer him the occasion. Going to the war front has proven to be futile. Just like other characters by Swift, the main character in the short story *Articles of War* is going on through a moment of psychological crisis at the present moment (Malcolm, 2003).

We do not deal only with realities. We also deal with our expectations of them and with how these two interact. The cognitive theory of the disconfirmation of expectation (Elkhani & Bakri, 2012) explains that when we expect a certain outcome or set for ourselves certain goals, if we fail, this leads to a mental gap which is the disappointment. The size of the gap matters with respect to the degree of intensity of our disappointment. In the case of the main character in this story, this gap is very large.

3. RESULTS

War is assigned with the meaning of action and heroism in the short story *Articles of War*. Readers resonate with the disappointment of the main character, as he makes clear his wish to prove that he is brave and a good leader, and as he is ready to do his duty during the war. War carries a stereotypical image of heroism and destruction, as well as tragedy and loss. Here, all of our expectations are challenged.

4. CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

A complete questioning of war comes with the challenging perspective presented in the short story *Articles of War*, where we deal with a war which does not go on according to our expectations. This perspective

completely contradicts the very meaning of war and of fighting during the war. We may expect characters to not be so heroic as they wish to be, yet the war practically does not even happen, at least where the main character is sent.

Such a reality can be baffling, especially since readers expect the plot to turn or twist, we expect suspense and a change in perspective of the character about heroism, yet there are no circumstances at all even able to make these possible. The war in this short story looks like a story with no plot and no action. We start waiting and we end up waiting.

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THE SHORT STORY *KNIFE* BY GRAHAM SWIFT: AN ANALYSIS

Lecturer, PhD Irina-Ana DROBOT

Technical University of Civil Engineering Bucharest, Faculty of Engineering in Foreign Languages,
Department of Foreign Languages and Communication, philology, anadrobot@yahoo.com, ORCID

0000-0002-2556-6233

Abstract

The purpose of this paper is to analyse the short story *Knife* by Graham Swift, from the short stories volume *England and Other Stories*. The main character is a twelve year-old boy whose gesture to take from the kitchen a knife belonging to his mother is done in relation to his thoughts about him hating her boyfriend. The text relies on the non-verbal clue regarding the taking of the knife and his hearing his mother and her boyfriend spending time together. His anger is towards her boyfriend, and the knife is associated with his hostile feelings towards the boyfriend, so that the implication is that the young boy may wish for his death. The short story does not leave readers to understand that the young boy will actually kill him, but that he fantasized about this. Psychoanalytically, this can be interpreted as a death wish, which makes us consider that the boy will not actually commit murder. However, the text leaves room for ambiguity, and echoes *Hamlet* by Shakespeare, suggesting that the boyfriend has taken the place of his father, even if he has not even known his father, who had left his mother before he was born. The methodological framework is made up of literary studies and psychoanalysis.

Keywords: Daydreaming, introspection, emotions, death wish, psychoanalysis

1. INTRODUCTION

Graham Swift is a contemporary British novelist whose works include novels, short stories, autobiographical writings, and poems. His main focus throughout his works is the interior life. Introspection is the defining element of all of his works. His stories rely on the self-analysis and self-exploration of the characters. Readers manage to relate to his characters and to participate together with them emotionally in their stories.

The personal element present in his stories maintains the readers' interest constant in his works. Even if certain motifs are repeated throughout his works – such as the psychological dilemma, the isolation of the characters, their interactions with historical events such as wars – there is always an element of surprise which makes the story move along an unexpected path. The characters are all different and highly individualized. Swift manages to create particular characters with particular inner worlds.

The present paper will focus on the analysis of a short story titled *Knife*, from the short stories volume *England and Other Stories*. The central element is that of a twelve year old boy looking at a kitchen knife and taking it, while reflecting on the way he feels about his mother's boyfriend.

1.1. Theoretical Framework

Reader-response criticism can explain how we readers relate to the main characters and their inner world, since reader-response criticism relies on our emotional reaction towards a text we read and also on our background knowledge (Mart, 2019), which we use to better understand the text. The emotional situations in Swift's works rely on common experiences. If we look at psychoanalytic theories, we can notice how daydreaming is present in everyone's life (Freud, 1908) and it allows us to come to terms with various situations we are confronted with. The death wish (Carmichael, 1943) against someone relies on a fantasy of us killing a person, or on a dream where we kill the respective person. The death wish represents, psychologically, a childish way in which we deal with a person, together with the situations and emotions associated with them. It is a daydream, night dream, or fantasy which expresses the way we cope with problematic situations and relationships.

2. METHOD

The short story *Knife* does not explicitly mention that the twelve year old boy wants to kill his mother's boyfriend. This can be implied by readers, once the short story focuses repeatedly on the knife, and on the way in which the boy believes he should get it. These details juxtapose with his mother and her boyfriend making love and him hearing them. The boy is in the kitchen and repeatedly encourages himself to get the kitchen knife, since it is a normal thing to do. All of these repetitions and interferences with his thoughts of his mother and her boyfriend making love suggest readers that the boy hates his mother's boyfriend and that he would like to kill

him, or, at least, that he is fantasizing about this. The story suggests his hesitation, and in this sense it makes readers think about Shakespeare's play *Hamlet* and the famous monologues delivered over his considering whether or not he should take his revenge on his uncle for killing his father, since he is not sure that his uncle has actually murdered his father.

Non-verbal communication is present in this short story by relying on focusing on the image of the knife and on repetitive thoughts about taking it from the drawer, suggesting his indecision which we can compare with Hamlet's hesitations and reflections.

Readers fill in the blanks and understand, from the boy's free associations (Freud, 2016), like psychoanalysts, that he is fantasizing about stabbing his mother's boyfriend. He hesitates because he feels guilty about his fantasy and death wish. He hesitates taking the kitchen knife, which is the equivalent of hesitating to kill his mother's boyfriend, just like Hamlet hesitates to kill his uncle, who is the current king.

Readers cannot feel like blaming the boy for his death wish, since he may feel that his mother is neglecting him and his brothers, or that the boyfriend has actually taken the place of his father, although he has left twelve years ago and he has never known him. The boy has started having issues with the police, since he mentions that once his mother had come to take him from the police station and she had beaten him. This may lead readers to think that maybe the fantasy is not a simple death wish, to do away with her boyfriend from their life, but an actual wish to literally kill him. However, we readers may hesitate in believing that the boy may not be afraid of the consequences of killing a man. The boy mentions that the kitchen knife belongs to his mother and that she may ask him where it is, and that he may blame her boyfriend. Gradually the boy begins to think that her boyfriend is not his enemy and that she may need him, yet if he stabbed him it would be similar to stabbing his own father, who had left them. Here readers understand that the boy has emotional issues and is angry from various points of view. He is also aware that the boyfriend can be an image of his father, and that he actually hates his own father while taking his revenge on him, at least when it comes to his thoughts and fantasies.

The entire short story consists of a few details which readers put together in order to form the larger psychological picture of the story. The entire setting all along is the kitchen and the drawer with the kitchen knife he eventually decides to take: "He put in his hand and took out the knife. It was the simplest, easiest, most ordinary thing, to take a knife from a drawer" (Swift, 2014).

Given the situation, readers believe that the young boy is entitled to feel angry. They also keep in mind that he is at the age of adolescence, when rebellious behaviour is a usual part of his psychology (Greydanus et al, 1997) and the death wish could be a simple way of rebelling. Taking the knife is considered at some points the

equivalent of stealing from his mother, which reduced the emotional and especially moral load of the act. The boy rebels not only against the rules, but against the presence of another person in his home – his mother's boyfriend. Readers sympathize with him as he mentions that his true father had abandoned the family when he was born. This, together with psychoanalytic knowledge about the death wish, and the psychology of adolescence reduce the moral and emotional impact of the boy's thoughts, both implied and mentioned by him directly, at some point.

3. RESULTS

The paper has shown how the fact that the young boy goes through stages in psychological and emotional development to his age which are common, as well as through a particular family situation, and through common psychoanalytic experiences reduces the readers' tendency to start judging him. Readers begin to sympathize with him and to side with him emotionally. What makes this story interesting is the honesty of the young boy, who confesses directly before us readers all of his thoughts and feelings, as if we were his analysts.

4. CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

The young boy presents his free associations without hiding what feels inappropriate. He repeatedly refers to the kitchen knife, and his story mirrors the free associations technique used in psychoanalysis. Even if the story is told using a third-person narrator, it feels for us readers as if he is telling the story from a first-person point of view. We cannot take a distance from the narrator, who manages to make us see all his emotions and thoughts and feel that he is right about everything. The ambiguity of the ending of the story makes us continue to further on make hypotheses and try to continue the story by using our own impressions and interpretations.

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THE SHORT STORY *KNIFE* AND THE NOVEL *THE LIGHT OF DAY* BY GRAHAM SWIFT: THE SIGNIFICANCE OF A MURDER

Lecturer, PhD Irina-Ana DROBOT

Technical University of Civil Engineering Bucharest, Faculty of Engineering in Foreign Languages,
Department of Foreign Languages and Communication, philology, anadrobot@yahoo.com, ORCID
0000-0002-2556-6233

Abstract

The purpose of this paper is to analyse the short story *Knife* comparatively with the novel *The Light of Day* by Graham Swift, in relation to the murder. While in *The Light of Day* the murder literally takes place, in *Knife* it is only suggested, and likely part of a fantasy more than of an actual happening. Both suggested and literal murder come from the psychoanalytic death wish for another character. In *The Light of Day*, Sarah Nash literally kills her husband, stabbing him with a kitchen knife as she has prepared dinner for him after he returns from the airport, where he has parted with Croatian refugee Kristina Lazic, with whom he has had an affair. Sarah clearly hates her husband, and motivates her stabbing him as she claims that she had realized that nothing would ever be the same between them again after his affair. Readers notice how the kitchen knife is present in both *The Light of Day* and *Knife*. In *Knife*, the situation is ambiguous, as we do not know if the twelve year-old boy who hates his mother's boyfriend will literally murder him. He is more than anything fantasizing about this, as he hates him. The methodological framework is made up of literary studies and psychoanalysis.

Keywords: Daydreaming, introspection, emotions, death wish, psychoanalysis

1. INTRODUCTION

We can find intertextuality, or common elements and situations, in Graham Swift's works, once we are readers familiar with his works. Swift can make subtle allusions to his other works in his new works if we know how to read them, or we may simply be imagining all of these. Matters are not clear. However, if we look at the short story *Knife*, from the short stories volume *England and Other Stories*, we may feel that we see an intertextual allusion to his earlier novel *The Light of Day*. The similarity starts from the presence of the same wish to kill someone, and with the same tool: a kitchen knife. In one of the works, *The Light of Day*, the murder is literal, while in the second work, *Knife*, the intention of the main character and the outcome of him taking the kitchen knife is not clear.

1.1. Theoretical Framework

In both works, we have to do with what psychoanalysis calls a death wish (Carmichael, 1943). The death wish is a psychological issue, which can be found in daydreams (Freud, 1908) and fantasies, as well as in dreams at night. Wishing someone to die is a childish defense mechanism. Children, when they are upset at adults, can wish them to die, but this is simply a matter of removing them from the picture and everything unpleasant or uncomfortable about them. Children do not know how to deal with emotions and with various issues, and this is one solution. However, they are not aware of what someone dying actually means. They may also dream that someone dies, which leads us to the same conclusions and solutions. Even as adults, we may dream that someone dies. Since dreams represent a means of wish fulfilment, a death wish against someone suggests a way of dealing with anything unpleasant related to the respective person. During their Oedipal period, children may wish for the same sex parent to die, so that they may take their place next to the opposite sex parent. It is through free associations (Freud, 2016) that psychoanalysts can help someone interpret a death wish. This process is especially visible in the repetitive image of the kitchen knife and preoccupation with it in the short story *Knife*.

2. METHOD

In both *Knife* and *The Light of Day*, the issue of murder, either suggested or literal, is not condemned by readers, but understood. Readers sympathize with the characters and their situation. In *Knife*, a twelve year old boy hates his mother's boyfriend and wishes, at some point, as he confesses it himself, and as readers have implied all along, to stab him. The short story focuses on how the boy goes to the kitchen and reflects about his situation, and finally manages to resort to action and actually take his mother's kitchen knife from the drawer. He has never known his real father, as he has left his family twelve years ago – and readers imply that it was

about the time when he had found out that the boy would be born. Ever since, he has never returned, and has never seen his son. At some point, the boy mentions that he would feel that he would stab his real father, not his mother's boyfriend, by stabbing the boyfriend. The boy is, thus, aware that the boyfriend stands for someone else he hates, namely his actual father. At the same time, he may also feel that his mother spends too much time with her boyfriend, neglecting him and his brothers. Readers understand that once the boy takes the kitchen knife, he would be on his brothers' side. This implies that the brothers also hate their mother's boyfriend and, through him, their real father, for leaving them.

The boy's immoral wish can actually be only a fantasy and only a daydream, through which he expresses his feelings and not his actual intent or actual outcome. He may or may not resort to actually stabbing the boyfriend. Since he is so preoccupied with what his mother would say once she discovers that her kitchen knife is gone, readers may be tempted to believe that he would not go through with the literal stabbing. At the same time, once readers find out that he has had issues with the police, and that his mother had come to take him home from the police station, maybe he would actually try to go through with actually stabbing the boyfriend or, at least, hurting him.

However, everything is understandable, since readers are impressed by the boy's situation.

The novel *The Light of Day* shows us readers Sarah literally stabbing her husband Bob with a kitchen knife, during the evening she cooks dinner for him and when they decide to make up. Sarah had decided to forgive him after he parts with Croatian refugee Kristina Lazic, leaving her at the airport, so that she can return home. They have had an affair. Sarah had wanted detective George Webb to make sure Bob does part with Kristina as he had promised. However, as he returns she grows aware of the fact that nothing can ever be the same after he has had an affair, even if he had decided to return back to her. Sarah, thus, stabs her husband. The act of her killing him does not make George judge her or condemn her. He analyses everything in an understanding manner. He himself had been left by his wife and has also gone through difficult moments, as he had also lost his old job. He understands how Sarah must have felt. Readers imply that the knife and the act of stabbing stand for someone being hurt. In addition, knowledgeable readers can make the connection with the death wish from psychoanalysis, and thus grow aware of the intensity of emotions. Sarah has felt an intense hatred against her husband, as readers can imply from her act of stabbing him. This feeling is understandable. The actual act of stabbing becomes a symbolic one, suggesting how much she has felt hurt by her husband having an affair and how much she can hate him. Since this is entirely understandable, readers can go through over her act and agree with George Webb that he would wait for her to come out of prison so that they can be together. All along

George looks at all the persons involved in his case with extreme understanding and sympathy. Readers understand that he can see himself and his loneliness, isolation, and frustration, as well as anger, in all of the characters involved. The actual act of murder is moved towards its symbolic level, and is not considered in its literal sense, even if this is not explicitly stated throughout the story. Readers accept to move past the immoral act of murder, much the same way as they accept the suspension of disbelief when they are introduced into a fictional world. The irrationality of the act is accepted due to the irrationality of feelings when someone feels hurt emotionally.

Both works rely on introspection, and both acts suggested by the knife and being made possible with the help of the knife acquire expressive value regarding the intensity and irrationality of emotions.

The analysis of both works relies on reader-response criticism, according to which readers react emotionally to the text they read, and they also rely on their background knowledge to complete their understanding of the text (Mart, 2019).

3. RESULTS

The knife, and, especially the kitchen knife, becomes in both works an everyday life object which turns into a means of self-expression and into a means of taking action for the characters to fulfill their wish. While otherwise destined for other purposes and part of everyday life, the kitchen knife changes into a weapon of murdering someone. The kitchen knife also suggests the change of the characters, from common persons into murderers.

4. CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

Both works suggest how there is a sudden change in emotions and reactions for the characters. These reactions are triggered by another person and his or her behaviour towards them or towards other persons. The kitchen knife becomes a solution, but also a symbol of a sudden burst of violent behaviour on the side of otherwise usual persons. The kitchen knife suggests a radical change of attitude on the part of both characters in both works analysed in this paper.

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EVALUATION OF CYTOKINES INTERLEUKIN-6 (IL-6) AND TUMOR NECROSIS FACTOR (TNF-A) AND OTHER BIOMARKERS IN HYPERTHYROIDISM IRAQI PATIENTS

Raed amer ali ALSAHOO^{1*}, Salih Abdullah Hussein², Ahmed fadhil kadhim³, Ameen hayder ahmed⁴,
Dhafir latief fayadh⁵

Department of Biotechnology, College of Science, University of Baghdad, Iraq¹

Email: raed.a@sc.uobaghdad.edu.iq salih.a@sc.uobaghdad.edu.iq ahmed.f@sc.uobaghdad.edu.iq

ameen.h@sc.uobaghdad.edu.iq dhafir.l@sc.uobaghdad.edu.iq

009647850007575

Abstract

Hyperthyroidism is a condition that is associated with excessive thyroid hormone secretion that impacts metabolic, cardiovascular, and immune systems. It is beginning to be suggested that pro-inflammatory cytokines like interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- 6) could be important in the pathophysiology of the disease. The aim of this study was to compare the serum levels of IL-6, TNF- 2, and lipid profile parameters in patients with hyperthyroidism and healthy people in Iraq. The total number of participants recruited was 55 participants, 40 with hyperthyroidism and 15 controls. A sandwich ELISA was used to measure serum levels of IL-6 and TNF-a, and the rest of the biomarkers (thyroid and lipid) were measured using common biochemical tests. The statistical analysis was carried out with the help of MannWhitney U test and Spearman correlation coefficients. These findings revealed a significant increase in T3 and T4 and a severe reduction in TSH in hyperthyroid individuals ($P < 0.0001$). The levels of IL-6 and TNF- a were significantly elevated in hyperthyroid subjects as compared to controls ($P < 0.0001$), which was a measure of systemic inflammation. Also, hyperthyroid patients had a high total cholesterol and triglycerides, HDL, VLDL and low LDL ($P < 0.0001$). The analysis of correlation showed that TSH and both IL-6 and TNF-A had negative relationships but that T3 and T4 were correlated with most lipid markers and pro-inflammatory cytokines. These results point to a complicated interplay between thyroid dysfunction, inflammation, and lipid metabolism. The high levels of cytokines show the presence of immune drive in hyperthyroidism, whereas the changed lipid profile evidences the high turnover. Collectively, these findings highlight the relevance of tracking inflammatory and metabolic indicators in hyperthyroid patients to enhance clinical evaluation and predict the possible complications.

Keywords: IL-6, Hyperthyroidism, TNF- α , pro-inflammatory cytokines.

1. INTRODUCTION

Hyperthyroidism is a medical disorder that is manifested by increased levels of circulating thyroid hormones triiodothyronine (T3) and thyroxine (T4), and reduced secretion of thyrotropin (thyroid-stimulating hormone, TSH). It occurs in one out of 0.2 to 1.4 individuals worldwide, and its occurrence is more common in women (Lee and Pearce, 2023). The disorder speeds up the metabolism and impacts various organ systems, such as cardiovascular system, gastrointestinal system, hepatic system, and immune system. In extreme instances, patients can develop thyroid storm, which is a life-threatening emergency that is marked by a high fever, Rapid weight loss, and multiorgan dysfunction (Farooqi et al., 2023).

Whereas the endocrine and the metabolic effects of hyperthyroidism are well-reported, new evidence points at its immunological aspect what concerns the dys-regulation of the cytokine networks. Hyperthyroid individuals have a great increase in pro-inflammatory cytokines, including interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- 6) which can lead to disease pathogenesis and progression (Fallahi et al., 2021). Macrophages and other immune cells make these cytokines in response to several stimuli, and they have important functions in the control of immune responses, inflammation, and tissue repair. Specifically, IL-6 modulates the B-cell maturation, autoantibody formation, and acute-phase (Hirano, 2021; Tanaka et al., 2016). TNF-alpha, in its turn, facilitates systemic inflammation and has been found to play a role in the pathophysiology of autoimmune thyroid diseases (Akber and Yenzeel, 2022). Various researchers, such as regional studies in Iraq, have found out that the levels of IL-6 and TNF-alpha are much higher in patients with hyperthyroidism than healthy controls (Hussein et al., 2022). These results indicate that the presence of excess thyroid hormone can actively mediate immune processes thus mediating a subclinical pro-inflammatory condition.

Simultaneously, the changes in lipid metabolism are related to hyperthyroidism as well. Thyroid hormones increase hepatic LDL receptors, boost cholesterol clearance, and stimulate lipolysis (Newman, 2023). These effects though are mostly nonlinear and may have a paradoxical outcome such as dyslipidemia. Research indicated the inconsistent changes in lipid profiles in hyperthyroid patients with a drop in total cholesterol and LDL and an increase in triglycerides and HDL, This dysregulation brings the risk of cardiovascular disease, in particular, when untreated or poorly treated (Yahaya, 2019).

It is worth noting that transporting lipids is not the only way in which lipoproteins can be involved in hyperthyroidism. An example of this is HDL which has been demonstrated to have anti-inflammatory and immune-modulating effects (Bonacina et al., 2021). Lipid-cytokine interaction has not been extensively studied and involves environmental and genetic influences that might contribute to the disease expression in the non-

Western population. Although many studies have been conducted to determine the systemic impact of hyperthyroidism, there are few studies that look at the combined actions of thyroid hormones, cytokines, and lipid markers. Such a gap is especially prominent in the case of the population of Middle East, as local statistics are few and may be affected by regional diet and environmental specifics, as well as by genetic peculiarities. These integrative studies can expose latent pathophysiological processes and can also be used to define those people who will be at higher risk of developing complications like atherosclerosis or autoimmune exacerbation. Thus, the current research was designed to compare the concentrations of the IL-6 and TNF- α and a complete lipid panel, such as total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and very low-density lipoprotein (VLDL) between the groups of the patients with hyperthyroidism and healthy controls in Iraq. In addition, we examined the possible relationships between these inflammatory and metabolic indicators and the levels of thyroid hormones in circulation, which provided the information about the endocrine-immune-lipid interactions which define hyperthyroid conditions.

2. MATERIAL AND METHODS

The study involved 55 individuals, whereby 40 patients were diagnosed with hyperthyroidism, and 15 healthy people. All the study subjects were sampled and their serum was separated to determine the concentration of the IL-6, and TNF- α through serum sandwich Enzyme-Linked Immunosorbent Assay (ELISA). The kits were the PicoKine Company (USA) products (shen et al., 2021).

The demographic, thyroidal, lipid, and inflammatory biomarkers were conducted using descriptive statistics and comparing the groups. Nonparametric Mann-Whitney U test was used in all comparisons because the assumption of normality was violated in several variables as was found as evidence by D Agostino Pearson, Shapiro Wilk, Anderson Darling, and kolmogorov Smirrov tests. GraphPad Prism Version 10.3.1 was applied to conduct statistical analyses.

Sex Distribution

The sex distortion was tested through the Fisher exact test. The control group consisted of 2 males and 13 females and the hyperthyroid consisted of 7 males and 33 females. The distribution difference did not show any statistically significant difference ($P > 0.9999$). This insignificance made us not stratify the analysis with sex when doing further comparisons.

3. RESULTS AND DISCUSSION

No statistically significant differences were found among the demographic characteristics of age ($P = 0.6564$) and BMI ($P = 0.468$) between the hyperthyroid and control groups, and in the sex distribution ($P > 0.9999$), which means that the groups were sufficiently comparable (Figure 1A-C; Table 1).

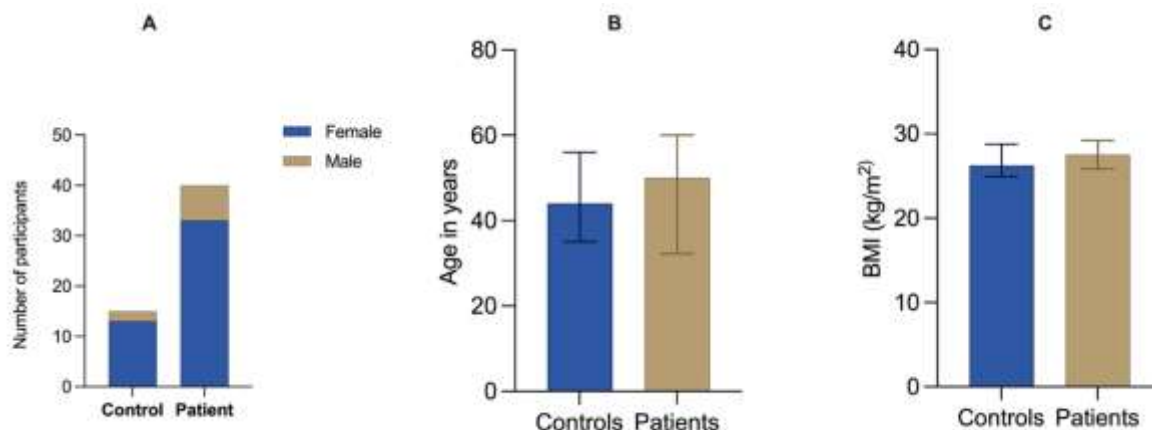


Figure 1. Trait of the study participants in terms of demographics. (A) Sex; (B) Age; (C) Body Mass Index (BMI). Interquartile range is expressed in error bars.

Thirdly, T3 and T4 were highly increased ($P < 0.0001$), and TSH was strongly decreased in hyperthyroid patients ($P < 0.0001$), as expected in the classical dysregulation of the thyroid axis in hyperthyroidism (Figure 2A–C; Table 1). These changes correspond with those of Altahir et al. (2013), Raguthu et al. (2022), and Ahmad et al. (2022), which indicate the hormonal profile of overt thyrotoxicosis.

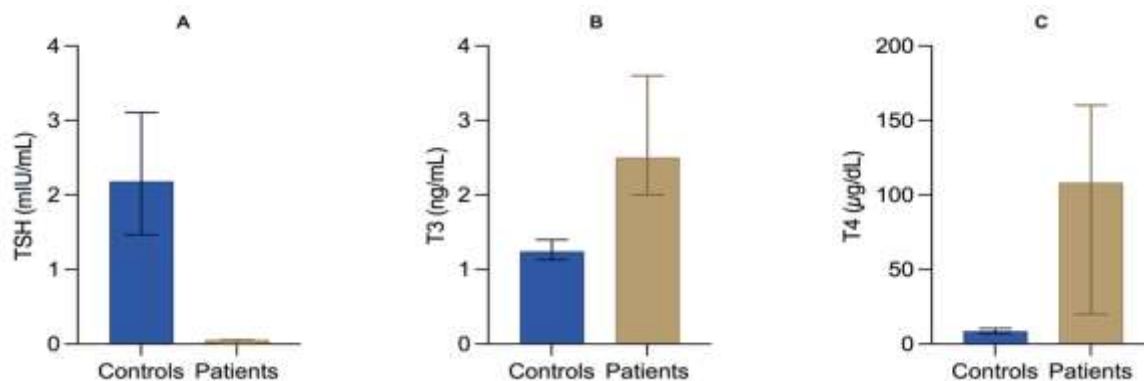


Figure 2. Thyroid hormone concentration in control and hyperthyroid patients. (A) TSH; (B) T3; (C) T4. Data are presented in the form of median IQR.

It is interesting to note that both IL-6 and TNF- α were significantly higher in hyperthyroid subjects than in controls ($P < 0.0001$), which further confirms the hypothesis of hyperthyroid systemic immune activation and inflammation (Figure 3A-B), and is consistent with the previous findings of Salvi et al. (2000), Senturk et al. (2003), and Jha et al. (2021).

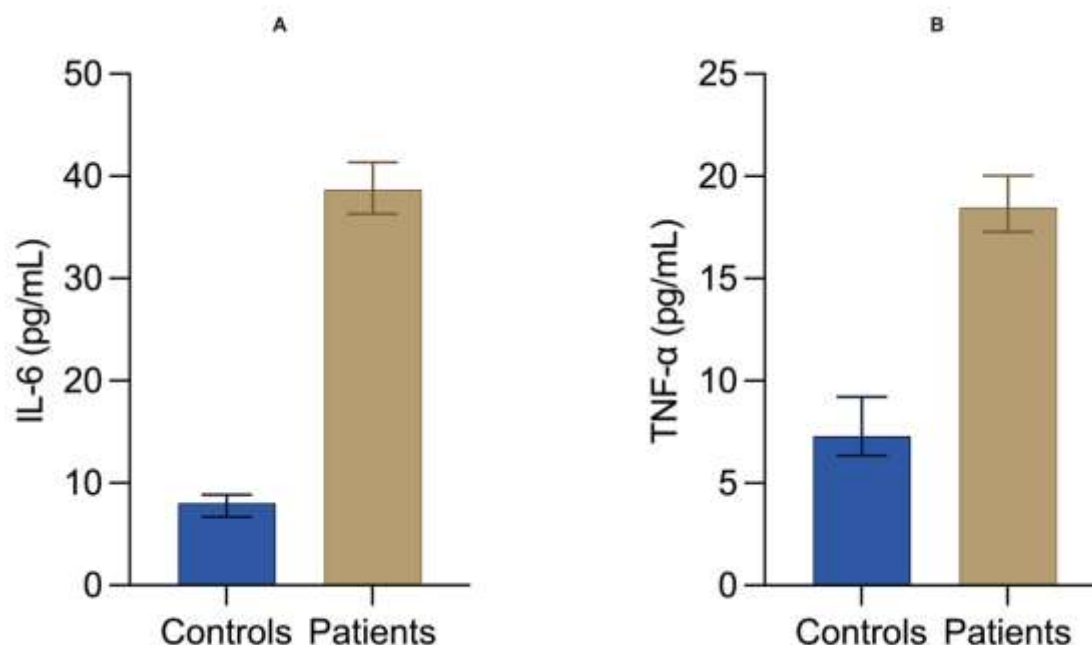


Figure 3. Cytokine levels. The two cytokines (A) Interleukin-6 (IL-6); (B) Tumor necrosis factor-alpha (TNF- α) in control and hyperthyroid groups.

Concerning the lipid metabolism, the hyperthyroid group had significantly increased total cholesterol, triglycerides, HDL, and VLDL ($P < 0.0001$), but LDL levels were paradoxically decreased ($P < 0.0001$) (Figure 4A–E; Table 1). This trend indicates a multifaceted adjustment of lipid homeostasis in hyperthyroid conditions, with a higher hepatic level of LDL receptor activity caused by T3 possibly boosting LDL clearance, as hypothesized by Genez Yeza et al. (2021) and Chin et al. (2014). In the meantime, the triglycerides, HDL, and VLDL increase are probably linked with enhanced lipolysis and hepatic lipid transportation caused by excess thyroid hormones,

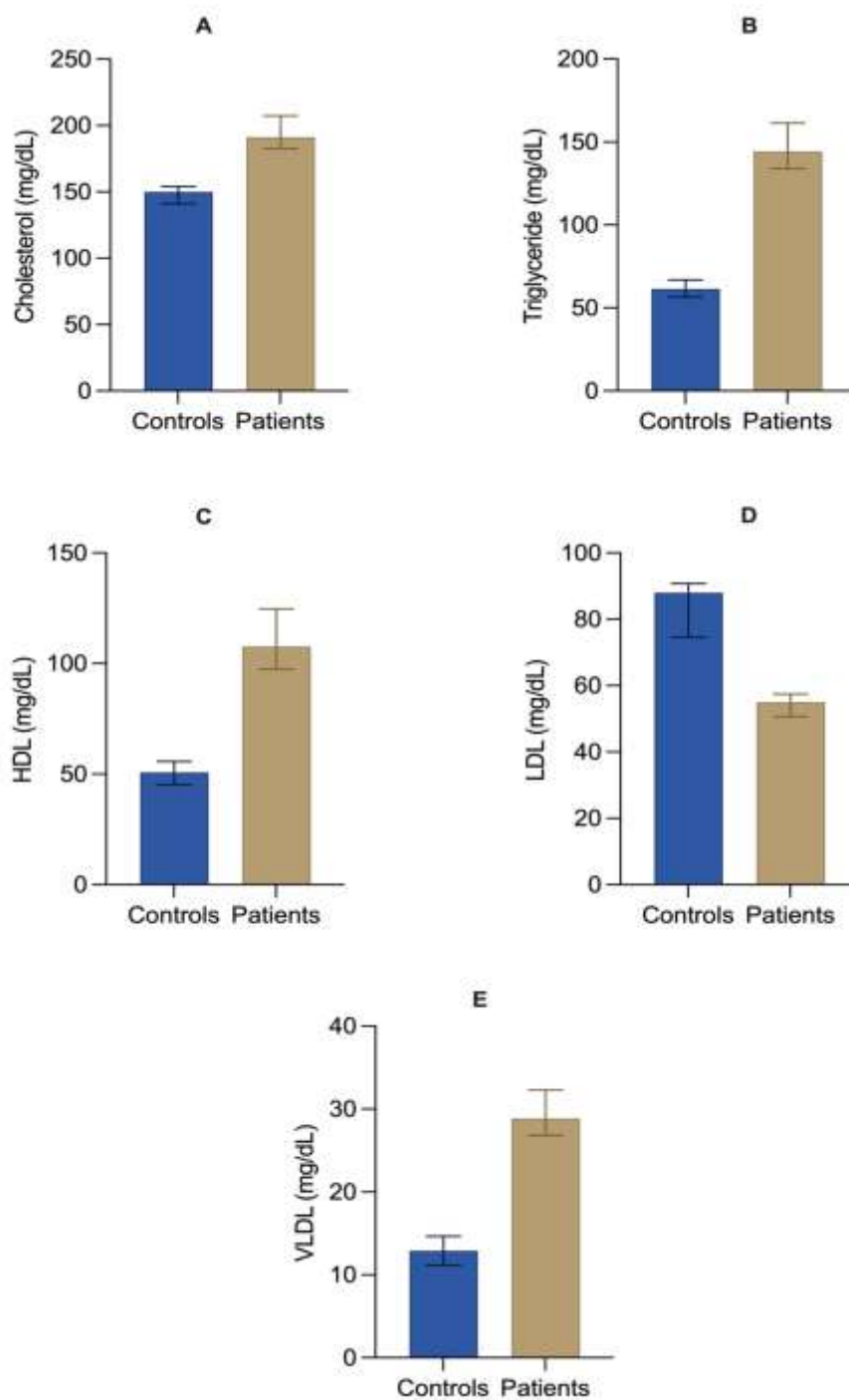


Figure 1. Lipid profile comparison between control and hyperthyroid groups. (A) Total cholesterol; (B) Triglyceride; (C) High-density lipoprotein (HDL); (D) Low-density lipoprotein (LDL); (E) Very low-density lipoprotein (VLDL).

Table 1. Comparison of demographic, hormonal, lipid, and cytokine variables between control and hyperthyroid participants. Data are presented as median [interquartile range]; statistical significance based on Mann-Whitney U test.

Characteristic	Control (n = 15)	Hyperthyroidism (n = 40)	P-value	Significance
Sex (M/F)	2/13	7/33	>0.9999	Ns
Age (years)	44 [35–56]	50 [32.25–60]	0.6564	Ns
BMI (kg/m ²)	26.26 [24.94–28.78]	27.53 [25.81–29.21]	0.468	Ns
TSH (μIU/mL)	2.18 [1.47–3.11]	0.05 [0.00525–0.05]	<0.0001	****
T3 (ng/mL)	1.24 [1.13–1.4]	2.5 [2–3.6]	<0.0001	****
T4 (μg/dL)	8.59 [7.17–10.36]	108 [19.82–160]	<0.0001	****
Cholesterol (mg/dL)	149.9 [141.1–154.1]	191.1 [182.6–207.4]	<0.0001	****
Triglyceride (mg/dL)	61.48 [56.64–66.89]	144.3 [134.1–161.5]	<0.0001	****
HDL (mg/dL)	50.7 [45.16–55.72]	107.6 [97.4–124.7]	<0.0001	****
LDL (mg/dL)	87.96 [74.54–90.78]	54.93 [50.72–57.48]	<0.0001	****
VLDL (mg/dL)	12.88 [11.14–14.67]	28.86 [26.83–32.29]	<0.0001	****
IL-6 (pg/mL)	8.027 [6.676–8.838]	38.7 [36.3–41.37]	<0.0001	****
TNF-α (pg/mL)	7.286 [6.333–9.19]	18.48 [17.29–20.02]	<0.0001	****

Spearman rank analysis showed a strong negative correlation between TSH and IL-6 ($r = -0.52$), TSH and TNF-alpha ($r = -0.72$), and confirmed the adverse relationship between the immunological reprimand of thyroid axis and the elevation of inflammatory cytokines (Figure 5). T3 and T4 were positively the ones that were correlated with all lipid parameters with the exception of LDL which was inversely correlated with both of them (T3: $r = -0.51$; T4: $r = -0.67$). On the same note, IL-6 and TNF- were found to be positively associated with cholesterol, TG, HDL, and VLDL, indicating that inflammatory condition in hyperthyroidism could be the cause or result of dyslipidemia. These results emphasize that a complex interaction of thyroid malfunction, inflammation, and lipid metabolism exists, and the combined importance of cardiovascular and immune measurements in hyperthyroid patients is mandatory.

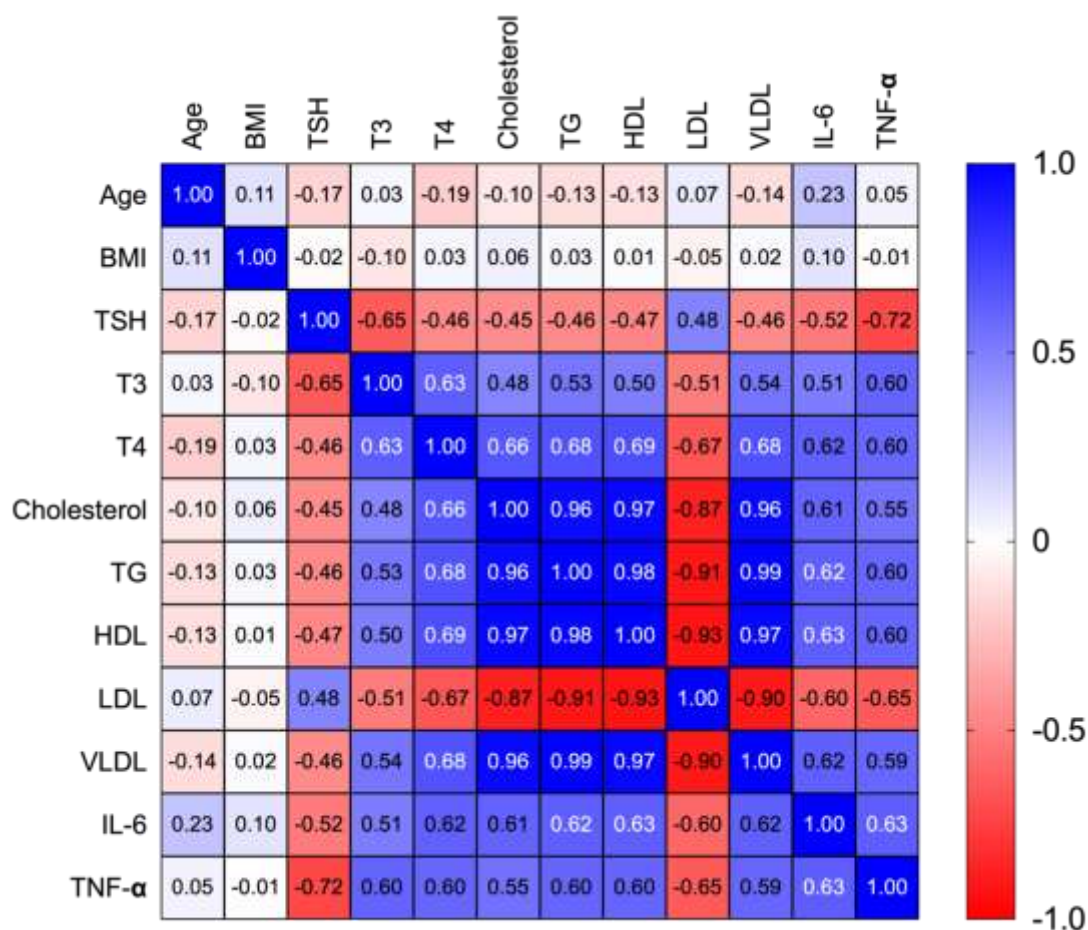


Figure 2. . Spearman correlation matrix depicting the strength and direction of associations among thyroid hormones, lipid parameters, and inflammatory markers across all participants ($n = 55$). Positive correlations are shown in blue, negative correlations in red. The intensity of the color represents the strength of the correlation (r value). Notably, T3 and T4 were positively correlated with inflammatory cytokines (IL-6, TNF- α), while TSH showed strong negative correlations with T3, T4, and inflammation-related markers.

All these findings highlight the importance of hyperthyroidism on the systemic level outside of the classical endocrine manifestations. The apparent changes in lipid profile and inflammatory cytokines indicate a wider pathophysiological imprint of metabolic and immune dysregulation. High levels of IL- 6 and TNF-a strengthen the hypothesis of chronic low-grade inflammation in the hyperthyroid condition, which may result in secondary cardiovascular or auto immunologic complications. Also, the fact that thyroid hormones, lipid fractions, and pro-inflammatory markers are significantly correlated with each other is evidence that endocrine, metabolic, and immune axis are interrelated. Though the study is cross-sectional and limits causal inference, these findings indicate the significance of lipid and inflammatory markers in identifying the management of hyperthyroid

patients in the clinical setting. Future longitudinal analyses that utilize cohorts of a larger size are also justified to further investigate these associations and determine their usability as prognostic or therapeutic biomarkers.

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CYBERSECURITY AWARENESS AMONG EDUCATORS AND STUDENTS IN VIRTUAL LEARNING ENVIRONMENTS

Muhammad Aanish

University of Management and Technology (UMT), Lahore, Pakistan

Field of Study: Information Technology

Email: f2022105077@umt.edu.pk ORCID: 0009-0005-5832-4088

Abdul Hannan

University of Management and Technology (UMT), Lahore, Pakistan

Field of Study: Information Technology

Email: f2022105094@umt.edu.pk ORCID: 0009-0000-2349-0659

Muhammad Subhan Tahir

University of Management and Technology (UMT), Lahore, Pakistan

Field of Study: Information Technology

Email: f2022105086@umt.edu.pk ORCID: 0009-0005-6291-9295

Abstract

The rapid expansion of virtual learning environments has transformed contemporary education by improving accessibility and flexibility for educators and students. However, this digital shift has also increased exposure to cybersecurity threats, largely due to insufficient cybersecurity awareness among users. Virtual classrooms rely heavily on learning management systems, cloud platforms, and videoconferencing tools, where insecure user behavior can lead to phishing attacks, unauthorized access, data breaches, and identity theft.

This study examines the level of cybersecurity awareness among educators and students in virtual learning environments and analyzes its relationship with safe online behavior. A quantitative approach was adopted using a descriptive and correlational research design. Data were collected through structured questionnaires to assess participants' awareness levels, common cybersecurity threats encountered, and perceptions of existing cybersecurity training and institutional guidelines.

The findings reveal noticeable gaps in cybersecurity awareness among both educators and students, with many participants engaging in risky online practices despite possessing basic knowledge of cyber threats. A positive relationship was identified between higher cybersecurity awareness and safer digital behavior. The results also indicate that existing cybersecurity training initiatives are often limited and insufficiently aligned with real-world threats faced in virtual classrooms.

The study highlights cybersecurity in virtual learning environments as a human-centered challenge and emphasizes the need for continuous awareness programs, practical training, and stronger institutional support to enhance digital safety.

Keywords: Cybersecurity Awareness, Virtual Learning Environments, Online Education, Safe Online Behavior

AI DRIVEN VIRTUAL TUTORS

Laiba Nasrullah (F2022105082), M Ahmad Naeem (F2022105081)

Department of Computer Science, University of Management and Technology (UMT), Lahore, Pakistan

Supervisor: Ms. Sidra Haron

Field of Study: Information Technology

E-mail: F2022105082@umt.edu.pk , F2022105081@umt.edu.pk

ORCID: 0009-0008-7214-8916, 0009-0007-4606-1246.

Abstract

The rapid expansion of digital education has exposed persistent limitations in traditional and online learning environments, including large class sizes, limited teacher availability, and insufficient personalization to meet diverse learner needs. Although conventional e-learning platforms offer flexibility, they often fail to provide adaptive instruction, real-time feedback, and sustained learner engagement. In response to these challenges, Artificial Intelligence (AI)-driven virtual tutors have emerged as a promising solution for delivering personalized, interactive, and adaptive learning experiences.

This study investigates the role and effectiveness of AI-driven virtual tutors in enhancing student engagement, academic performance, and learning accessibility. Using a mixed-methods research design, the study combines a quantitative comparative approach with qualitative exploratory methods. Learning outcomes of students using AI-driven virtual tutors are compared with those receiving traditional or non-AI instruction through pre- and post-assessments. Additionally, surveys, interviews, and focus groups are conducted to examine usability, user satisfaction, acceptance, and ethical concerns, including data privacy and algorithmic bias. The findings highlight the potential of AI-driven virtual tutors to address learning gaps by adapting to individual learning styles, providing immediate feedback, and supporting learners with varying paces and abilities. However, the study also identifies key challenges related to technical reliability, ethical safeguards, and effective integration into existing educational frameworks. Overall, the study concludes that AI-driven virtual tutors are most effective when used as a complement to human instruction, offering scalable and equitable learning support while preserving the critical role of educators.

Keywords: Artificial Intelligence, Virtual Tutors, Adaptive Learning, Educational Technology, Personalized Instruction

THE IMPACT OF ARTIFICIAL INTELLIGENCE ON HUMAN CREATIVITY AND ORIGINALITY

Izza Saleem

University of Management and Technology, Lahore

BSc Sociology

F2024127001@umt.edu.pk

ORCID: 0009-0000-3492-5421

Abstract

Due to the rapid rise of AI (Artificial Intelligence), it has transformed from a technical tool to a significant contributor towards creative production. Questions are raised about what its impact is upon the creativity and originality of humans. Since such systems are capable of the mass generation of images, texts, and designs which closely resemble human works, this leads to concerns about how this content influences the perceptions of originality and creative thought within individuals and whether it is viewed as a helpful tool or a replacement. A quantitative research design was used which consisted of an online survey distributed among university students, as they are frequent users of digital tools. The data was collected through Likert-scale statements in order to measure the behavior towards AI generated content and originality. From this study, the findings are expected to provide insight about how the role of AI systems is perceived among individuals, and how confidence in one's creative abilities is affected. The research makes a contribution towards ongoing discussions about the educational, ethical, and creative implications of AI in today's technologically advanced society.

Keywords: Artificial Intelligence, creativity, digital technologies

**NEVŞEHİR JANDARMA AT VE KÖPEK EĞİTİM MERKEZİ (JAKEM) AT VE KÖPEKLERİNDE
TOXOPLASMA GONDII'NİN ARAŞTIRILMASI**

Mustafa KARATEPE¹, Bilge KARATEPE², Şehriban Nur KANDEMİR³

**¹Prof. Dr. Niğde Ömer Halisdemir Üniversitesi, Fen Fakültesi, Biyoteknoloji Bölümü, Niğde/Türkiye,
mkaratepe@ohu.edu.tr, 0000-0002-2944-6837**

**²Prof. Dr. Niğde Ömer Halisdemir Üniversitesi, Fen Fakültesi, Biyoteknoloji Bölümü, Niğde/Türkiye,
bkaratepe@ohu.edu.tr, 0000-0001-5612-2697**

**⁴Niğde Ömer Halisdemir Üniversitesi, Fen Bilimleri Enstitüsü, Niğde/Türkiye, sehribannurr@gmail.com,
0000-0002-2868-8244**

Özet

Bu çalışma, Nevşehir Jandarma At ve Köpek Eğitim Merkezi (JAKEM)'nde bulunan at ve köpeklerde *Toxoplasma gondii* seroprevalansının belirlenmesi amacıyla yürütülmüştür. Araştırmanın materyalini farklı yaş, cinsiyet ve ırklardaki 57 at (14 dişi, 43 erkek) ile 256 köpek (139 dişi, 117 erkek) oluşturmuştur. Atlardan vena jugularis, köpeklerden vena cephalica antebrachii'den alınan kan örneklerinden elde edilen serumlar ELISA Test kiti (ID Screen® Toxoplasmosis Indirect Multi-species, ID.Vet, France) kullanılarak *T. gondii* antikorları yönünden incelenmiştir. ELISA testi ile 57 atın 10'unda (%17.5) ve 256 köpeğin 32'sinde (%12.5) *T. gondii* seropozitifliği tespit edilmiştir. Atlarda cinsiyet, yaş ve ırklar açısından seropozitiflik oranları arasında istatistiksel olarak anlamlı bir fark bulunmamıştır ($p>0.05$). Köpeklerde ise cinsiyete göre seropozitiflik açısından istatistiksel bir fark saptanmazken ($p>0.05$), yaş grupları ve kullanım amaçlarına göre seropozitiflik oranları istatistiksel olarak anlamlı bulunmuştur ($p<0.05$). Yavru köpeklerde seropozitiflik tespit edilmezken, özellikle damızlık köpeklerde yüksek oranda (%35.8) seropozitiflik belirlenmiştir. Köpek ırkları arasında ise seropozitiflik yönünden anlamlı bir fark bulunmamıştır ($p>0.05$). Sonuç olarak, JAKEM'de bulunan at ve köpeklerde *T. gondii* enfeksiyonunun varlığı ortaya konmuş, özellikle yetişkin ve damızlık köpeklerde enfeksiyon riskinin daha yüksek olduğu belirlenmiştir. Bu bulgular, toxoplasmosise karşı koruyucu önlemlerin alınması ve zoonotik risklerin azaltılması açısından önem taşımaktadır.

Anahtar kelimeler: At, köpek, *Toxoplasma gondii*, ELISA

INVESTIGATION OF *TOXOPLASMA GONDII* IN HORSES AND DOGS IN NEVŞEHİR
GENDARMERIE HORSE AND DOG TRAINING CENTER (JAKEM)

Mustafa KARATEPE¹, Bilge KARATEPE², Şhriban Nur KANDEMİR³

¹Prof. Dr. Niğde Ömer Halisdemir University, Faculty of Science, Biotechnology Department,
Niğde/Türkiye, mkaratepe@ohu.edu.tr, 0000-0002-2944-6837

²Prof. Dr. Niğde Ömer Halisdemir University, Faculty of Science, Biotechnology Department,
Niğde/Türkiye, bkaratepe@ohu.edu.tr, 0000-0001-5612-2697

³Niğde Ömer Halisdemir University, Graduate School of Natural and Applied Sciences, Biotechnology
Dept., Niğde/Türkiye, sehribannurr@gmail.com, 0000-0002-2868-8244

Abstract

This study was carried out to determine the seroprevalence of *Toxoplasma gondii* in horses and dogs in Nevşehir Gendarmerie Horse and Dog Training Center (JAKEM). The study material consisted of 57 horses (14 females, 43 males) and 256 dogs (139 females, 117 males) of different age, sex, and breed. Blood samples were collected from vena jugularis in horses and from vena cephalica antebrachii in dogs, and the obtained sera were examined for *T. gondii* antibodies by using an ELISA test kit (ID Screen® Toxoplasmosis Indirect Multi-species, ID.Vet, France). Seropositivity for *T. gondii* was detected in 10 of 57 horses (17.5%) and in 32 of 256 dogs (12.5%) by ELISA. In horses, no statistically significant differences in seropositivity rates were found with respect to sex, age, and breeds ($p>0.05$). In dogs, no statistically significant difference was observed according to sex ($p>0.05$); however, seropositivity rates differed significantly according to age groups and purpose of use ($p<0.05$). While no seropositivity was detected in puppy dogs, a high seropositivity rate (35.8%) was determined particularly in breeding dogs. No statistically significant difference in seropositivity was found among dog breeds ($p>0.05$). In conclusion, the presence of *T. gondii* infection in horses and dogs at JAKEM was demonstrated, and the risk of infection was found to be higher especially in adult and breeding dogs. These findings are important for implementing preventive measures against toxoplasmosis and reducing zoonotic risks.

Keywords: Horse, dog, *Toxoplasma gondii*, ELISA

1. GİRİŞ

Toxoplasma gondii, Apicomplexa köküne ait zorunlu hücre içi bir protozoondur ve tüm dünyada yaygın olarak görülen toxoplasmosise neden olmaktadır. Son konağı kedigiller olup, insanlar dahil tüm memeliler ve kuşlar ara konak olarak enfekte olabilmektedir. Enfeksiyon genellikle subklinik seyretmekle birlikte, özellikle immün sistemi baskılanmış bireylerde ve gebelerde ciddi klinik tablolara yol açabilmektedir (Dubey, 1994; Dubey & Beattie, 1988).

Atlarda toxoplasmosis çoğunlukla subklinik seyirli olup klinik tanı güçtür. Köpeklerde ise enfeksiyon asemptomatik olabileceği gibi solunum, gastrointestinal ve nörolojik sistem belirtileriyle seyreden ağır klinik formlar da görülebilmektedir (Dubey vd. 1999a, b; Babür vd., 2007a,b; Aktaş vd., 1998).

At ve köpekler son konak olmamakla birlikte, çevresel kontaminasyonun göstergesi olmaları ve insanlarla yakın temas halinde bulunmaları nedeniyle epidemiyolojik açıdan önem taşımaktadır. Bu çalışma, Nevşehir Jandarma At ve Köpek Eğitim Merkezi (JAKEM)'nde bulunan at ve köpeklerde *T. gondii* seroprevalansının belirlenmesi amacıyla gerçekleştirilmiştir.

2. YÖNTEM

2.1 Araştırma Materyali

Bu çalışma, resmi kurum ve etik kurul izinleri alındıktan sonra JAKEM'de bulunan çeşitli amaçlarla kullanılan görev köpekleri, yavru ve damızlık köpekler ile yerli ve yabancı safkan atlar üzerinde 2023 yılında yürütülmüştür. Bu çalışmanın materyalini farklı yaş ve ırklardaki 5-25 yaş arası 57 at (14 dişi, 43 erkek) ve 8 ay-5 yaş arası 256 köpek (139 dişi, 117 erkek) oluşturmuştur. JAKEM'de bulunan toplam 313 hayvandan tekniğine uygun olarak köpeklerde vena cephalica antebrachii'den, atlarda vena jugularis'ten steril vakumlu tüplere toplanan 5 ml kan örneklerine protokol numaraları verilerek kayıt altına alınmış ve soğuk zincirde laboratuvara getirilmiştir.

2.2 Laboratuvar Çalışması

At ve köpeklerden alınan kan numuneleri 3000rpm'de 10 dakika santrifüj edilerek serumlar elde edilmiş ve her bir hayvana ait serum 1.5ml'lik mikrotüplere konularak protokol numaraları verilmiştir. Kayıt altına alınan kan serumları mikrotüplerde ELISA testine tâbi tutuluncaya kadar -20°C'lik derin dondurucuda muhafaza altına alınmıştır.

2.2.1 Enzyme Linked Immunosorbent Assay Testi (ELISA)

Kan serumları Niğde Ömer Halisdemir Üniversitesi Fen Fakültesi, Biyoteknoloji Bölümü Laboratuvarında ELISA tekniği ile incelenmiş ve seroprevalans değerleri tespit edilmiştir.

ELISA testine başlanmadan önce serumlar, test solüsyonları ve mikropleytler (Antigen-Coated Plate) oda sıcaklığına çıkarılarak kullanıma hazır hale getirilmiştir. Toplanan kan numunelerinde *T. gondii* antikorlarının varlığının tespiti için *T. gondii* ELISA test kiti (ID Screen Toxoplasmosis Indirect Multi-species, ID.Vet, France) kullanılmıştır. Test işlemi kit prosedüründeki talimatlara göre yapılmıştır. Mikropleytler ELISA cihazında (MR-96A, mikropleyt okuyucu) 450 nm dalga boyunda okutulmuş ve test prosedüründe bildirilen formülle hesaplanması yapılmıştır.

2.3 İstatistiksel değerlendirmeler

Yapılan çalışmada, incelenen at ve köpeklerde *T. gondii* prevalansı ile yaş, cinsiyet ve ırkların istatistiksel olarak değerlendirilmesinde Ki-kare testi kullanılmıştır. Bu amaçla IBM SPSS Statistics 24.0 İstatistik Paket Programından yararlanılmıştır.

3. BULGULAR

Bu çalışmada Nevşehir Jandarma At ve Köpek Eğitim Merkezi (JAKEM)'nde muayene edilen 57 at ve 256 köpektan elde edilen kan serumları ELISA testi ile analiz edilerek 57 atın 10'unda (%17.5) ve 256 köpeğin 32'sinde (%12.5) *T. gondii* antikorları tespit edilmiştir.

Tablo 1. At ve köpeklerde *Toxoplasma gondii*'nin ELISA testi ile seropozitifliği

Hayvan türü	Muayene Edilen Hayvan Sayısı	Pozitif Hayvan Sayısı	(%)
At	57	10	17.5
Köpek	256	32	12.5

Cinsiyete göre 43 erkek atın 7'si (%16.2) ve 14 dişi atın 3'ü (%21.4) *T. gondii* yönünden pozitif bulunmuş olup istatistiksel bir fark belirlenmemiştir ($p=0.694$). Yaş grupları açısından ise, 5-10 yaş arasındaki 30 atta seropozitiflik oranı %10, 11-15 yaş arasındaki 17 atta seropozitiflik oranı %29.4 ve 16-25 yaş arasındaki 10 atta ise seropozitiflik oranı %20 olarak tespit edilmiştir. Buna göre, yaş grupları bakımından da seropozitiflik oranları arasında istatistiksel olarak fark bulunmamaktadır ($p=0.237$).

At ırkları açısından ELISA testi ile *T. gondii* seropozitifliği yerli safkan 20 atın 4'ünde %20 ve yabancı safkan 37 atın 6'sında %16.2 oranında belirlenmiş ve ırklar açısından *T. gondii* seropozitifliği önemsiz olarak bulunmuştur ($p=0.728$).

Köpeklerde cinsiyete göre, 117 erkek köpeğin 11'i (%9.4) ve 139 dişi köpeğin 21'i (%15.1) *T. gondii* yönünden pozitif bulunmuş olup istatistiksel bir fark belirlenmemiştir ($p=0.188$). Yaş grupları açısından ise, 8 ay-1 yaş arasındaki 126 köpekte seropozitiflik saptanamazken 3-5 yaş arasındaki 130 köpekte seropozitiflik oranı %24.6 olarak tespit edilmiş ve yaş grupları bakımından seropozitiflik oranları istatistiksel olarak önemli bulunmuştur ($p=0.000$).

Çalışmada çeşitli görevlerde kullanılan (bomba, mayın, iz takip vb.) 63 köpeğin 8'inde %12.6 oranında, damızlık olarak kullanılan 67 köpeğin 24'ünde %35.8 oranında *T. gondii* pozitifliği saptanırken 126 adet yavru köpeğin hiçbirinde pozitiflik belirlenmemiştir. Köpek grupları açısından seropozitiflik oranları istatistiksel olarak anlamlı bulunmuştur ($p=0.000$).

Köpek ırkları açısından; Belçika Malinois %11.2, Alman Çoban Köpeği %15.3, Labrador Retriever %13.1, Golden Retriever %33.3, Alman Pointer %9 oranında *T. gondii* seropozitifliği gösterirken incelenen 1 adet Tarsus Çatalburun köpeğinde seropozitiflik saptanamamıştır. Buna göre, köpek ırkları açısından seropozitiflik oranları arasında istatistiksel olarak anlamlı bir farklılık saptanamamıştır ($p=0.839$).

4. SONUÇ, TARTIŞMA VE ÖNERİLER

Toxoplasmosis, tüm dünyada insan ve hayvanlarda yaygın olarak görülen zoonotik enfeksiyonlardan biridir. Atlarda toxoplasmosis subklinik enfeksiyonlara neden olduğundan farklı coğrafi bölgelerde bulunan ülkelerde çeşitli serolojik yöntemler kullanılarak *T. gondii* antikorlarının varlığı bildirilmiştir. Hastalık köpeklerde de genellikle asemptomatik ve latent olarak seyrederek ve köpeklerde hiçbir klinik bulgu oluşturmayaabileceği gibi çok ağır sistemik belirtilere neden olarak ölüme de yol açabilir (Dubey, 1994; Dubey vd. 1999a, b).

Bu çalışmada Nevşehir Jandarma At ve Köpek Eğitim Merkezi (JAKEM)'nde bulunan at ve köpeklerde *T. gondii* seroprevalansı ELISA yöntemi ile araştırılmış; atlarda %17.5, köpeklerde ise %12.5 oranında seropozitiflik saptanmıştır. Elde edilen bulgular, hem Türkiye'de hem de dünyada farklı hayvan türlerinde bildirilen seroprevalans oranları ile karşılaştırıldığında, bölgesel ve çevresel faktörlerin toxoplasmosis epidemiyolojisinde önemli rol oynadığını göstermektedir.

Türkiye'de atlarda toxoplasmosisin seroprevalansı üzerine yapılan çalışmalardan; Weiland & Dalchow (1970) %13.3, İnci vd. (1996) %1.9, Babür vd. (1997) %8.33, Karatepe vd. (2010) Niğde'de %7.2 ve Erol vd. (2022) Nevşehir'de %8.57 oranında *T. gondii* seropozitifliği bildirmiştir. Buna karşılık Ankara yöresinde %36.9 (Gazyagcı vd., 2011) ve Muş yöresinde %42.77 (Sertel & Kırbaş 2022) gibi daha yüksek oranlar saptandığı belirtilmiştir. Bu çalışmada atlarda %17.5 olarak belirlenen seropozitiflik oranı ile daha önce yapılan çalışmalarda tespit edilen seropozitiflik oranları arasındaki farklılıklar; kullanılan serolojik yöntemin farklılığı (SFDT, ELISA, IFAT vb.), örnek sayısı, coğrafi ve iklimsel koşullar ile hayvanların barınma ve beslenme şartlarından kaynaklanabilmektedir. Bu araştırmada kontrollü bir ortamda yetiştirilen atlarda tespit edilen bu seropozitiflik oranı, su ve yem kaynaklarının ookistlerle kontamine olmuş olabileceğini akla getirmektedir.

Dünyada at toxoplasmosisi ile ilgili bildirilen oranlar incelendiğinde; İsveç'te %1 (Uggla vd., 1990), Güney Kore'de %2.6 (Gupta vd., 2002), Kuzey Amerika'da %6.9 (Dubey vd., 1999b), Çin'de %17.92 (Zhang vd.,

2018) ve Brezilya'da %27.36 (Munhoz vd., 2019) oranları rapor edilmiştir. Bu çalışmada elde edilen %17.5'lik oran, Çin'de bildirilen sonuçlara yakın olup birçok Avrupa ülkesinden daha yüksektir. Nevşehir'in karasal iklim özellikleri ve çevredeki kedi popülasyon düzeyi bu durumu etkileyen faktörler arasında değerlendirilebilir.

Atlarda cinsiyet, yaş ve ırk açısından seropozitiflik oranları arasında istatistiksel olarak anlamlı bir fark bulunmamıştır ($p>0.05$). Yapılan literatür taramasında da benzer şekilde cinsiyet ve ırkın genellikle risk faktörü oluşturmadığı bildirilmektedir. Yaş gruplarında 11-15 yaş aralığında daha yüksek oran görülmesine rağmen istatistiksel olarak anlamlı bulunmamıştır. Genel olarak yaş ilerledikçe maruziyet süresinin artması beklenmekle birlikte bu çalışmada anlamlı farkın oluşmaması, hayvanların kontrollü ve benzer bakım şartlarında tutulmaları ile açıklanabilir. Dişi atlarda seropozitifliğin (%21.4) erkek atlara nazaran (%16.2) nispeten yüksek bulunmasına rağmen cinsiyetler arasında istatistiki yönden bir fark belirlenmemiştir.

Köpeklerde belirlenen %12.5'lik seropozitiflik oranı, Türkiye'de bildirilen birçok çalışmadan oldukça düşük bulunmuştur. Babür vd. (2007b) Şanlıurfa'da köpeklerin 97.5'inde, Kırbaş vd. (2011) Nevşehir'de askeri köpeklerde %57.86, Karatepe & Karatepe (2024) Niğde'de %37.5, Altay vd. (2013) Sivas'ta %95.8, Alali vd. (2021) Konya yöresinde %98.5 oranında pozitiflik bildirmiştir. Bu çalışmada elde edilen daha düşük oran, JAKEM'deki köpeklerin düzenli veteriner kontrolü altında bulunması, kontrollü beslenmeleri ve çevresel hijyen koşullarının iyi olması ile açıklanabilir.

Dünya genelinde bildirilen oranlar incelendiğinde; Kore'de %12.8 (Nguyen vd., 2012), Çin'de %9.1 (Jiang vd., 2016), İtalya'da %24 (Machacova vd., 2016) ve Brezilya'da %16.3 (Benitez vd., 2017) oranları bildirilmiştir. Bu çalışmada elde edilen %12.5'lik oran bazı Kore, Çin ve Brezilya'da elde edilen sonuçlar ile benzerlik göstermektedir.

Köpeklerde cinsiyet açısından seropozitiflik oranları arasında istatistiksel olarak anlamlı bir fark bulunmamıştır ($p>0.05$). Bu durum literatür ile uyumludur ve enfeksiyonun cinsiyetten bağımsız olarak çevresel maruziyetle ilişkili olduğunu düşündürmektedir. Buna karşılık yaş grupları açısından istatistiksel olarak anlamlı fark saptanmış ($p<0.05$) olup yavru köpeklerde (8 ay-1 yaş) seropozitiflik görülmezken, 3-5 yaş grubunda %24.6 oranında pozitiflik belirlenmiştir. Bu durum, yaş ilerledikçe enfeksiyon etkeni ile karşılaşma olasılığının arttığını göstermektedir. Benzer şekilde birçok çalışmada da erişkin köpeklerde daha yüksek seroprevalans bildirilmektedir (Babür vd., 2007a; Doğan vd., 2014).

Köpeklerin kullanım amaçlarına göre değerlendirildiğinde, damızlık köpeklerde %35.8 gibi yüksek bir seropozitiflik oranı saptanmıştır. Bu oran, aktif görev köpeklerine (%12.6) göre belirgin derecede yüksektir ve istatistiksel olarak anlamlı bulunmuştur ($p<0.05$). Damızlık köpeklerin yaşça daha büyük olmaları ve daha uzun

süre çevresel maruziyete açık kalmaları bu sonucu açıklayabilir. Ayrıca damızlık hayvanlarda enfeksiyonun varlığı, olası vertikal bulaşma riski açısından da önem arz etmektedir.

Köpek ırkları bazında *T. gondii* seropozitifliği değerlendirildiğinde, Golden Retriever ve Alman Çoban Köpeklerinde seropozitiflik oranlarının daha yüksek bulunması, bu ırkların merkezdeki yaş dağılımı ve kullanım süreleri ile ilişkili olabilmekle birlikte köpek ırkları açısından istatistiksel olarak anlamlı bir farklılık saptanmamıştır ($p>0.05$).

Sonuç olarak bu çalışma, Nevşehir Jandarma At ve Köpek Eğitim Merkezi (JAKEM)'nde bulunan at ve köpeklerde *T. gondii* enfeksiyonunun varlığını ortaya koymuş; ELISA yöntemi ile atlarda %17.5, köpeklerde ise %12.5 oranında seropozitiflik saptanmıştır. Bu sonuçlar toxoplasmosis enfeksiyonunda at ve köpekler son konak olmasalar da, çevresel kontaminasyonun göstergesi olmaları açısından önem taşımaktadırlar. Özellikle köpeklerde yaş ve kullanım amacına bağlı farklılıkların belirlenmiş olması, enfeksiyonun çevresel maruziyet ile yakından ilişkili olduğunu göstermektedir. Elde edilen bulgular, kontrollü bakım ve beslenme koşullarına sahip hayvanlarda da *T. gondii* enfeksiyonunun bulunabileceğini ve çevresel faktörlerin enfeksiyonun ortaya çıkmasında önemli rol oynadığını göstermektedir. *Toxoplasma gondii* enfeksiyonunda sadece kedilerin son konak olduğu ve dışkıları ile *T. gondii* oositlerini çevreye yayarak otçullara ve insanlara bulaştırabileceği unutulmamalıdır. Bu nedenle yem ve su kaynaklarının ookist kontaminasyonundan korunması, barınak ve çevresinde kedi popülasyonunun kontrol altına alınması ve hayvanlara çiğ et verilmemesi önem taşımaktadır. At ve köpeklerin insanlarla aynı çevreyi paylaşmaları nedeniyle elde edilen bulgular, hem halk sağlığı hem de hayvan sağlığı açısından dikkate alınmalıdır. Bu bağlamda yem ve su hijyeninin sağlanması, kedi popülasyonunun kontrolü ve periyodik serolojik taramaların yapılması ile moleküler yöntemlerle desteklenen araştırmaların artırılması önerilmektedir.

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ISOLATION OF TOTAL MICROBIOTA FROM CONTAMINATED AND UNCONTAMINATED SOILS AND DETERMINATION OF BIOREMEDIATION POTENTIAL BY FTIR ANALYSIS

Assoc. Prof. Dr., Fadime ÖZDEMİR¹ / Undergraduate Student, Zeynep Naz KOÇAK²

¹ Bilecik Şeyh Edebali University, Faculty of Science, Department of Molecular Biology and Genetics, 11230, Bilecik, Turkey, Microbiology, fadime.ozdemir@bilecik.edu.tr, <https://orcid.org/0000-0002-8557-5166>

² Mimar Sinan Fine Arts University, Department of Architecture, Istanbul, 34854, Türkiye, architecture, zeynepnazkocak02012006@gmail.com, <https://orcid.org/0009-0008-1740-1309>

Abstract

Soil, which is one of the ecological units most affected by environmental pollution, has a natural capacity for self-renewal. However, today, pollution factors often exceed the soil's natural regenerative capacity, leading to soil contamination as a significant environmental problem. Bioremediation, which enables the removal of pollutants from soil, is an effective biotechnological approach that exploits the natural potential of microorganisms. In this study, total microbiota were isolated from soil contaminated with industrial waste and from uncontaminated soil collected at a distance of 200 m from the polluted area. Two formulations of liquid medium, prepared with and without antibiotics, were used, and the obtained microbial populations were applied for the remediation of contaminated soil. The organic matter content of the contaminated soil was determined using FTIR analysis, and pollutant profiles were compared with those of control samples. Peaks observed at the wavelength ranges of 2980–2840 cm⁻¹, 1633 cm⁻¹, 1594 cm⁻¹, 1313 cm⁻¹, 1237 cm⁻¹, 1025 cm⁻¹, 833 cm⁻¹, and 685 cm⁻¹ were evaluated. Notably, changes in organic pollutant groups were observed following the addition of the isolated microbiota to the environment. The results demonstrate that total microbiota cultures can be effectively utilized for waste remediation.

Keywords: Bioremediation, Soil Pollution, FTIR

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KİRLİ VE KİRLİ OLMAYAN TOPRAKLARDAN TOPLAM MİKROBİYOTA İZOLASYONU VE FTIR ANALİZİ İLE BİYOREMEDİASYON POTANSİYELİNİN BELİRLENMESİ

Assoc. Prof. Dr., Fadime ÖZDEMİR¹ / Undergraduate Student, Zeynep Naz KOÇAK²

¹ Bilecik Şeyh Edebali University, Faculty of Science, Department of Molecular Biology and Genetics, 11230, Bilecik, Turkey, Microbiology, fadime.ozdemir@bilecik.edu.tr, <https://orcid.org/0000-0002-8557-5166>

² Mimar Sinan Fine Arts University, Department of Architecture, Istanbul, 34854, Türkiye, architecture, zeynepnazkocak02012006@gmail.com, <https://orcid.org/0009-0008-1740-1309>

Özet

Çevresel kirlilikten en çok etkilenen ekolojik birimlerden biri olan toprak, doğal bir kendini yenileme kapasitesine sahiptir. Ancak günümüzde kirlilik faktörleri genellikle toprağın doğal yenilenme kapasitesini aşarak, toprak kirliliğini önemli bir çevre sorunu haline getirmektedir. Topraktan kirleticilerin uzaklaştırılmasını sağlayan biyoremediasyon, mikroorganizmaların doğal potansiyelini kullanan etkili bir biyoteknolojik yaklaşımdır. Bu çalışmada, endüstriyel atıklarla kirlenmiş topraktan ve kirlenmiş alandan 200 m uzaklıkta toplanan kirlenmemiş topraktan toplam mikrobiyota izole edilmiştir. Antibiyotikli ve antibiyotiksiz olmak üzere iki farklı sıvı ortam formülasyonu kullanılmış ve elde edilen mikrobiyal popülasyonlar kirlenmiş toprağın iyileştirilmesinde uygulanmıştır. Kirlenmiş toprağın organik madde içeriği FTIR analizi kullanılarak belirlenmiş ve kirletici profilleri kontrol örneklerinin profilleriyle karşılaştırılmıştır. 2980–2840 cm⁻¹, 1633 cm⁻¹, 1594 cm⁻¹, 1313 cm⁻¹, 1237 cm⁻¹, 1025 cm⁻¹, 833 cm⁻¹ ve 685 cm⁻¹ dalga boyu aralıklarında gözlemlenen pikler değerlendirildi. Özellikle, izole edilmiş mikrobiyotanın ortama eklenmesinin ardından organik kirletici gruplarında değişiklikler gözlemlendi. Sonuçlar, toplam mikrobiyota kültürlerinin atık arıtımında etkili bir şekilde kullanılabileceğini göstermektedir.

Anahtar kelimeler: Biyolojik iyileştirme, Toprak Kirliliği, FTIR

Q-FOLD THERMO-CORE: ENERJİ MATERYALLERİ İÇİN MİLİSANIYE HIZINDA TERMODİNAMİK KARARLILIK VE REAKTÖR GÜVENLİK ANALİZ MİMARISI

Dr. Öğr. Üyesi, Barış KURT¹

¹Muş Alparslan Üniversitesi, Teorik Kimya, b.kurt@alparslan.edu.tr, ORCID: 0000-0002-1406-0915

Özet

Kimyasal proseslerin güvenliği ve verimliliği, moleküler termodinamik parametrelerin (İç Enerji, Isı Kapasitesi) doğru tahminine bağlıdır. DFT gibi uzun süren hesaplamalar ise bu tahminleri hem zaman hem de para açısından oldukça maliyetli bir hale getirmektedir. Günümüzde yapay zeka sistemleri pek çok alanda kullanılmaya başlansa da henüz DFT tahminleri yapabilme konusunda yeterince uzmanlaşmadıkları ve bu alanda yaygınlaşmadıkları görülmektedir. Bu çalışmada, büyük miktarda moleküle ait kuantum kimyasal hesaplama sonuçları ile eğitilen ve Q-Fold hesaplamalı ekosisteminin termodinamik motorunu oluşturan " Q-Fold Thermo-Core" mimarisi tanıtılmaktadır. Geliştirilen bu yapay zeka çerçevesi (framework), hesaplama maliyeti son derece yüksek olan kuantum mekaniksel (CCSD(T)) analizleri bypass ederek, moleküler iç enerjiyi (u_0) $R^2=0.9902$ gibi endüstriyel standartların üzerinde bir doğrulukla ve oldukça hızlı bir şekilde tahmin etmektedir. Sistem, vektörel özellikler (dipol momenti) yerine skalar büyüklüklere (enerji ve ısı kapasitesi) odaklanan topoloji öncelikli bir yaklaşım benimseyerek, reaktör tasarımı ve malzeme kararlılığı analizlerinde 10^7 kat hızlanma sağlamıştır. Isı kapasitesi (C_v) $R^2=0.9633$ performansı ile kimyasal proses simülasyonları için mühendislik hassasiyetinde veri üretmektedir.

Anahtar kelimeler: Q-Fold Thermo-Core, yz termodinamik, enerji kararlılığı, proses güvenliği

Q-FOLD THERMO-CORE: MILLISECOND-SCALE THERMODYNAMIC STABILITY AND REACTOR SAFETY ANALYSIS ARCHITECTURE FOR ENERGY MATERIALS

Abstract

The safety and efficiency of chemical processes depend on the accurate prediction of molecular thermodynamic parameters (Internal Energy, Heat Capacity). However, computationally intensive calculations such as DFT make these predictions prohibitively expensive in terms of both time and cost. Although artificial intelligence systems are becoming prevalent in many fields, they have not yet sufficiently specialized in performing DFT predictions or achieved widespread adoption in this domain. In this study, we introduce the "Q-Fold Thermo-Core" architecture, which constitutes the thermodynamic engine of the Q-Fold computational ecosystem, trained on quantum chemical calculation results of large amount of molecules. This developed AI framework bypasses highly expensive quantum mechanical (CCSD(T)) analyses, predicting molecular internal energy (u_0) with a speed and accuracy exceeding industrial standards ($R^2=0.9902$). By adopting a topology-first approach that prioritizes scalar quantities (energy and heat capacity) over vector properties (dipole moment), the system achieves a 10^7 -fold acceleration in reactor design and material stability analyses. With a heat capacity (C_v) performance of $R^2=0.9633$, it generates data with engineering-grade precision for chemical process simulations.

Keywords: Q-Fold Thermo-Core, AI thermodynamics, energy stability, process safety

1. GİRİŞ VE ENDÜSTRİYEL HESAPLAMA ZORLUKLARI

1.1. Termodinamik Hesaplamalarda Ölçeklenebilirlik Sorunu

Yeni nesil enerji depolama materyalleri (lityum-iyon pil katotları) ve yüksek performanslı kimyasalların tasarımında en büyük darboğaz, termodinamik kararlılık analizlerinin hesaplama maliyetidir [1,2].

Geleneksel Yaklaşım ve Kısıtlar:

Bir molekülün termodinamik kararlılığını belirlemek için 'Gold Standard' olarak kabul edilen **Coupled Cluster (CCSD(T))** ve **buna eşdeğer doğruluk sağlayan yüksek seviyeli kompozit kuantum yöntemleri (G4MP2 vb.)** kullanılmaktadır [3,4,5]:

Tek bir molekül için 4-72 saat CPU zamanı gerektirir

Yüksek bellek (RAM) ve süper bilgisayar altyapısına ihtiyaç duyar

Geniş moleküler kütüphanelerin (>10.000 molekül) taranmasını maliyet ve zaman açısından imkansız kılar

Bu kısıtlar nedeniyle, endüstriyel Ar-Ge süreçleri genellikle sınırlı sayıda adayın incelendiği dar kapsamlı taramalara veya deneysel "deneme-yanılma" süreçlerine hapsolmaktadır .

Daha hızlı bir alternatif olan DFT (Density Functional Theory) bile, geniş moleküler kütüphanelerin taranması için yeterince verimli değildir [6]. Örneğin, bir molekülün standart yoğunluk fonksiyoneli seviyesinde optimizasyonu 2-8 saat sürebilmektedir.

1.2. Q-Fold Thermo-Core Yaklaşımı

Bu çalışmanın amacı, kuantum mekaniksel hassasiyeti korurken, hesaplama maliyetini minimize eden endüstriyel ölçeklenebilirliğe sahip bir tahmin mimarisi önermektir.

"Thermo-Core" Mimarisi:

Moleküler yapıları saniyeler içinde tarayarak, sentez öncesi "Enerji-Güvenlik" profilini çıkaran yüksek verimli (high-throughput) bir modüldür. Bu modülün bulut tabanlı (cloud-native) sistemlere entegre edilebilir yapı haline getirilmesi amaçlanmaktadır böylece kuruluma gerek kalmadan browser üzerinden çalışması herkese ulaşmasını sağlayacaktır.

Geleneksel Yüksek Doğruluklu Yöntem: 100 molekül $\times$ 24 saat Quantum DFT düzeyinde hesaplama = 2400 saat (Paralleleştirmede bile pek verimli olamamaktadır)

Thermo-Core- GPU Paralel (intel i7 13650HX (20 CPU)) işlemci ve GNvidia Gforce RTX 4060 ekran kartı ile
: 100 molekül $\times$ 50 ms = 5 saniye (paralleleştirmek mümkün)

2. MATERYAL VE METOT

2.1. Eğitim Verisi: Kuantum Doğruluğunda Kalibrasyon

Çalışmada, geniş kapsamlı bir kimyasal evren havuzundan türetilen **başlangıç havuzu**, yapısal tutarlılık testleri ve geometrik optimizasyon kararlılık kriterleri (post-screening validation) doğrultusunda filtrelemeye tabi tutulmuştur. Bu kalite kontrol süreci sonucunda, eğitim ve test aşamalarında kullanılmak üzere **geniş ölçekli, çok katmanlı kalite filtrelemesinden geçirilmiş, yüksek güvenilirlikli (high-fidelity)** veri seti oluşturulmuştur [7].

2.2. Hibrit Öznitelik Mimarisi: Stratejik Optimizasyon

Model, hız ve doğruluk arasındaki dengeyi optimize etmek için "Topolojik Öncelikli" (Topology-First) bir yaklaşım benimser.

Girdi Katmanı:

3D konformasyon analizi doğrudan alınmamış bunun yerine klasik bağ uzunlukları doğrudan kullanılmıştır bu aslında kuvvet alanı sabitlerinin moleküler dinamik simülasyon için kullanılmasına oldukça benzer bir ön hesaplama yöntemidir böylece hesaplama maliyeti çok daha düşük olan yapısal kodlama yaklaşımı benimsenmiştir [8]. Ek olarak, molekülün özelliğini belirleyen yapısal ve fizikokimyasal tanımlayıcılar kullanılmıştır. Enerji ve ısı kapasitesi gibi skalar özellikler, 2D yapısal veriden yüksek doğrulukla bile türetilbilirken ek olarak GAFF'daki kuvvet sabitleri ve uzunluklar da veri katmanına eklemiştir. Bu tercih, geometri optimizasyonu adımını QM düzeyinde ortadan kaldırarak maksimum tarama hızı (throughput) sağlar. Sonradan klasik nöral ağlar ile karar ağaçları tek tek denenmiş ve en uygun olanlar seçilerek pipeline oluşturulmuştur [9,10,11]. İlk veri ve tahmin katmanı birden fazla ağ ve oldukça yavaş bir süreç içerse de sonradan bunlar üzerinden yapılan eğitimler ile nihayet daha hızlı modeller elde edilmiştir. Son aşamada ise tüm süreç paralel işlem haline getirilmiş ve hızın maximuma geçmesi sağlanmıştır.

2.3. Algoritmik Motor

Tarafımızca geliştirilen ve optimize edilen özgün hibrit tahmin mimarisi (geometri tahmini → enerji tahmini → Cv tahmini) kullanılmıştır.

Model Eğitimi için öncelikle kuvvet sabiti ve bağ ile açılış uzunluklarına bağlı bir geometri tahmini geliştirilmiş ardından bu tahmin üzerinden oluşturulan kütüphane smiles olarak girilen moleküller için ön arama metodu olarak kullanılmıştır. Son aşamada ise önceki aşamalardaki tahminlerden yola çıkılarak oldukça hızlı bir karar ağacı yapılandırılmıştır.

2.4. Performans Değerlendirme Metrikleri

Model başarısı şu metriklerle ölçülmüştür:

R^2 (Determination Coefficient): Modelin açıklama gücü

RMSE (Root Mean Squared Error): Kimyasal doğruluk için kritik

MAE (Mean Absolute Error): Ortalama mutlak sapma

Pearson korelasyon katsayısı

Hesaplamalı termokimyada 'kimyasal doğruluk' (chemical accuracy) eşiği ~ 1 kcal/mol olarak tanımlanmıştır [12]; Bu durumda $\pm 2-3$ kcal/mol hata payı yaygın hata payının hız açısından getirdiği avantajları da göz önüne alarak kabul edilebilir seviyede olduğunu söylemek mümkün olacaktır.

3. MİMARİ PERFORMANS VE KABİLİYETLER

Sonuçlar, motorun skalar termodinamik özelliklerde (enerji ve ısı) kusursuz, vektörel özelliklerde (dipol) ise mimari tercih gereği seçici davrandığını göstermektedir.

3.1. Atomlaşma Enerjisi (u_0): Kararlılık Analizi

Bir molekülün termodinamik kaderini belirleyen iç enerji (u_0), motorumuz tarafından $R^2=0.9902$ kesinlikle tahmin edilmektedir.

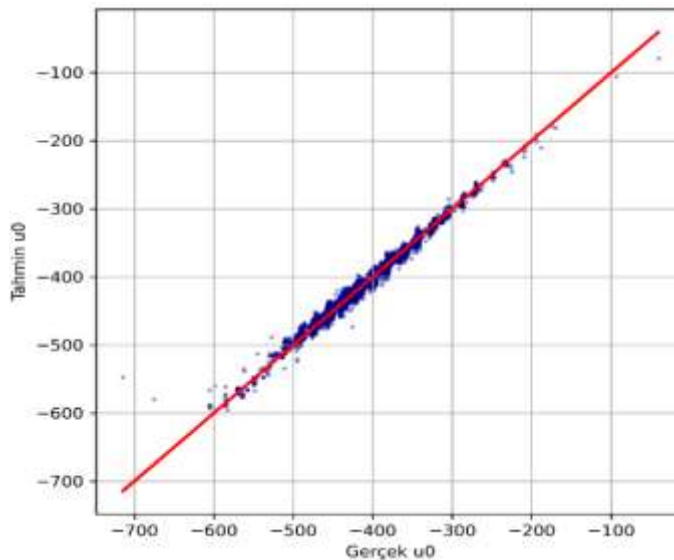
Performans Metrikleri:

R^2 Score: 0.9902

RMSE: 2.1 kcal/mol (Kimyasal doğruluk sınırları içinde)

MAE: 1.2 kcal/mol

Pearson r: 0.995



Şekil 1: Atomlaşma enerjisi (u_0) tahmin performansı. DFT referans değerleri (x eksen) ile Q-Fold ThermoCore tahminleri (y eksen) arasında $R^2=0.9902$ korelasyon elde edilmiştir. MAE=1.2 kcal/mol, RMSE=2.1

kcal/mol. Grafikte, -700'den -100'e (Hartree) kadar geniş bir enerji aralığında modelin tutarlı performansı görülmektedir.

Kimyasal Anlam:

Atomlaşma enerjisi, molekülün toplam bağ enerjilerinin bir ölçütüdür ve moleküler kararlılığın en temel göstergesidir [13]. Model, aşağıdaki fiziksel prensipleri başarıyla öğrenmiştir:

Karbon atom sayısı ile enerji arasında doğrusal ilişki (C-C bağ enerjisi ~83 kcal/mol)

Elektronegatif atomların (O, N) polar bağlar oluşturarak enerjiyi düşürmesi

Aromatik sistemlerde rezonans stabilizasyonu (~36 kcal/mol)

Bu bulgular, modelin sadece istatistiksel korelasyon değil, fiziksel yasaları da öğrendiğini göstermektedir [14].

Endüstriyel Anlamı:

Bu doğruluk seviyesi, binlerce aday molekül arasından sadece termodinamik olarak kararlı yapıların sentez hattına seçilmesine olanak tanır. Özellikle enerji depolama malzemeleri (pil elektrolitleri, katı hal iyonik iletkenleri) ve yüksek enerji yoğunluklu kimyasallar için kritik öneme sahiptir.

3.2. Isı Kapasitesi (Cv): Proses Güvenliği

Reaktör tasarımlarında ve ısı yönetimi (heat management) simülasyonlarında kritik olan ısı kapasitesi, $R^2=0.9633$ başarıyla modellenmiştir.

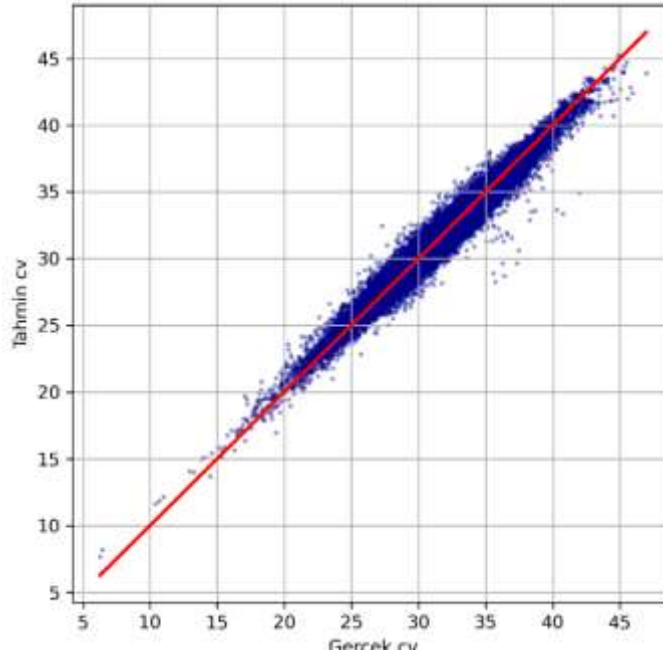
Performans Metrikleri:

R^2 Score: 0.9633

RMSE: 0.8 cal/mol·K

MAE: 0.5 cal/mol·K

Pearson r: 0.981



Şekil 2: Isı kapasitesi (C_v) regresyon grafiği. Tahmin edilen değerler ile DFT hesaplamaları arasında $R^2=0.9633$, $MAE=0.5$ cal/mol·K korelasyonu gözlemlenmiştir. Grafikte, moleküler ağırlık ve titreşim serbestlik dereceleri arttıkça C_v 'nin doğrusal olarak arttığı trend açıkça görülmektedir.

Termodinamik Anlam:

Isı kapasitesi, bir molekülün sıcaklık değişimine termal tepkisini tanımlar [15]. Bu parametre:

Kimyasal reaktör tasarımında reaksiyon ısısının hesaplanması

Faz diyagramlarında erime/kaynama noktası tahminleri

Enerji dengelerinde proses simülasyonları

için kritik öneme sahiptir.

Fiziksel Prensipten Öğrenme:

Model, klasik termodinamik ile uyumlu olarak şu ilişkileri kavramıştır:

Titreşim serbestlik dereceleri: Atom sayısı arttıkça C_v artar ($3N-6$ normal mod)

Moleküler ağırlık etkisi: Daha ağır moleküller daha fazla ısı absorbe eder

Yapısal rijitlik: Aromatik ve sıkı yapıli moleküller daha düşük C_v gösterir

Kullanılan veri setindeki C_v değerleri 6-50 cal/mol·K aralığındadır, bu da tipik organik moleküllerin termal davranışını kapsar [7].

3.3. Dipol Momenti ve Kademeli Mimari (Tiered Architecture)

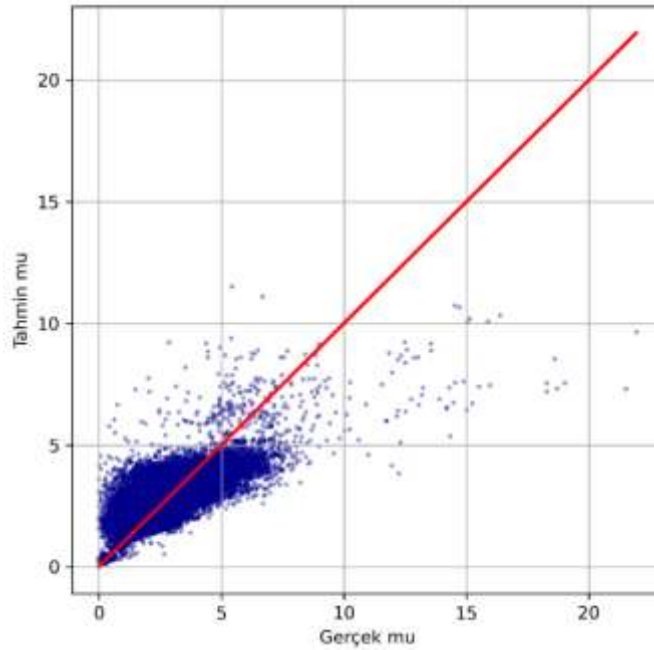
Dipol momenti tahminlerinde elde edilen skor ($R^2=0.6139$), mimarimizin bilinçli tasarım tercihini yansıtmaktadır.

Performans Metrikleri:

R^2 Score: 0.6139

RMSE: 1.1 Debye

MAE: 0.8 Debye



Şekil 3: Dipol momenti tahminlerinde saçılım (scatter) analizi. $R^2=0.6139$, MAE=0.8 Debye. Yüksek dipol momentli moleküllerdeki ($\mu > 3$ Debye) sapma, modelin topoloji öncelikli yaklaşımının bir sonucudur ve gelecek sürümler (3D geometri modülü) için bir gelişim alanını işaret eder.

Durum Analizi:

Dipol momenti, moleküldeki yük dağılımının asimetrisinin bir ölçüsüdür ve aşağıdaki faktörlere aşırı hassas bir şekilde bağlıdır:

3D Geometri: Polar bağların uzaysal düzenlenmesi

Konformasyonel Tercihler: cis-trans izomerliği, gauche vs anti rotamerler

Simetri: Moleküler simetri dipol momentini sınırlayabilir

Örneğin, 1,2-difloroetan molekülünde, anti konformerde $\mu \approx 0$ Debye iken, gauche konformerde $\mu \approx 2.5$ Debye'dir [16]. Kullanılan topoloji öncelikli gösterim, bu tür konformasyonel farklılıkları kodlayamadığından, model dipol momentini sistematik olarak eksik tahmin etmektedir.

Stratejik Tercih:

Mevcut "Thermo-Core" modülü, maksimum hız için topoloji öncelikli kapalı-devre mimari üzerinde çalışacak şekilde optimize edilmiştir. Bu yaklaşım:

Enerji ve ısı kapasitesi için $R^2 > 0.99$ doğruluk sağlar (skalar özellikler)

İşlem hızını ~1000x artırır (geometri optimizasyonu yok)

Termodinamik kararlılık ve reaktör güvenliği analizleri için yeterlidir

Gelecek Perspektifi (Roadmap):

Dipol momentleri gibi yüksek hassasiyetli 3D özellikler için, hesaplama maliyeti daha yüksek olan ileri düzey geometri modülü entegrasyonu planlanmıştır. Bu, sistemin "Hız Odaklı Core Modül" ve "Hassasiyet Odaklı İleri Modül" şeklinde kademeli bir yapıya (tiered architecture) evrilmesini sağlayacaktır.

Literatürde, geometri odaklı derin öğrenme mimarileri [17,18] ile dipol momentleri tahminlerinde $R^2 > 0.90$ performansı elde edildiği gösterilmiştir. Ancak bu modeller, molekül başına ~500 ms işlem süresi gerektirmektedir; bu da yüksek verimli tarama senaryoları için uygun değildir.

3.4. Karşılaştırmalı Performans Analizi

Q-Fold Thermo-Core'un performansı, literatürdeki benzer çalışmalarla karşılaştırıldığında:

Akademik Modeller:

Referans derin öğrenme mimarisi [17]: u_0 için $R^2 = 0.95$, ancak ~500 ms/molekül

ANI-1 [19]: u_0 için $R^2 = 0.97$, ancak sadece CHNO elementleri

Q-Fold Thermo-Core:

u_0 için $R^2 = 0.9902$

İşlem süresi: <50 ms/molekül

Cv için $R^2 = 0.9633$ (literatürde nadir raporlanır)

Avantaj, hem doğruluk hem de hız kombinasyonudur.

4. ENDÜSTRİYEL UYGULAMA SENARYOLARI (Öncül Molekül ve Monomer Ölçeği)

Q-Fold Thermo-Core, makro ölçekli polimerler veya devasa kompleksler yerine, bu yapıların temel yapıtaşları olan öncül moleküllerin (precursors) ve monomerlerin taranmasında stratejik bir karar destek sistemi olarak

çalışır. Aşağıda, sistemin makine öğrenmesi sınırları dahilinde endüstriye sunduğu çözümler örneklendirilmektedir.

4.1. Senaryo 1: Enerji Depolama (Yeni Nesil Elektrolit Çözücüler) Problem:

Lityum-iyon ve katı hal bataryalarında solvent (çözücü) veya katkı maddesi olarak kullanılmak üzere, yüksek elektrokimyasal kararlılığa sahip binlerce küçük organik aday molekülün termodinamik dayanımının taranması.

Geleneksel Yaklaşım: 5.000 farklı küçük aday molekül (karbonatlar, eterler vb.) için CCSD(T) veya yüksek seviyeli DFT analizi aylar süren ciddi bir CPU yükü gerektirir. **Q-Fold Thermo-Core Yaklaşımı:** Sistem, aday moleküllerin atomlaşma enerjilerini (u_0) molekül başına <50 ms hızla tarar. Toplamda sadece birkaç dakika süren bu işlem sayesinde, sentez aşamasına geçilmeden önce yalnızca termodinamik olarak en kararlı (u_0 değeri hedeflenen aralıkta olan) adaylar laboratuvar ortamına aktarılır. Bu, "fail-early, fail-cheap" prensibinin batarya Ar-Ge süreçlerine doğrudan entegrasyonudur.

4.2. Senaryo 2: Reaktör ve Proses Güvenliği (Monomer Isı Kapasitesi Tayini) Problem:

Yeni sentezlenecek bir monomerin veya ara ürünün, endüstriyel reaktörlerde polimerizasyona veya kompleks reaksiyonlara girmeden önce, ani ısı birikimi (runaway reaction) riskinin değerlendirilmesi.

Geleneksel Yaklaşım: Isı kapasitesi (C_v) ölçümleri DSC (Diferansiyel Tarama Kalorimetrisi) cihazlarıyla deneysel olarak veya kuantum mekaniksel simülasyonlarla haftalar süren bir ön hazırlık gerektirir.

Q-Fold Thermo-Core Yaklaşımı: Sisteme monomerin verisi girildiğinde, milisaniyeler içinde C_v tahmini üretilir. Kimya mühendisleri, $R^2=0.9633$ hassasiyetindeki bu veriyi kullanarak adyabatik sıcaklık artışını (ΔT_{ad}) simüle edebilir ve reaktör prototipi kurulmadan önce kritik soğutma (cooling) kapasitesini optimize edebilirler. Bu durum, proses güvenliğini sentez öncesi aşamada teminat altına alır.

5. SONUÇ

Bu çalışma, termodinamik hesaplama paradigmasını değiştirme potansiyeline sahip bir mimari sunmaktadır.

Ana Bulgular:

Atomlaşma enerjisi (u_0): $R^2=0.9902$, $RMSE=2.1$ kcal/mol → Kuantum mekaniksel hassasiyet

Isı kapasitesi (C_v): $R^2=0.9633$, $MAE=0.5$ cal/mol·K → Mühendislik hassasiyeti

İşlem hızı: 10^7 kat hızlanma (Geleneksel yüksek maliyetli yöntemlere göre)

Uygulanabilirlik: Endüstriyel ölçekte yüksek verimli tarama (High-Throughput Screening)

Mimari Tercihler:

Sistemin topoloji ve tahmin öncelikli mimarisi üzerinde çalışması, bilinçli bir hız-doğruluk optimizasyonudur. Skalar termodinamik özellikler için bu yaklaşım yeterli olurken, vektörel özellikler (dipol momenti) için gelecekte ileri düzey geometri modülü entegrasyonu planlanmaktadır.

Etki: Q-Fold Thermo-Core, kimyasal Ar-Ge süreçlerinde "Sentezle-Ölç" döngüsünü "Hesapla-Ele-Sentezle" döngüsüne dönüştürerek, "fail-early, fail-cheap" (erken ve düşük maliyetli eleme) prensibini hayata geçiren stratejik bir araçtır. Gelecek çalışmalarda, eğitim setinin S, P, Cl gibi heteroatomlarla genişletilmesi ve transfer learning teknikleri ile modelin farklı kimyasal uzaylara adaptasyonu planlanmaktadır.

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NANOSELÜLOZ DOLGULU POLİVİNİL ALKOL (PVA) KOMPOZİT FİLM SENTEZİ VE KARAKTERİZASYONU

Sinem VURAL¹/ Prof. Dr. Mehmet KALENDER²

¹Fırat Üniversitesi Fen Bilimleri Enstitüsü Biyomühendislik Anabilim Dalı, Elazığ / Türkiye, Endüstriyel Biyoteknoloji, sinemsaydam23@gmail.com, 0009-0008-5663-4631

²Fırat Üniversitesi Mühendislik Fakültesi Biyomühendislik Bölümü, Elazığ / Türkiye, Endüstriyel Biyoteknoloji, mkalender@firat.edu.tr, 0000-0002-8932-8840

Özet

Dünya karbon salınımlarında kontrol kriterleri günden güne zorlaştırılmaktadır. Gaz akımlarında bulunan kirleticilerin uzaklaştırılmasında düşük enerji tüketimi, yüksek seçicilik, modüler yapı ve sürekli işletme imkanı gibi pek çok avantaj nedeniyle membran teknolojisi öne çıkmaktadır. Fakat, bu amaçla kullanılan membranlar genellikle biyobozunur olmayan petrol türevi materyallerden üretilmektedir. PVA, PLA ve PHA gibi biyobozunur membranların bazı özellikleri ise gaz geçirgenlik uygulamalarında birtakım dezavantajlara yol açmaktadır. Düşük geçirgenlik, mekanik dayanım, termal ve kimyasal stabilite ve seçicilikte yetersizlikler bazı gaz ayırma proseslerinde olumsuzluklar oluşturabilmektedir. Bu dezavantajları iyileştirmek için alternatiflerden biri nanoselüloz gibi dolgu ilaveleriyle polimerik kompozit film sentezlemektir. Bu çalışmada, PVA'ya nanoselüloz ilave ederek bu tür bir kompozit film sentezlenmesi amaçlanmıştır. Nanoselüloz mikrokristalin selülozun hidroliziyle elde edilmiştir. Üretilen nanoselülozun FTIR ve partikül boyut dağılımı analizleri yapılmıştır. FTIR spektrumlarında tipik selüloz pikleri görülmüştür. Asit hidrolizi sonucu elde edilen son ürün materyalin ortalama 386.6 nm boyutunda olduğu saptanmıştır. Dolgulu polimer film kompozit materyalin SEM görüntülerden, yapıda nanoselüloz varlığı açıkça gözlenmiştir.

Anahtar kelimeler: Nanoselüloz, dolgulu PVA, kompozit film

SYNTHESIS AND CHARACTERIZATION OF NANOCELLULOSE-FILLED POLYVINYL ALCOHOL (PVA) COMPOSITE FILM

Abstract

The control criteria for global carbon emissions are progressively becoming more stringent. Membrane technology is coming forefront in removal of hazards in the gas streams because of numerous advantages, such as low energy consumption, high selectivity, modular design, and the possibility of continuous operation. However, the membranes used for this purpose are generally produced from petroleum derived-materials. Certain properties of biodegradable membranes such as PVA, PLA, and PHA lead to some disadvantages in gas permeability applications. Insufficient permeability, mechanical strength, thermal and chemical stability, and selectivity may result in limitations in some gas separation processes. An alternative approach to overcome these disadvantages is the synthesis of nanocellulose-filled composite polymer films. In this study, the aim was to synthesize such a composite film by incorporating nanocellulose into PVA. Nanocellulose has been obtained by hydrolysing the microcrystalline cellulose with acid. FTIR analysis and particle size distribution of the produced nanocellulose samples were carried out. The results of FTIR analyses showed that cellulose peaks were present in the structure of the synthesized nanocrystalline cellulose. The final product obtained by acid hydrolysis was found to have an average size of 386.6 nm. SEM images of the nanocellulose-filled polymer composite film clearly revealed the presence of nanocellulose in the structure.

Keywords: Nanocellulose, filled PVA, composite film

1. GİRİŞ

1990'lı yıllardan bu yana iklim değişikliği ile mücadelede sera gazı emisyonlarının azaltılması, yenilenebilir enerji kaynaklarının araştırılması/kullanılması gibi çeşitli önleme faaliyetleri gerçekleştirilmektedir. Birçok dünya ülkesi tarafından kabul edilen çeşitli protokollere benzer bir uygulamanın son örneklerinden bir tanesi Avrupa Yeşil Mutabakatı adı altında yayınlanmıştır. Bu mutabakata göre 2050 yılına kadar sera gazı salınımının net olarak sıfıra indirgenmesi hedeflenmektedir ("A European Green Deal" 2019-2024). Sera gazları denildiğinde ilk akla gelen karbondioksittir. Global karbondioksit seviyeleri endişe verici boyutlara ulaşmıştır. Çevrede yol açılan olumsuzluklar direkt ya da indirekt olarak insan yaşamını da tehdit etmektedir (Gong ve ark., 2017; Ma ve ark., 2018). Küreselleşme ile birlikte, insan kaynaklı CO₂ salınımının yılda yaklaşık 40 milyar ton olduğu rapor edilmiştir (Kupgan ve ark., 2018).

CO₂ uzaklaştırmada şimdiye kadar birçok teknik geliştirilmiştir: absorpsiyon, adsorpsiyon (fiziksel ya da kimyasal), kriyojenik distilasyon, membran ayırma teknolojisi (Gong ve ark., 2017; Sepahvand ve ark., 2020). Absorpsiyonla CO₂ uzaklaştırma tekniği halihazırda da oldukça yaygın kullanılan bir teknolojidir. Fakat bu teknik büyük boyutlu ekipmanlar gerektirmesi, çözücü rejenerasyonunda yüksek maliyet, yüksek su içeriğinde ayırmada güçlükler gibi dezavantajlara sahiptir. Adsorpsiyon ile CO₂ uzaklaştırmada rejenerasyon ve adsorbent kirlenmesi en çok karşılaşılan zorluklardır. Kriyojenik CO₂ uzaklaştırma yavaş, pahalı ve düşük konsantrasyonlar için fizibil olmayan bir tekniktir. (Kupgan ve ark., 2018). Son zamanlarda, CO₂ uzaklaştırılması için membran temelli ayırma üzerine çalışmalar artarak devam etmektedir (Kupgan ve ark., 2018; Ma ve ark., 2018). CO₂ uzaklaştırmada membran ayırma teknolojileri, yüksek seçicilikleri ve çevre dostu işlem özellikleri sayesinde geleneksel uzaklaştırma tekniklerine kıyasla önemli üstünlükler sunmaktadır.

Membran gaz ayırma işlemleri birçok büyük ölçek gaz ayırma işlemlerinde yaygın olarak kullanılmaktadır. Gaz ayırıcı membranlar inorganik, organik ve hibrit olmak üzere üç kategoride incelenebilir. İnorganik membranlar hafif ve kompakt boyutlarda olmaları ve daha az enerji tüketmeleri nedeniyle avantajlıdır, ancak bu membranların endüstriyel ölçekte uygulanmasında düşük mekanik direnç, orta derecede tekrarlanabilir üretim, yüksek imalat maliyeti, ölçek büyütme sorunları ve biyobozunurluk gibi birçok dezavantaj taşımaktadır (Gul ve ark., 2023). Bu araştırmacıların gaz ayırma işlemleri için organik polimerik membranlara yönelmesine yol açmıştır. Polimerik membranlarda gaz ayırma mekanizması genelde çözünme-difüzyon mekanizması şeklindedir. Bu tür membranlara yoğun membranlar adı da verilir. Yoğun membranlarda gaz taşınımı gazın membran yüzeyinde adsorplanması ve asorplanan gazın polimer arasında etkileşimler nedeniyle membranda çözünmesi suretiyle gerçekleştir (Seader ve ark., 2006).

Polisülfon, selüloz asetat, poliimid/poliaramid, polikarbonat ve polifenil oksit gibi membran materyalleri endüstriyel olarak yaygın kullanım alanına sahiptir. Bu materyaller çoğunlukla oyuk fiber ve spiral sargı modül tipleriyle işletilmektedir. Kirletici uzaklaştırmada kullanılan polimerik materyalin bertaraf edilmesi sırasında çevresel problemlerle karşılaşılması son derece istenmeyen bir durumdur. Bu nedenle, polimer membranların biyobozunur özellikte olması önemlidir (Seader ve ark., 2006; Seidi ve ark., 2022; Syrtsova ve ark., 2019). Biyobozunur polimerler, ISO standartlarına göre, belirli çevresel koşullar altında kimyasal yapısında önemli değişiklikler geçirerek, sınıflandırmasını belirleyen süre içinde plastik özelliklerinin bazılarını kaybedebilen ve bu kayıp, uygulamaya uygun standart test yöntemleriyle ölçülebilen plastikler olarak tanımlanır. Başka bir tanıma göre, biyobozunurluk; bakteri, mantar, maya ve bu mikroorganizmaların enzimlerinin bir maddeyi besin kaynağı olarak kullanarak, maddenin orijinal formunun yok olmasına yol açtığı bir süreçtir (Chandra & Rustgi, 1998). Doğal olarak oluşan veya biyolojik kaynaklardan elde edilen polimerler biyopolimer olarak adlandırılır. Doğal biyobozunur polimerler, polisakkaritler (nişasta, selüloz, kitin, kitosan, aljinik asit), doğal polipeptitler (ör. jelatin) ve bakteriyel poliestерleri (PHA) içerir. Hidrolize uğrayabilen sentetik polimerler ise biyobozunur özelliğe sahip ester veya amid bağları içeren polimerlerdir; bunlara polikaprolakton (PCL), poliamidler, poliüretanlar, polianhidritler ve poli(amid-enamin)ler örnek olarak verilebilir. Polivinil alkol (PVA) ve poli(vinil asetat) ile poliakrilatlar karbon zincirli polimer sınıfındadırlar (Chandra & Rustgi, 1998; Gul ve ark., 2023).

PVA, PCL vb. gibi polimerik membranların gaz geçirgenliği gazın membrandaki çözünürlüğü, membranın polimer zincir yapısı, kristalinite derecesi ve dolgu malzemelerine bağlıdır. Selüloz nanokristallerinin (CNC'ler), takviyeli biyobazlı nanomalzemelerin hazırlanmasında önemli bir yer tuttuğu yapılan çalışmalarla gösterilmiştir (Follain ve ark., 2018). Bu çalışmada, çeşitli gazların geçirgenliğini araştırmak üzere nanoselüluloz dolgulu PVA film membranlarının sentezlenmesi ve üretilen kompozit materyalin bazı karakteristik özellikleri belirlenmiştir.

1.1. Kuramsal Çerçeve

Hauenstein ve ark. (2017) yapmış oldukları bir çalışmada, CO₂ ve N₂ ayırımı için biyobazlı poli(limonen karbonat) sentezlenmiştir. 30 °C'de 68 barrer CO₂ ve N₂ geçirgenliğinin elde edildiği bu çalışmada, sentelenen materyalde çalışılan gaz çiftine ait seçicilik parametresi yaklaşık 19 olarak hesaplanmıştır. Yapılan bir derleme çalışmada, çeşitli membranlarda bazı inorganik ve organik gazların filtrelenmelerini özetlemişlerdir (Lippi ve ark., 2022). Selüloz ve selüloz asetat gibi selüloz bazlı materyallerin filtre ortamı olarak kullanıldığı bazı çalışmalarda O₂, N₂, CO₂, H₂, formaldehit ve tolüen filtrasyonu için bilgiler sunulmuştur. CO₂/CH₄ ayırımı için

selüloz asetatın sorpsiyon, difüzyon ve plastikleşme özelliklerini incelendiği bir çalışmada, selüloz asetatın özellikle gaz karışımlarının ayrılmasında kıyas edildiği malzemelere göre daha üstün özelliklere sahip olduğu tespit edilmiştir (Genduso & Pinnau, 2020). Yapılan bir başka çalışmada, organik nanodolgu materyali olarak selüloz nanokristalin kullanılarak saydam polikarbonat filmler sentezlenmiştir (Xu ve ark., 2013). Polikarbonat matriksine % 0, 2, 3, 5, 8 ve 10 oranlarında ilave edilen NKS-kompozit materyallerden en iyi mekanik dayanım özelliğine %3 katkı oranında ulaşıldığı sonucu elde edilmiştir. Follain ve ark. (2018) ağırlıkça %12 selüloz nanokristalin dolgulu PCL dolgulu kompozit malzeme sentezlemiş ve çeşitli gazların geçirgenlik ve seçiciliğini incelemişlerdir. Yapılan bu çalışma sonucunda 106 barrer CO₂, 94 barrer oksijen ve 30 barrer azot geçirgenlik değerlerine ulaşılabilmektedir.

2. YÖNTEM

2.1. Nanoboyutlu Selüloz Sentez Çalışmaları

Nanoboyutlu selüloz (NS) mikrokristalin selülozun (MKS, ALFAOL E460) asit hidrolizi ile üretilmiştir. Bu amaçla Vasconcelos ve ark. (2017)'nin metodu kullanılmıştır: %4 MKS/asit (w/v) oranında karışım hazırlanarak bir beher içerisinde manyetik karıştırıcıda karıştırılarak çözündürme işlemi gerçekleştirilmiştir. Hidroliz çalışmalarında % 65 'lik H₂SO₄ (Merck, analitik saflıkta) kullanılmıştır. Karıştırma işlemi 45°C sıcaklıkta ve 500 rpm'de 40 dakika boyunca yürütülmüştür. Bu süre sonunda hidroliz, toplam hacminin 15 katı deiyonize su eklenerek sonlandırılmıştır. Son karışım oda sıcaklığında 1 gün boyunca bekletilmiştir. NS partiküller 13000 rpm'de santrifüjlenmek suretiyle daha küçük hacimlerde toplanmıştır. Son aşamada asidik karışımın pH'ı diyaliz yöntemiyle (Sigma-Aldrich, diyaliz torbası) deiyonize su kullanarak nötral pH'ya ayarlanmıştır.

2.2. Kompozit Film Döküm Deneyleri

Polimer döküm deneyleri Sigma-Aldrich 363146 PVA (M_w 85.000-124.000, %99 hidrolize) ile gerçekleştirilmiştir. Ağırlıkça %5 olacak şekilde tartılan PVA deiyonize suda 85 °C'de manyetik karıştırıcı kullanılarak ortalama 40 dakika boyunca homojen bir çözelti elde edilinceye kadar çözündürülmüştür. Hazırlanan çözelti cam matrikste hazırlanan kalıplarda dökülmüştür. Çözündürülen PVA kütlesinin ağırlıkça 0 (saf PVA), %2 ve %4'üne tekabül eden NS kütlesi manyetik karıştırıcıda karıştırma aşamasında çözeltiye ilave edilmiştir. Bu ilavede daha önce MKS den hidrolizle elde edilen NS çözeltisindeki katı madde miktarı dikkate alınarak yapılan hesaplama sonucu gerçekleştirilmiştir.

2.3. Karakterizasyon Deneyleri

2.3.1. FTIR Deneyleri

MKS ve hidroliz edilen nanoselüloz örneklerinin FTIR analizleri ShimadzuIR Spirit Spectrophotometer QATR-S cihazında gerçekleştirilmiştir.

2.3.2. NS Konsantrasyon Belirleme Deneyleri

Üretilen son karışımda NS konsantrasyonunu belirlemek için, karışımdan alınan belirli hacim örnek Shimadzu MOC63u marka nem tayin cihazında kurutulmuştur. Kurutma sonucu kütlesi ölçülen NS katı miktarından faydalanarak w/v katı konsantrasyonu belirlenmiştir.

2.3.3. Tane Boyutu Belirleme Deneyleri

MKS örneklerinin tane boyutu Hitachi SU3500 marka Taramalı Elektron Mikroskop (SEM) cihazıyla ölçülmüştür. Üretilen NS örneklerinin tane boyutunu ölçmek için nötral pH'daki son karışım bir ultrasonik banyoda (Medisson marka) 60 kHz, 300 W ve 3 dk dakika boyunca ultrasonik etkiye tabi tutulmuştur. Tane boyutu Malvern Panalytical Zetasizer (MAL1305718) cihazında ölçülmüştür.

2.3.4. Kompozit Filmlerin SEM Görüntüleri

NS dolgulu PVA filmlerin SEM görüntüleri Zeiss-EVO MA10 cihazı ile alınmıştır.

2.3.5. Film Kalınlığı Belirleme Deneyleri

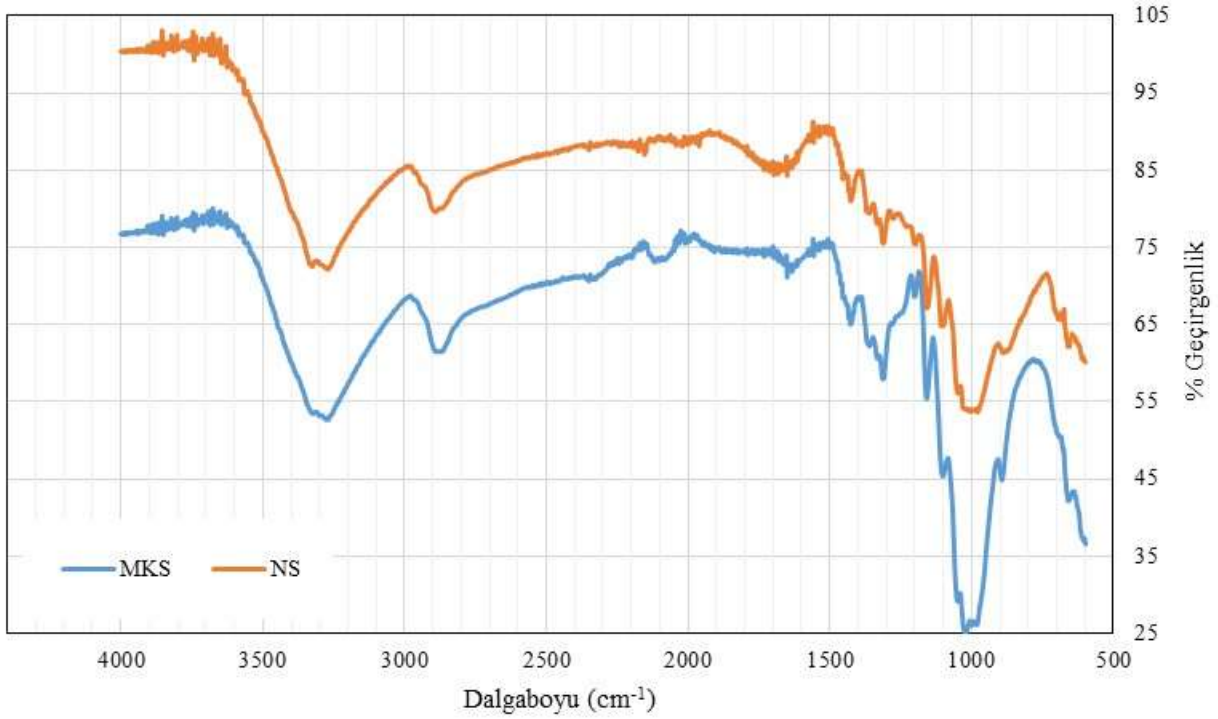
Bu çalışmada üretilen NS dolgulu PVA kompozit film malzemelerinin kalınlıkları, sentezlenen filmlerin renklendirilmiş epoksi reçine içerisine gömülmesiyle elde edilen ince tabletlerin Olympus CX21 inoküler ışık mikroskopunda ölçülmesiyle belirlenmiştir. Ölçümler oküler mikrometre ile 10'luk ve 40'luk objektif büyütmelelerinde yapılmıştır.

2.3.6. Çekme Deneyleri

Sentezlenen dolgusuz, %2 ve %4 NS dolgulu filmlerin çekme deneyleri 1 kN kapasiteli universal bir çekme test cihazı (UTEST, Ankara, Türkiye) ile 20 mm/dakika hızda gerçekleştirilmiştir. Numuneler ASTM D638M-91a standardına göre hazırlanmıştır.

3. BULGULAR

Bu çalışmada kullanılan MKS ve hidroliz sonucu üretilen nanoselüloz örneklerinin FTIR analizleri sonucu elde edilen spektrumlar Şekil 1'de gösterilmiştir.



Şekil 1. MKS ve ondan asit hidroliziyle elde edilen NS örneklerine ait FTIR spektrumları

Şekil 1’den görüldüğü gibi 1055, 1367, 1430, 1640, 2800-300 ve 3100-3600 cm^{-1} dalga boylarında selüloza ait tipik FTIR spektrumları elde edilmiştir. Bu sonuçlar literatürle oldukça uyumludur (Öz & Kalender, 2023). Elde edilen spektrumların hangi fonksiyonel gruplara karşılık geldiği ve ilgili referanslar Tablo 1’de verilmiştir.

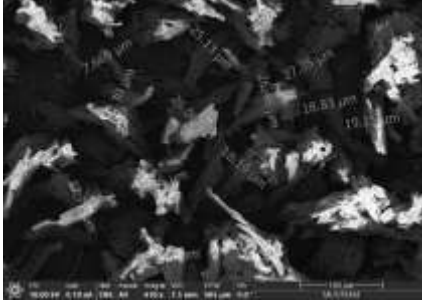
Tablo 1. FTIR spektrumlarında dalga boyuna karşılık gelen fonksiyonel gruplar

Dalgaboyu (cm^{-1})	Fonksiyonel grup	Referans
3600-3100	O–H gruplarının gerilme titreşimleri	(Wang ve ark., 2019; Yin ve ark., 2020)
3000-2800	Alifatik hidrokarbonlara ait CH_2 ve CH_3 gruplarının simetrik ve asimetrik C–H gerilme titreşimleri	(Salari ve ark., 2019)
1640 ve 1055	Adsorbe suyun bükülme titreşimine (H–O–H) ait pikler	(Ashori ve ark., 2012)
1430	CH_2 bükülme titreşimlerine	(Akintunde ve ark., 2022; Salari ve ark., 2019)
1367	Simetrik bükülme veya yüzey karboksilat grupları, CH_2 sallanma (wagging), C–O–C (eter) fonksiyonel grupları ve C–OH (alkol) gerilme titreşimleri	(Ashori ve ark., 2012)

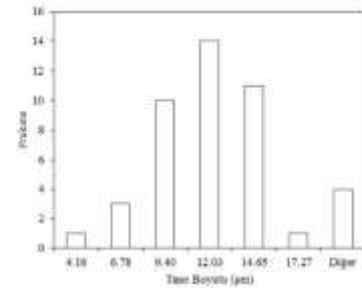
MKS nin asit hidrolizi sonucu üretilen NS hidrolizatındaki katı konsntrasyonu nem tayin cihazında 105 $^{\circ}\text{C}$ ’de kurutma yöntemiyle belirlenmiştir. Sonuç olarak ağırlıkça %98.8 nem içeriğine sahip hidrolizart üretilmiş ve

+4°C'deki buzdolabında muhafaza edilmiştir. Polimer dökümünde ilave yüzdesine göre NS katı miktarına eşdeğer hidrolizat hacmi bu karışımdan sağlanmıştır.

Çalışmalarda kullanılan MKS örneğinin tane boyutu SEM analizi ile belirlenmiştir. Katı numunenin SEM görüntüleri ve bu görüntüden elde edilen histogram grafik Şekil 2'de gösterilmiştir.



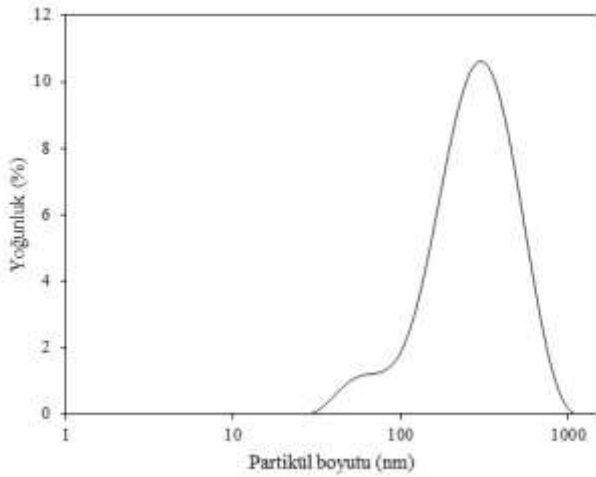
(a)



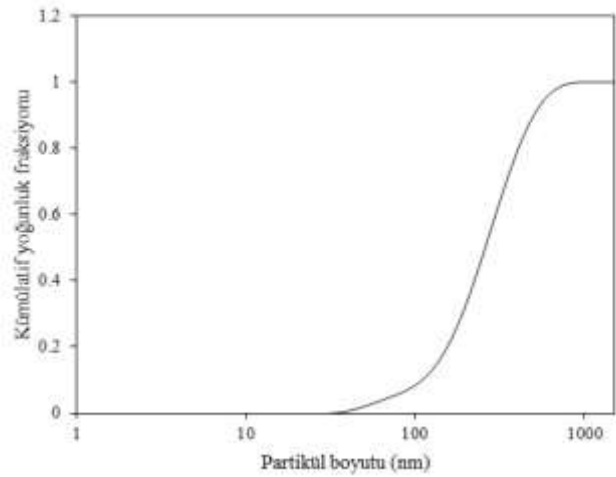
(b)

Şekil 2. MKS katı örneğinin SEM görüntüsü (a) ve yapılan analiz sonucu histogram grafik (b)

Şekil 2'teki histogram grafiğine sahip olan MKS örneğinin ortalama partikül boyutu 11.632 µm olarak hesaplanmıştır. Hidrolizattaki NS tane boyutu ise çözelti ortamında analiz edilmiştir. Analiz sonucu elde edilen partikül boyut dağılımı grafikleri Şekil 3'te gösterilmiştir.



(a)



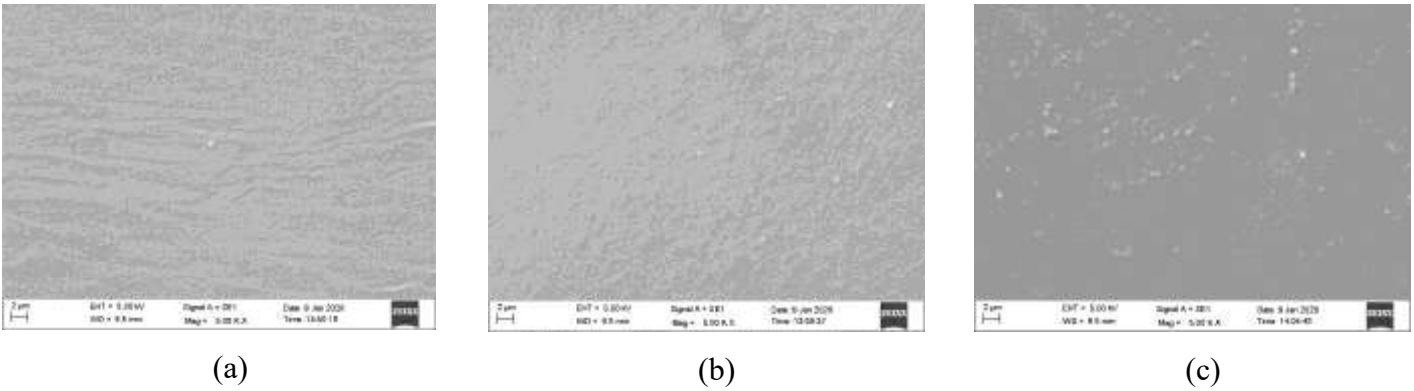
(b)

Şekil 3. Sentezlenen NS örneklerine ait partikül boyut dağılımı (a) ve kümülatif yoğunluk (b) eğrileri

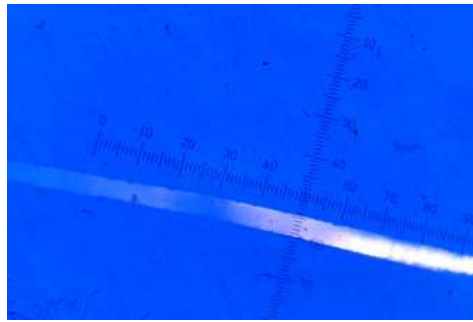
Şekil 3'teki gibi partikül boyut dağılımına sahip olan NS örneğinin ortalama partikül boyutu 308.803 nm; d10, d50 ve d90 değerleri ise sırasıyla 125.6 nm, 267.2 ve 568.3 olarak hesaplanmıştır.

Sentezlenen NS dolgulu PVA filmlerin SEM görüntüleri Şekil 4'te gösterilmiştir. Şekil 4'ten tipik PVA filmleri açıkça görülmektedir. Bu sonuçlar literatürde mevcut PVA filmlerinin SEM görüntüleriyle uyumludur (Jahan ve ark., 2018). Resmedilen görüntülerden dolgulu PVA filmlerinde nanoboyutta selüloz olduğu söylenebilir. Dolgu arttıkça PVA filmde nanoselüloz parçacık yoğunluğunun belirgin bir şekilde arttığı Şekil 4'ten gözlenen bir diğer sonuçtur.

NS dolgulu kompozit PVA filmlerin kalınlıklarının belirlenmesi amacıyla gerçekleştirilen mikroskop görüntüleme sonucunda elde edilen örnek bir resim (%2 dolgulu PVA) Şekil 5'te gösterilmiştir. Şekil 5'teki görüntüden görüldüğü üzere %2 NS dolgulu PVA film 50 μm kalınlığındadır. Benzer şekilde saf ve %4 dolgulu filmlerin kalınlıkları sırasıyla 20 μm ve 70 μm olarak ölçülmüştür.

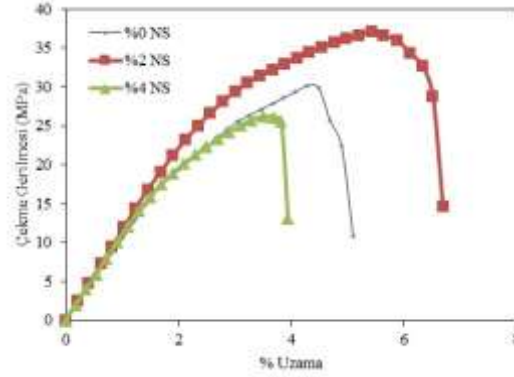


Şekil 4. NS dolgulu PVA filmlerinin SEM görüntüleri (a) dolgusuz, (b) %2 dolgulu, (c) %4 dolgulu



Şekil 5. %2 NS dolgulu PVA filmin elektron mikroskop görüntüsü

Sentezlenen filmlerin çekme testi sonuçlarına göre elde edilen çekme gerilmesine karşılık %uzama grafikleri Şekil 6'da gösterilmiştir. Bu grafikteki verilerden yararlanarak elde edilen dolgusuz ve NS dolgulu PVA örneklerine ait mekanik parametreler Tablo 2'de verilmiştir.



Şekil 6. Dolgusuz ve NS dolgulu PVA filmlerinin gerilme–% uzama davranışı

Tablo 2. NS dolgulu PVA filmlerin çekme testi sonuçları

Parametre	Dolgusuz PVA	%2 NS dolgulu PVA	%4 NS dolgulu PVA
Young Modülü (MPa)	10	11	12
Akma Gerilmesi (MPa)	19	23	20
Maksimum Çekme Dayanımı (MPa)	30	37	26
Maksimum Gerilmedeki Birim Uzama	4.2	5.8	3.6
Kopma Gerilmesi (MPa)	11	14	13
Kopma Noktasındaki Birim Uzama	5	7	4
Malzeme Davranışı	Sünek	Sünek	Orta Sünek

Tablo 2’den görüldüğü üzere, katkı maddesi miktarı arttıkça kompozit malzemenin sertliği ve dayanımı genel olarak artış göstermektedir. Benzer şekilde, Jahan ve ark. (2018) çalışmasında da nanoselüloz katkısı, özellikle %55 bağıl nem koşullarında PVA filmlerin mekanik dayanımını artırmıştır (Jahan ve ark., 2018). Yüksek dolgu miktarında meydana gelen dayanım düşüşü, dolgu aglomerasyonu ile ilişkilendirilebilir. Tablo 2’den ayrıca, akma gerilmesinin %2 dolgu oranında artarken %4 dolgu oranında düşmesi, yüksek dolgu içeriğine bağlı olarak aglomerasyon oluştuğunu göstermektedir. Maksimum çekme gerilmesinde de benzer bir eğilimin gözlenmesi, dolgu miktarındaki artışla birlikte malzemenin sünek davranıştan gevrek davranışa doğru kaydığını ortaya koymaktadır.

4. SONUÇ, TARTIŞMA VE ÖNERİLER

MKS’den hidroliz yöntemiyle NS üreterek PVA matriksine ilave etmek suretiyle polimer film üretilmesinin amaçlandığı bu çalışmada, hedeflenen boyutlarda NS dolgusuna sahip kompozit materyal sentezlenmiştir. Hammadde MKS ve üretilen NS materyalin FTIR spektrumlarından selülozun tipik piklerine rastlanmıştır. Spektrumlardan ayrıca üretilen materyalde saçsızlıkların yok denecek kadar az olduğu söylenebilir. MKS’un mikron seviyesinde, üretilen NS’un ise nanoboyutlarda (yaklaşık 300 nm) olduğu tane boyut analizi sonuçlarından açıkça görülmüştür. Dökülen film örneklerinde dolgu materyallerinin yer aldığı SEM görüntüleri ile kanıtlanmıştır. Film örneklerinin gaz geçirgenliğinde kullanılabilecek kalınlıklarda (20-70 µm aralığı)

oldukları ise, film kalınlığı ölçümleriyle ortaya koyulmuştur. Son olarak, filmlerin mekanik dayanım testlerinden NS ilavesiyle film dayanıklılığının belirgin şekilde arttırıldığı buna karşın %2'lik dolgudan sonra mateyral sünekliğinin gevrekliğe kaydığı gözlenmiştir. Bu çalışma, devam etmekte olan gaz geçirgenliği ölçüm çalışmalarımızın ön aşamasını oluşturmaktadır. Gelecek çalışmalarda, sentezlenen filmlerde bazı gazların geçirgenlik deneyleri gerçekleştirilecektir.

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4-DIMENSIONAL CATALAN-MOTZKIN MATRIX AND SOME NEW DOUBLE SEQUENCE SPACES

Bilal TURANCI¹/ Doç.Dr. Sezer ERDEM²

¹Kerem Aydınlar Science High School, functional analysis, bturanci44@gmail.com,

<https://orcid.org/0009-0006-9332-9762>

² Malatya Turgut Özal University, Faculty of Engineering and Natural Sciences, Department of Basic Engineering Sciences, functional analysis, sezererdem8344@gmail.com,

<https://orcid.org/0000-0001-9420-8264>

Abstract

Double sequence spaces constitute a natural extension of classical single sequence spaces and play a fundamental role in summability theory, functional analysis, and the study of multidimensional convergence. Since their introduction, various authors have investigated their topological and geometric structures, matrix transformations between them, and their dual spaces. In recent years, the construction of new double sequence spaces via infinite 4-dimensional matrices has attracted considerable attention, particularly in connection with integer sequences.

In this study, a new four-dimensional infinite matrix is constructed by using the Catalan and Motzkin integer sequences, and a new family of double sequence spaces is defined as the matrix domain of this newly generated four-dimensional infinite matrix. It is shown that the resulting spaces are normed spaces and that they are complete. In addition, the α -, β -, and γ -duals of the newly defined spaces are explicitly computed, and the necessary and sufficient conditions for membership in these duals are derived in terms of the associated matrix transformations. As an application, several classes of matrix transformations from the new spaces into the classical double sequence spaces and conversely are characterized. The results obtained here are regarded as natural counterparts in the setting of double sequence spaces of certain studies carried out on single-indexed sequence spaces, and in this sense they provide original contributions to the existing literature.

Keywords: Catalan numbers, Motzkin numbers, 4-dimensional matrix, Double sequence spaces

TARIMIN EKOSISTEM HİZMETLERİ VE EROZYON

Prof.Dr., Alaeddin BOBAT¹

YL. Öğrencisi Satılmış Eren Özdemir² YL. Öğrencisi Ömer Fatih BİLDİK³

¹Kocaeli Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü, 41285 Kartepe-KOCAELİ
bobatus@gmail.com, ORCID ID: 0000-0003-4654-0208

²Kocaeli Üniversitesi, Fen Bilimleri Ens., YL. Öğrencisi, 41001 Umuttepe-İZMİT
satilmiserenozdemir@gmail.com, 0009-0002-3105-9569

³Kocaeli Üniversitesi, Fen Bilimleri Ens., YL. Öğrencisi, 41001 Umuttepe-İZMİT
omrfatihbldk@gmail.com, 0009-0004-2836-003X

Özet

Erozyon yer kabuğundaki toprakların su, rüzgâr gibi dış etkenlerle aşındırılıp, taşınması ve biriktirilmesi olarak tanımlanan jeolojik bir süreçtir. Doğal dengede toprak oluşumu ile telafi edilebilen bu süreç, bilinçsizlik ve insan müdahalesiyle doğanın karşılayamayacağı oranda artarak "hızlandırılmış erozyona" dönüşmektedir.

Erozyon türleri arasında en yaygın ve etkili olanı Su Erozyonu'dur. Bu tür; yağmur damlalarının toprağı ayırttığı sıçrama/damla erozyonu, belirli kanallar oluşturmada toprağın yüzeyde aşındığı yüzey akış erozyonu, küçük yarıkların olduğu oluk (parmak) erozyonu ve 30 cm'den derin kanalların olduğu yarıntı erozyonu gibi alt çeşitlere ayrılır. Diğer önemli bir tür olan Rüzgâr Erozyonu ise, gevşek, kuru ve çıplak toprakların rüzgârın etkisiyle sürüklenme, sıçrama ve havada asılı kalma şeklinde taşınmasıdır.

Küresel ölçekte, tarım için kullanılan alanların yaklaşık %70'i özelliklerini kaybederek dünya genelinde %30 civarında çölleşmeye neden olmuştur. Birleşmiş Milletler Çevre Programı (UNEP), çölleşme ve erozyonla mücadele için yılda 42 milyar dolar harcanması gerektiğini hesaplamıştır. Türkiye'de, toprakların %90'ı su erozyonuna maruz kalmakta, tarım topraklarında bu oran %75'e ulaşmaktadır. Bu durumun başlıca nedenleri arasında; arazi eğimi organik maddece fakir jeolojik yapı, sağanak yağış rejimleri, ormansızlaşma ile zayıflayan bitki örtüsü ve aşırı/yanlış otlatma gibi yanlış arazi kullanım uygulamaları yer almaktadır. Erozyon tarımsal üretimi azaltıp maliyetleri artırsa da, doğru tarım uygulamaları önemli ekosistem hizmetleri sunarak bu sorunun çözümüne katkı sağlar. Toprak kaybının ötesinde su rejimleri, biyoçeşitlilik ve sosyo-ekonomik yapıları etkileyen çok boyutlu bir çevresel sorun olan erozyonun önlenmesi, sürdürülebilir doğal kaynak yönetimi ve tarımsal verimlilik için kritik önemdedir.

Bu çalışmanın amacı erozyonun doğal ve insan kaynaklı nedenleri, çeşitleri ve tarımsal ekosistemlerin erozyonu önlemede sunduğu olumlu olumsuz ekosistem hizmetleri üzerine kapsamlı bir değerlendirme sunmaktır.

Anahtar Sözcükler: Ekosistem hizmetleri, Erozyon, Tarımsal Faaliyetler

AGRICULTURAL ECOSYSTEM SERVICES AND EROSION

Abstract

Erosion is a geological process defined as the disintegration, transport, and deposition of soil on the Earth's crust by external factors such as water and wind. Although this process can be balanced by natural soil formation under normal conditions, human intervention and mismanagement can accelerate it beyond nature's capacity to recover, leading to "accelerated erosion."

Among erosion types, water erosion is the most common and impactful. It includes several sub-types: splash/raindrop erosion caused by the impact of raindrops, sheet erosion where soil is removed uniformly without forming channels, rill erosion characterized by small channels, and gully erosion where channels deeper than 30 cm develop. Another significant type is wind erosion, which involves the movement of loose, dry, and bare soils through suspension, saltation, and surface creep under the influence of wind.

Globally, nearly 70% of agricultural lands have lost their characteristics, contributing to approximately 30% desertification worldwide. The United Nations Environment Programme (UNEP) estimates that 42 billion dollars per year are required to combat desertification and erosion. In Türkiye, 90% of soils are exposed to water erosion, and this rate reaches 75% in agricultural lands. Major causes include steep terrain, geologic structures poor in organic matter, intense rainfall patterns, deforestation leading to weakened vegetation cover, and improper land-use practices such as overgrazing.

Although erosion reduces agricultural productivity and increases costs, well-planned agricultural practices can provide important ecosystem services that help mitigate this issue. Beyond soil loss, erosion is a multidimensional environmental problem affecting water regimes, biodiversity, and socio-economic structures. Preventing erosion is therefore essential for sustainable natural resource management and maintaining agricultural productivity.

The aim of this study is to present a comprehensive assessment of the natural and human-induced causes of erosion, its types, and the positive and negative ecosystem services provided by agricultural ecosystems in preventing erosion.

Keywords: Ecosystem services, erosion, agricultural activities

1. GİRİŞ

Uzun bir oluşum sürecine sahip olan toprak, üzerinde yaşayan insan ve diğer bütün canlılar için yaşam ve besin kaynağının temelini oluşturduğu için en önemli doğal varlıklardandır. Aynı zamanda yaşamlarını sürdürebilmeleri için gerekli olan hava ve su ile yiyecek ve yakıt gibi temel ihtiyaçların sağlanmasında ve bütün canlı yaşamının devamlılığında en önemli bileşen olarak kabul edilmektedir (Blanco ve ark., 2008). Toprak hidrolojik döngünün sağlanması, bitkiler için fiziksel ortam, besin maddelerinin tutulması ve paylaşılması, atıkların ve organik atıkların dönüşümü, atıkların yenilenmesi ve başlıca element döngülerinin düzenlenmesi olmak üzere temelde altı ana ekosistem hizmeti sunmaktadır (Daily ve ark., 1997).

Ekosistem hizmetleri temel olarak *“insan yaşamının sürdürülebilmesi ve insan refahının sağlanabilmesi için ekosistemlerin sunduğu durumlar, süreçler, işlevler, faydalar ve ürünlerin tümü”* olarak tanımlanabilir (Hassan ve ark., 2005). Dünya Kaynakları Enstitüsü tarafından 2005 yılında yayınlanan Binyıl Ekosistem Değerlendirmesi (MEA) raporunda; ekosistem hizmetleri, *“ekosistemlerden elde edilen faydalar”* olarak tanımlanmıştır (MEA, 2005; Arslan ve Tazebay, 2017).

Karasal ekosistemler, toprağı rüzgâr ve su erozyonundan koruyarak insan refahını sağlayan temel ekosistem hizmetlerinden biri olan erozyon kontrol hizmeti sağlamaktadır (Çilek, 2021). Ancak son yıllarda toprakların yanlış kullanımı ve yanlış toprak işleme çalışmaları sonucunda çok kısa sürede ve büyük miktarlarda erozyonun meydana gelmesine ve bu varlıkların sürdürülebilir kullanımlarının azalmasına neden olmaktadır. Toprak erozyonu tarımı, doğal yaşamı ve çevreyi ciddi şekilde tehdit ettiği için bugün dünyadaki en ciddi çevre sorunlarından biri olarak kabul edilmektedir. Toprak erozyonu zaman içinde meydana gelen doğal bir süreçtir ve erozyonla ilgili endişelerin çoğu, insan faaliyetleriyle önemli ölçüde artan hızlandırılmış erozyonla ilgilidir. Hızlandırılmış toprak erozyonu dünya çapında ciddi bir sorundur ve kapsamı, büyüklüğü, hızı ve bununla ilişkili karmaşık süreçler nedeniyle ekonomik ve çevresel etkisini doğru bir şekilde değerlendirmek zordur (Erkal ve Yıldırım, 2012).

Deniz seviyesi ile 5165 m yükseklik arasında olan bir topografyaya sahip ve 250-2500 mm arasındaki yağış dağılımı görülen ülkemiz topraklarının %73’ü ileri derecede erozyona uğramıştır (Doğan, 1995).

Erozyonla sadece ülke toprakları yitirilmemiş, aynı zamanda tarım alanlarında gerçekleşen verimli toprak kayıpları da tarımsal üretimde kronik verim kayıplarına neden olmuştur. Tarım alanlarındaki verimli toprakların erozyonla yitilmesi, başta toprak derinliği olmak üzere organik madde kaybı ve su tutma yeteneğinin azalmasına, yetiştiricilik için uygun olmayan toprak koşullarının ortaya çıkmasına neden olmakta ve daha fazla

tarımsal girdi (gübre, sulama, toprak işleme vs.) kullanılmasını zorunlu kılarak verimliliğin azalmasına yol açmaktadır.

Erozyon, topraklarımızın yok olmasına neden olan etkenlerin başında gelmektedir. Ülkemiz erozyonla taşınan materyal bakımından Asya kıtasına hemen hemen eşit bir konumda iken, Avrupa kıtasından 17, Afrika kıtasından 22, Kuzey Amerika'dan 6, Güney Amerika'dan 10 kat daha fazla aşınmakta ve verimli toprak taşımaktadır. Ülkemizdeki toprakların % 7.22'sinde hafif, % 20.04'ünde orta, % 36.42'sinde şiddetli, % 22.32'sinde çok şiddetli olmak üzere toplam % 83.20'sinde erozyon yaşanmaktadır (URL1, 2005).

Erozyon nedeni ile toprağın verimi azalmakta, besin maddeleri yok olmakta, sular kirlenmekte, ürünlerde verim ve kalite düşmektedir. Ülkemizde erozyon sonucu her yıl 500 milyon ton verimli toprak kaybolmaktadır (Doğan, 1995). Bu çalışmanın amacı da bu kayıpları önlemek için tarım alanlarında erozyonu etkileyen olumlu veya olumsuz faaliyetlerin neler olduğu, bunlarla nasıl mücadele edilmesi gerektiği ve ekosistemin hangi hizmetlerinden yararlanılarak erozyonla mücadele edildiğini incelemektir.

2. EROZYON ÇEŞİTLERİ

2.1.Su erozyonu

En yoğun görülen erozyon çeşididir. Toprağın su tarafından orijinal yerinden uzaklaştırılması veya yer değiştirmesi olarak tanımlanabilir. Yağmur, eriyen kar, akan nehirler, buzulların hareketi veya donma/çözülme döngüleri nedeniyle meydana gelir. Su erozyonu; sıçrama erozyonu, yüzey akış erozyonu, oluk erozyonu, yarıntı erozyonu, akarsu yataklarının yarattığı erozyon olarak 5'e ayrılabilir (Karaoğlu, 2016).

2.1.1.Sıçrama erozyonu

Yüksek yoğunluğa sahip yağmur damlaları toprak agregatları ve keseklerin üzerine düştüğü zaman daha küçük parçacıklara ayırır ve toprağın infiltrasyon kapasitesinin düşmesine neden olmaktadır.

Yağmur damlalarının toprağa aktardıkları harekete bağlı olarak iki etki söz konusudur. Birincisi; toprakta sıkışmaya neden olan sertleştirme kuvveti veya konsolidasyon (Görcelioğlu, 2003; Morgan, 2005) ve ikincisi ise bazı toprak parçacıklarının ayrışması ve havaya doğru sıçratılmasıdır (Karaoğlu, 2016).

2.1.2.Yüzey akış erozyonu

Suyun toprak yüzeyini, belirli ve sürekli su kanalları oluşturmadan, oldukça tekdüze bir şekilde aşındırması olayına yüzey erozyonu denir (Şekil 1a). Yüzey erozyon olayında ayrışan toprak parçacıkları; yüzey sürüklenmesi, suda asılı kalma ve sıçrama hareketlerinin birleşimi ile taşınırlar (Çanga, 1995).

2.1.3. Oluk erozyonu (Parmak erozyonu)

Yüzey akış suları, arazi yüzeyindeki çöküntülerde çoğalmaya başladığı zaman küçük ve fakat belirgin kanallar oluşturur ve ayrılmış toprak parçacıkları bu akış suları içinde asılı olarak taşınabilir. Eğer bu kanallar normal sürüm işlemleri ile kapatılmazlarsa rill veya parmak olarak adlandırılırlar. Parmak erozyonu için Balcı (1996) “oluk” erozyonu ve Görçelioğlu (2003) “çizgi” veya “çığır” erozyonu ifadelerini kullanmışlardır (Karaoğlu, 2016).

2.1.4. Yarıntı erozyonu (Gully)

Oluk erozyonunun ilerleyen aşamasından sonra artık Yüzey kanalları normal sürüm işlemleri ile düzeltilemeyecek derinliğe (30 cm’den fazla) ulaşmışsa bu kanallar artık gully veya oyuntu olarak adlandırılırlar (Çanga, 1995).

2.1.5. Akarsu yataklarının yarattığı erozyon

Akarsuların hem yatak içinde hem de kenarlarında meydana gelen erozyondur (riverbed erosion). Akarsuların yatağında meydana gelen erozyon akıntı kanalının kenarları ve içinde meydana gelen toprak taşınmasıdır. Yanlardan gelen yüzey akış suları ile akarsu yatağının kenarları aşındırılır (Aalan, 1983). Akarsu yatak erozyonu için “kanal”, “yatak” veya “mecra” erozyonu terimleri de kullanılmıştır (Balcı, 1996; Görçelioğlu, 2003).

2.2. Rüzgâr erozyonu

Rüzgâr erozyonu, toprağın ayrışma, taşınma ve birikmesidir. Gevşek, kuru ve çıplak toprakların kuvvetli rüzgârlarla taşındığı enerjik ve fiziksel bir işlemdir.

Rüzgâr erozyonu sonucu verimli toprakların kaybı, buharlaşmanın hızlanmasıyla toprak nemliliğinin azalması, bitki büyümesinin yavaşlaması, ulaşımın aksaması ve verimin düşmesi olumsuzluklarını ortaya çıkarmaktadır. Taşınan kum ve verimsiz toprak, üretken tarım topraklarını kaplayarak, tarım yapılamaz hale getirmektedir. Rüzgâr erozyonu bitki örtüsünün fazla olmadığı yerlerde çok etkilidir (Şekil 1b).

Rüzgârla savrulan materyal üç şekilde hareket eder. Bu hareketler sürüklenme (=soil creep), sıçrama (=saltation) ve havada asılı kalma (=suspension) olaylarıdır (Çanga, 1995).



Şekil 1. a. Yüzey akışlarıyla birlikte fazla suyun neden olduğu erozyon b. Rüzgâr erozyon (Akıncı, 2005).

3.ÜLKEMİZDE EROZYON OLUŞUMUNA ETKİ EDEN BAŞLICA ETMENLER

3.1.Arazi Eğimi

Ülkemiz arazilerinin eğimleri ve toprak derinlikleri Çizelge 3’de verilmiştir. Buna göre yurdumuz topraklarının % 50.5’i % 0-20 oranında eğime, geri kalan % 49.5’i ise % 20 ve daha yüksek eğime sahiptir. Eğimin az olduğu yerlerde tabaka erozyonu görülmektedir (Karaşahin, 1995).

3.2.Jeolojik Yapı

Yurdumuz topraklarının önemli bir bölümü tortul ve metamorfik kayalardan oluşmuş olup, organik madde yönünden oldukça fakirdir. Topraklarımızın %64’ünde organik madde oranı %1’in altında, %22’sinde % 1-2 arasında ve %14’ünde %2’nin üzerindedir. Organik madde oranının düşük seviyede olması toprak agregatlarındaki ayrışmayı kolaylaştırmakta ve erozyonun artmasına sebep olmaktadır. Kil oranı %27’nin altında olan topraklar birbirlerine yapışmayacağından rüzgârın hızına bağlı olarak taşınma miktarı artar (Karaşahin, 1995).

3.3.İklim

İklim değişikliğine bağlı olarak bölgesel yağış rejimlerinin değişmesi erozyonu doğrudan etkileyecektir. Daha fazla ani yağış alan yerlerde su erozyonu artacak ancak toprağın bundan etkilenme seviyesini bölgedeki insan faaliyetleri ve ormansızlaşma net olarak belirleyecektir. Aynı zamanda iklim değişikliğine bağlı olarak sıcaklık artışları da çeşitli bölgelerdeki bitki örtüsünü kurutacak ve toprağı rüzgar erozyonuna açık hale gelecektir (Nearing ve ark.,2004).

İklim değışikliğı ile erozyon seviyelerinin artması, toprakta var olan birçok canlı türünün yok olmasına sebep olmakla birlikte, verimli toprak tabakasını ciddi oranda azaltacak; bu durum da gıda güvenliğini tehdit edecektir (URL2, 2025).

3.4.Bitki Örtüsü Durumu

Tüm çabalara, iyileştirme proje ve çalışmalarına rağmen ülkemizde orman ve çayır mera bitki örtüsü alanları günbegün azalmakta, bu alanlar sürülerek sürekli işlenebilir tarım arazisi haline getirilmektedirler (Karaşahin, 1995).

Erozyonu önlemede kökleri ile yüzeysel akışa engel olan, bitki artıkları ile toprağı verimli kılan, yaprakları vasıtası ile yağışın şiddetini azaltan ormanların yok edilmesi, ülkemizi hızlı bir şekilde çölleşmeye götürmektedir. Ormanların tahribi ve erozyon, önlem alınmadan aynı hızla devam ederse, NASA'nın yaptığı araştırmalara göre 2040 yılında Türkiye yüz ölçümünün % 85'inde çöl iklimi yaşanacaktır (URL3, 2005).

3.5.Aşırı Hayvan Otlatma ve Yanlış Arazi Kullanımı

Orman ve çayır mera alanları olarak kullanılması gereken dik ve çok eğimli arazilerde, erozyona karşı hiçbir tedbir alınmaksızın (sürüm şekilleri ve toprak işleme yönünden) tarım yapılmaktadır. Çayır mera alanları üzerinde otlatmaya erken başlanmakta, otlatma periyodu boyunca yapılan yoğun otlatma bitki tür ve sayılarını önemli ölçüde azaltmakta, böylece birim alandaki bitki yoğunluğu giderek seyrekleşmekte ve erozyon şiddeti buna bağlı olarak artmaktadır. Ülkemizde hayvancılık genellikle açık mera hayvancılığı biçimindedir. Ancak her meranın besleyebileceğı bir hayvan kapasitesi vardır. Meraya besleyebileceğinden fazla sayıda hayvanın sokulması, bu hayvanların otları kökleri ile birlikte yemesi, henüz otların yeni büyümeye başladığı ve tam olarak gelişmediğı ilkbahar aylarında otlatma yapılması, toprak yüzeyini örten bitki örtüsünün ortadan kalkmasına ve mera kalitesinin bozulmasına neden olmaktadır.

Öte yandan insanın aşırı müdahalesi veya zararlı etkisi olmasa, erozyon jeolojik süreç içerisinde olumlu sonuçlar da doğurabilmektedir. Ülkemizin tarımsal bakımdan verimli ovaları konumunda olan Menemen, Bafra ve Çarşamba ovaları erozyon sonucu taşınan toprakların nehir ağzında birikmesi ile oluşmuşlardır. Ancak arazinin tahribi, yanlış ve aşırı kullanımı, erozyonu doğal süreci dışına çıkartarak, önemli toprak kaybına neden olmaktadır (URL3, 2005).

4. TARIMDA EKOSİSTEM HİZMETLERİ VE EROZYON İLİŞKİLERİ

4.1.Tarımsal Faaliyetlerin Erozyona Etkisi

4.1.1.Hatalı Toprak İşleme Yöntemleri ve Sürüm

Bilimsel çalışmalar, özellikle eğimli arazilerde, toprağın eğim yönüne paralel sürülmesinin suyun akış hızını artırdığını ve oluk (rill) ve oyuntu (gully) erozyonunun oluşumunu kolaylaştırdığını göstermektedir. Bu, suyun bir kanal gibi akmasına ve toprağın hızlı bir şekilde taşınmasına yol açmaktadır.

Eğime dik sürülen karıklar yüzey akış ve toprak kaybının azaltılmasında daha etkilidir. Ayrıca karık derinliğinin artışı yüzey akış ve toprak kayıplarını azaltmıştır. Arazi eğimi ve toprak derinliği uygun olan yerlerde eğime dik sürülen 4 cm derinliğinde karıklar toprak erozyonunu azaltmada bir yöntem olarak kolaylıkla uygulanabilir. (Yönter ve Sinkprhoun, 2018)

4.1.2. Toprağı Çıplak Bırakmak ve Anız Yakmak

4.1.2.1. Bitki Örtüsünün Yok Edilmesi

Bitki örtüsünün sürekli veya geçici oluşu, sık veya seyrek oluşu erozyonu farklı olarak etkiler. İyi yetişmiş yoğun bir bitki örtüsü, sık bir çayır veya orman, toprak erozyonuna neden olan faktörlerin etkisini azaltır. Kültür bitkilerinin ise toprak erozyonunu kontrol etmedeki rolleri daha azdır.

Bitki örtüsünün su erozyonuna olan etkileri 3 bölüm altında toplanabilir. Bunlar; Yağmur damlalarının çarpma etkisinin bitkilerin toprak üstü kısımları ile önlenmesi, Yüzey akış hızının kesilmesi ve toprağı aşındırma gücünün önlenmesi, Toprağın granülasyon ve porozitesini artıran kök etkileri, olarak sıralanabilir (Yılmaz ve Alagöz, 1999)

4.1.2.2.Anız Yakma

Anız yakma neticesinde özellikle topraktaki organik madde miktarı azalmakta, mikrobiyolojik aktivite gerilemekte, toprak canlıları yok olmakta, su tutma kapasitesi azalmakta, biyolojik denge bozulmakta ve erozyon riski yükselmektedir (Cerit, 2001; Avşar ve Kamburoğlu, 1996).

Hasattan sonra toprak yüzeyinde bırakılan anızın, hasat sonrası işlemlerde oluşturacağı bazı olumsuz etkilerinin yanı sıra, toprağın ve suyun korunması başta olmak üzere birçok olumlu etkileri de bulunmaktadır. Anızın yakılmaksızın sürümle toprağı verilmesi durumunda mikroorganizmaların sağladığı enzimler ile sapın önemli bir bölümünü (%40–60) içeren selülozun parçalanarak C/N oranının düzeltildiği bilinmektedir. Bu arada, toprakta organik maddenin artışına bağlı olarak meydana gelen humin maddeleri, yağmur damlaları ve rüzgârın erozif etkilerini ve yüzeyde meydana gelen akışı azaltmakta, suyun toprak tarafından emilmesini sağlayacak toprak kanallarının oluşmasına yardımcı olmakta ve toprak zerrecilerinin arasında bağlayıcı rol oynamak sureti ile

erozyonu azaltmaktadır. Ayrıca, topraktaki organik maddenin artması, kurak dönemde toprağın su tutma kapasitesini artırmakta ve dolayısıyla verimde artış sağlanmaktadır (Avşar ve Kamburoğlu, 1996; Mc Kenney ve ark., 1993; Sağlam, 1994; Shelton ve ark., 1997; Wysocki, 1988).

4.2. Toprağın Amaç Dışı Kullanımı

Arazinin yanlış kullanımından kaynaklanan önemli sorunlardan biri toprak kaybıdır. Bu nedenle Dünya’da ve Türkiye’de büyük miktarda toprak kaybedilmektedir. Tarım alanlarının %52’sinin IV. sınıf tarım arazisi üzerinde ve %83’ünün orta şiddetli erozyon riski taşıyan bölgelerde; yerleşim alanının %49’u ile sanayi bölgesinin %67’sinin ise I. sınıf tarım arazi üzerinde olduğu belirlenmiştir. Toprağın erozyondan ve kirlilikten korunması, tarım topraklarının amaç dışı ve yetenek dışı kullanılması ile yanlış arazi kullanımı nedeniyle toprak kaybının engellenmesi ekolojik dengesinin korunması anlamında büyük önem taşımaktadır (Açıksöz ve ark., 2008). Arazinin genelinin yüksek eğime sahip olması topraklarda erozyon risk seviyesinin yüksek çıkmasında başlıca faktördür (Erdem ve Türkmen, 2020)

5. TARIMIN EROZYONU ÖNLEYİCİ EKOSİSTEM HİZMETLERİ

5.1. Toprağın Bitki Örtüsü İle Kaplanması

Bitki örtüsü, yağmur damlasının çarpma hızının düşürülmesini ve bir rüzgârkıran gibi su ve rüzgârın aşındırıcı kuvvetlerinin azaltılmasını sağlar. Böylece yağmur damlalarının çarpma etkisiyle parçalanan ve sıçrayan toprak taneciklerinin toprak yüzeyindeki gözenekleri tıkamasının önüne geçilmiş olur ve dolayısıyla yüzey akışı azalır. Bitkiler; toprak taşınmasına fiziksel direnç gösterir, yüzey akış hızını düşürür ve kök sistemleri toprağı kararlı hale getirerek toprak kayıplarını azaltır. Bitki kalıntıları da benzer işlevleri uygular ve ilave olarak yüzey akışın gecikmesine, suyun toprağı sızmasına yardımcı olan ve böylece erozyonu azaltan küçük su birikintilerine neden olur (Öztürk ve Ünlükara, 2005).

Örtü bitkileri arasında baklagiller, otlar, turpgiller ve tahıllar gibi çeşitli bitki türleri bulunur. Yaygın örtü bitkileri arasında yonca, fiğ, çavdar, yulaf ve turp bulunur.

Bitki yoğunluğunun erozyona etkisi üzerine mısır ile yapılmış bir denemede hektar başına düşen bitki sayısı arttıkça yüzey akış ve toprak kaybının azaldığı belirlenmiştir. Denemede hektardaki bitki sayısı 25 bin olduğunda yüzey akış 250 mm ve toprak kaybı 12.3 ton/ha iken bitki sayısı hektar başına 37 bine çıkarıldığında yüzey akış 20 mm’ye düşerken toprak kaybı da 0.7 ton/ha’a düşmüştür. Denemede, birinci parseldeki verim düzeyi orta ve ürün miktarı 5 ton/ha iken ikinci parseldeki verim düzeyi yüksek ve ürün miktarı da 10 ton/ha olarak tespit edilmiştir (Taysun, 1983).

5.2. Kök Sistemleri ile Toprak Stabilizasyonu

Bitkiler, ancak mm ile ifade edilebilecek derecede ince köklerden, çok kalın kazık ve dalıcı köklere kadar değişik çap ve uzunlukta köklere sahiptir. Bunlar toprağı bir ağ gibi sarar ve toprağın doğal kuvvetlerle taşınmasını engeller (Çepel, 1996). Konu ile ilgili olarak Weaver tarafından yapılmış bir çalışma ile köklerin bağlayıcı etkilerinin toprağın erozyona hassasiyetini azaltıcı rolü incelenmiştir. Bu amaçla kılçıksız brom, yonca, taş yoncası, sudan otu, kışlık buğday ve darı bitkileri ele alınmış ve bu bitkiler doğal olarak yetişmiş çayır salkım otu ve sakal otu ile karşılaştırılmıştır. Bu çalışmada, laboratuvara getirilen toprak örnekleri üzerinden beher 1.5 inç kare 1 pound basınca sahip suyun akıtılması ile bu bitkilerin erozyonunu gösterilmiştir. Bu bitkilerin toprak üstü kısımları hasat edildiğinde toprağı koruyucu etkileri çok azalmıştır (Akalın, 1973).

5.3. Organik Madde Artışı ve Toprak Yapısının İyileştirilmesi

Tarımda bitki artıkları, örtü bitkileri ve organik gübre kullanımı toprağın agregat stabilitesini artırarak erozyon duyarlılığını düşürür.

Bitki yoğunluğunun erozyona etkisi üzerine mısır ile yapılmış bir denemede hektar başına düşen bitki sayısı arttıkça yüzey akış ve toprak kaybının azaldığı belirlenmiştir. Denemede hektardaki bitki sayısı 25 bin olduğunda yüzey akış 250 mm ve toprak kaybı 12.3 ton/ha iken bitki sayısı hektar başına 37 bine çıkarıldığında yüzey akış 20 mm'ye düşerken toprak kaybı da 0.7 ton/ha'a düşmüştür. Denemede, birinci parseldeki verim düzeyi orta ve ürün miktarı 5 ton/ha iken ikinci parseldeki verim düzeyi yüksek ve ürün miktarı da 10 ton/ha olarak tespit edilmiştir (Taysun, 1983).

5.4. Agroforestry Uygulamaları

Agroforestry, tarımsal üretim sistemlerinde ağaçların ve çalılarının entegre edilmesiyle oluşturulan bir arazi kullanım yaklaşımıdır. Bu sistem, tarım ve orman bileşenlerini bir araya getirerek hem üretim hem de ekosistem hizmetlerini artırır. Agroforestry, kök derinliği ve organik madde katkısı sayesinde su tutma kapasitesini yükseltir, infiltrasyonu artırır ve erozyonu azaltır (Jose, 2009).

5.5. Rüzgâr Erozyonunun Azaltılması (Rüzgâr Perdeleri / Siper Bitkiler)

Rüzgâr perdesi, diğer adıyla yelkıran, toprağın rüzgâr erozyonu ile kaybını engellemek için canlı bitkiler kullanılarak kurulmuş çok sıralı ağaç şeritleridir

Rüzgâr perdesi kurulumunun genel amacı rüzgâr hızını azaltmaktır. Yapılan bir simulasyonda tek sıralı, aynı sırada dikilmiş iki ağaçlı ve üçgen dikim yapılmış iki ağaç sıralı rüzgâr şeritlerinde ağaçlık alanda rüzgâr hızı sırasıyla %71, %85 ve %98 oranında, 15 ağaç boyu mesafede ise rüzgâr hızının sırasıyla %20,%30 ve %50 oranında düştüğü belirlenmiştir (URL4,2025)

6. SONUÇ VE ÖNERİLER

Yapılan incelemeler, erozyonun yalnızca toprağın fiziksel kaybı olarak değerlendirilmemesi gerektiğini; su rejimleri, tarımsal verimlilik, biyolojik çeşitlilik ve sosyo-ekonomik yapılar üzerinde doğrudan ve dolaylı etkiler yaratan çok boyutlu bir çevresel sorun olduğunu öne çıkarmaktadır. Özellikle yanlış arazi kullanımı, eğimli topografyada yapılan tarımsal faaliyetler ve ormansızlaşma gibi etkenlerin erozyon hızını doğal süreçlere göre önemli ölçüde artırdığı gözlemlenmiştir. Türkiye özelinde görülen dağılım da bu bulguları desteklemektedir. Toprak kaybı miktarının artması hem ekosistemin üretkenliğini düşürmekte hem de ekonomik maliyetleri yükseltmektedir. Bu bağlamda, erozyonun önlenmesi, sürdürülebilir doğal yaşamın temel bileşenlerinden biri olarak ele alınmalıdır.

Erozyonun önlenmesi için tarımın sunabileceği ekosistem hizmetleri, öncelikli olarak “*Arazi Kullanım Planlamasının İyileştirilmesi*” ile başlamalıdır. Bu kapsamda, eğimli arazilerde tarımsal faaliyetlerin sınırlandırılması, uygun yerlerde ise teraslama ve kontur sürüm tekniklerinin yaygınlaştırılması erozyon hızının azaltılmasında rol oynar. İkinci olarak, ormansızlaşmanın önlenmesi, bozuk orman alanlarının rehabilite edilmesi ve meralarda kontrollü otlatma uygulamalarına geçilmesi yoluyla “*Bitki Örtüsünün Güçlendirilmesi*”, toprakların doğal koruma kapasitesini artıracaktır. Üçüncü olarak, havza bazlı erozyon kontrol projeleri, sel kontrol yapıları, sediment tutucu bentler ve biyoteknik yapılar gibi “*Toprak Koruma Projeleri*”nin yaygınlaştırılması özellikle riskli bölgelerde uygulama alanı bulmalıdır. Sürdürülebilir arazi kullanımını desteklemek amacıyla, çiftçilere yönelik erozyonun sonuçları ve toprak koruma yöntemleri hakkında eğitim programları düzenlenerek “*Eğitim ve Bilinçlendirme Çalışmaları*” yürütülmelidir. Ayrıca, uzun dönemli toprak kaybı izleme sistemlerinin kurulması, uzaktan algılama ve CBS tabanlı analizlerin yaygınlaştırılması ile erozyon risk haritalarının güncelliği sağlanarak “*Bilimsel İzleme ve Veri Toplama*” faaliyetleri artırılmalıdır. Yasal çerçevede ise, toprak koruma kanunlarının uygulanabilirliğinin artırılması, kaçak kazı, yanlış arazi açma ve uygunsuz tarımsal faaliyetlere yönelik denetimlerin sıklaştırılması ile “*Mevzuat ve Denetim Mekanizmalarının*” güçlendirilmesi gerekmektedir. Son olarak, anız yakma gibi erozyonu hızlandıran uygulamaların önlenmesi; çok yıllık bitki yetiştiriciliğinin, organik tarımın ve koruyucu toprak işleme tekniklerinin teşvik edilmesi yoluyla “*Sürdürülebilir Tarım Uygulamaları*” yaygınlaştırılmalıdır.

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DİRSEK ÜSTÜ AMPUTELERDE PROTEZ KULLANIMININ YÜRÜYÜŞTE KOL SALINIMI ÜZERİNE ETKİSİ

Dr. Fzt. Merve SARIİPEK¹/Dr. Fzt Ali İmran YALÇIN²

¹Fizyoterapi ve Rehabilitasyon Bölümü, Ordu Üniversitesi, Ordu, Türkiye, Biyomekanik, El Rehabilitasyonu, mervesariipek@odu.edu.tr, <https://orcid.org/0000-0001-8532-0019>

² Hacettepe Üniversitesi, Hareket Analizi ve Podiatri Uygulama ve Araştırma Merkezi (HAPUAM), Ankara Türkiye, Protez Rehabilitasyonu, Biyomekanik, fztaliyalcin@gmail.com, <https://orcid.org/0000-0002-7361-4535>

Özet

Üst ekstremitte amputelerinde yürüyüş sırasında üst ekstremitenin kinematik organizasyonu, denge ve hareket koordinasyonu açısından önemli bir rol oynamaktadır. Protez kullanımı, kol salınımı ve eklem hareketleri üzerinde belirleyici olabilirken, protezsiz yürüyüşte farklı hareket stratejileri ortaya çıkabilmektedir. Ancak üst ekstremitte amputelerinde protezli ve protezsiz yürüyüş sırasında üst ekstremitte kinematiklerinin karşılaştırmalı olarak incelendiği çalışmalar sınırlıdır. Bu çalışmanın amacı, üst ekstremitte amputelerinde protez kullanımının yürüyüş sırasında omuz ve dirsek eklemi kinematikleri üzerindeki etkisini değerlendirmektir. Çalışmaya manuel kilitli dirsek eklemleri protez kullanan 25 dirsek üstü ampute ve benzer demografik ve antropometrik özelliklere sahip 25 sağlıklı birey dahil edildi. Yürüyüş sırasında eklemlerin aldığı açısal değerleri ölçmek amacıyla yürüme yolunun sağ ve sol tarafından eş zamanlı olarak Basler marka yüksek hızlı kameralarla 100 kare/saniye hızda kayıt alınmıştır. Alınan kayıtlar Dartfish Prosuit7 yazılımı ile video üzerinden analiz yapılarak değerlendirilmiştir. Yürüyüş sırasında üst ekstremitte kinematikleri amputelerde protezli ve protezsiz ampute taraf ile sağlam tarafta, sağlıklı bireylerde ise dominant ve nondominant taraf arasında karşılaştırıldı. Amputelerde hem protezli hem de protezsiz koşullarda ampute taraf ile sağlam taraf arasında kol salınımı açısından anlamlı fark bulundu ve ampute taraf kol salınımının daha az olduğu belirlendi ($p<0,01$). Sağlıklı bireylerde dominant ve nondominant taraflar arasında kol salınımı açısından fark saptanmadı ($p>0,05$). Amputelerde protezli ve protezsiz aynı taraf karşılaştırıldığında kol salınımı açısından anlamlı fark bulunmadı ($p>0,05$); ancak protezsiz koşulda ampute taraf kol salınımının protezli koşula göre daha fazla olduğu görüldü. Protezli ve protezsiz amputeler sağlıklı bireylerle karşılaştırıldığında, ampute tarafta kol salınımının anlamlı olarak azaldığı tespit edildi ($p<0,05$). Ayrıca, amputelerin protezli koşulda ampute tarafı ile sağlıklı bireylerin nondominant tarafı arasında dirsek maksimum ekstansiyonu açısından anlamlı fark bulundu ($p<0,05$). Bu durumun çalışmaya dahil edilen amputelerin manuel kilitli dirsek eklemi kullanmalarından

kaynaklandığı düşünülmektedir. Çalışmadan elde edilen sonuçlar ışığında üst ekstremité amputelerinde rehabilitasyon programlarına özellikle simetrik kol salınımına yönelik yürüyüş eğitiminin dahil edilmesinin önemli olduğu görüşüne varıldı.

Anahtar kelimeler: Ampute, protez, üst ekstremité, yürüyüş, kol salınımı

EFFECT OF PROSTHESIS USE ON ARM SWING DURING GAIT IN INDIVIDUALS WITH TRANSHUMERAL AMPUTATION

Abstract

Upper limb kinematic organization during gait is important for balance and movement coordination in individuals with upper limb amputation. Prosthesis use may influence arm swing and joint motion, while different strategies may emerge during prosthesis-free walking. However, comparative studies examining upper limb kinematics during prosthetic and non-prosthetic gait are limited. This study investigated the effect of prosthesis use on shoulder and elbow joint kinematics during gait in individuals with upper limb amputation. Twenty-five individuals with transhumeral amputation using a prosthesis with a manual locking elbow joint and 25 healthy individuals with similar demographic characteristics were included. Joint angular data during gait were recorded simultaneously from both sides of the walkway using high-speed cameras at 100 frames per second and analyzed using Dartfish Prosuit7 software. Upper limb kinematics were compared between the prosthetic and non-prosthetic amputated side and the intact side in amputees, and between the dominant and nondominant sides in healthy individuals. In amputees, arm swing was significantly lower on the amputated side compared to the intact side in both prosthetic and non-prosthetic conditions ($p<0.01$). No difference in arm swing was observed between dominant and nondominant sides in healthy individuals ($p>0.05$). No significant difference was found between prosthetic and non-prosthetic conditions on the same side in amputees ($p>0.05$); however, arm swing tended to be greater without the prosthesis. Compared with healthy individuals, amputees showed reduced arm swing on the amputated side ($p<0.05$). A significant difference in maximum elbow extension was found between amputees in the prosthetic condition and healthy individuals ($p<0.05$), likely related to the manual locking elbow joint. These findings highlight the importance of gait training targeting symmetrical arm swing in upper limb amputees.

Keywords: Amputation, Prosthesis, Upper limb, Gait, Arm swing

1. GİRİŞ

Yürüyüş yalnızca alt ekstremitelerin oluşturduğu bir hareket paterni olmayıp, üst ekstremitelerin kinematik organizasyonu da denge, postüral kontrol ve hareket koordinasyonu açısından önemli bir rol oynamaktadır (Bruijn et al., 2010; Collins et al., 2009). Normal yürüyüş sırasında kol salınımı; gövde rotasyonunu dengelemeye, açısal momentumu azaltmaya ve enerji verimliliğini artırmaya katkı sağlar (Collins et al., 2009; Pontzer et al., 2009). Ayrıca kol salınımının kısıtlanmasının metabolik maliyeti artırdığı ve gövde stabilitesini olumsuz etkilediği bildirilmiştir (Ortega et al., 2008).

Üst ekstremitate amputasyonu varlığında ise bu doğal salınım paterni değişebilmekte ve bireyler gövde, pelvis ya da karşı taraf üst ekstremitate hareketlerini artırarak kompensasyon stratejileri geliştirebilmektedir. Üst ekstremitate kaybı sonrası gelişen bu kompensatuar hareketlerin omuz ve gövde biyomekaniğini değiştirdiği ve uzun dönemde kas-iskelet sistemi üzerine ek yük oluşturabileceği belirtilmektedir (Burger & Vidmar, 2016; Østlie et al., 2011).

Protez kullanımı, kaybedilen segmentin kısmen yerine konulması sayesinde kol salınımının simetrisini ve omuz-dirsek eklemler hareket açıklıklarını etkileyebilir. Bununla birlikte protezin ağırlığı, mekanik özellikleri ve askı sistemi gibi faktörler, üst ekstremitate ve gövde kinematiklerini farklı şekillerde modifiye edebilir (Carey et al., 2015). Protezsiz yürüyüşte ise rezidüel ekstremitenin hareketi, gövde lateral fleksiyonu veya karşı taraf kol salınımında artış gibi farklı hareket stratejileri gözlenebilmektedir. Bu değişikliklerin uzun dönemde sekonder kas-iskelet sistemi problemlerine zemin hazırlayabileceği bildirilmektedir (Burger & Vidmar, 2016).

Ancak literatürde üst ekstremitate amputelerinde protezli ve protezsiz yürüyüş sırasında üst ekstremitate kinematiklerinin karşılaştırmalı olarak incelendiği çalışmaların sınırlı olduğu görülmektedir. Özellikle omuz ve dirsek eklemlerine ait açısal değişimlerin ve salınım paternlerinin ayrıntılı analizi, protez kullanımının biyomekanik etkilerini daha iyi anlamak açısından önem taşımaktadır. Bu çalışmanın amacı, üst ekstremitate amputasyonu olan bireylerde protez kullanımının yürüyüş sırasında omuz ve dirsek eklemleri kinematikleri üzerindeki etkisini değerlendirmek ve protezli ile protezsiz yürüyüş arasındaki olası farklılıkları ortaya koymaktır.

2. YÖNTEM

Çalışmaya unilateral dirsek üstü amputasyonu olan, en az 6 aydır, manuel kilitli dirsek eklemleri protez kullanan, yürüyüşü etkileyebilecek herhangi bir nörolojik/ortopedik ya da herhangi bir metabolik problemi olmayan, 25 dirsek üstü ampute ve benzer demografik ve antropometrik özelliklere sahip 25 sağlıklı birey dahil edildi. Yürüyüş sırasında eklemlerin aldığı açısal değerleri ölçmek amacıyla yürüme yolunun sağ ve sol tarafından eş

zamanlı olarak Basler marka yüksek hızlı kameralarla 100 kare/saniye hızda kayıt alınmıştır. Alınan kayıtlar Dartfish Prosuit7 yazılımı ile video üzerinden analiz yapılarak değerlendirilmiştir. Yürüyüşün zaman mesafe parametreleri GAITRite (CIR Systems, NJ, USA) elektronik yürüme yolu kullanılarak analiz edildi. Yürüyüş sırasında üst ekstremité kinematikleri amputelerde protezli ve protezsiz ampute taraf ile sağlam tarafta, sağlıklı bireylerde ise dominant ve nondominant taraf arasında karşılaştırıldı. Katılımcılardan elde edilen veriler SPSS 21.00 yazılımı kullanılarak analiz edildi. Değerlendirmeler sonucunda elde edilen verilerin ortalama ve standart sapmaları her bir grup için tanımlandı. Verilerin normal dağılıma uygunluğu, görsel (histogram ve olasılık grafikleri) ve analitik yöntemlerle (Kolmogorov- Smirnov/ Shapiro- Wilk testleri) kullanılarak değerlendirildi. Ampute ve sağlıklı grup karşılaştırmalarında Mann Whitney U testi kullanıldı. Amputelerin protezli- protezsiz verilerinin karşılaştırılmasında Wilcoxon testi kullanıldı. Ampute grupta protezli ve protezsiz yürüyüş parametreleri arasındaki ilişkinin analizinde Spearman korelasyon analizi kullanıldı.

3. BULGULAR

Çalışmaya dahil edilen bireyler demografik ve antropometrik özellikleri Tablo 1’de verildi. Gruplar arasında yaş,boy ve vücut ağırlığı bakımından fark olmadığı görüldü.

Tablo 1. Katılımcıların demografik özellikleri ve karşılaştırılması

	Min		Max		X±SS		P
	Ampute (n=25)	Sağlıklı (n=25)	Ampute (n=25)	Sağlıklı (n=25)	Ampute (n=25)	Sağlıklı (n=25)	Ampute- Sağlıklı
Yaş(yıl)	30	22	57	51	44,16±9,11	37,50±7,09	0,065
Boy(cm)	157	160	190	192	173,75±9,08	175,27±8,44	0,458
Vücut Ağırlığı (kg)	56	54	96	100	79,91±13,48	83,38±13,20	0,34

Yürüyüş sırasında üst ekstremité kinematiklerinin (kol salınımı, omuz maksimum fleksiyon, omuz maksimum ekstansiyon, dirsek hareket sınırı, dirsek maksimum fleksiyon ve dirsek maksimum ekstansiyonu) amputelerde protezli ve protezsiz ampute taraf ve sağlam tarafta, sağlıklılarda ise dominant ve nondominant tarafta açısıl değerlerinin ortalamaları Tablo 2’de gösterildi.

Tablo 2. Yürüyüş sırasında omuz ve dirsek eklemlerinin kinematik analiz sonuçları

	Protezli		Protezsiz		Sağlıklı	
	Ampute taraf	Sağlam taraf	Ampute taraf	Sağlam taraf	Nondominant taraf	Dominant taraf
	IA	IB	IIA	IIB	IIIA	IIIB
Omuz hareket sınırı	8,59±7,12	34,7±14,46	13,72 ±13,51	33,69±11,7	29,64±11,02	30,45±14,88
Omuz maksimum fleksiyonu	-0,62±15,80	17,77±7,99	9,17±14,27	17,32±7,39	13,77±9,51	13,84±12,23
Omuz maksimum ekstansiyonu	9,22±12,49	16,93±9,07 15,09±11,0	4,55±8,08	16,38±7,21	15,87±6,57	14,94±7,57
Dirsek hareket sınırı	33,33±7,63	4		11,60±3,14	18,07±5,8	19,63±11,13
Dirsek maksimum fleksiyonu	33,33±7,63*	30,35±7,46		30,1±5,60	34,67±8,28	33,28±7,96
Dirsek maksimum ekstansiyonu	33,33±7,63*	16,08±13,7 1		-18,49±5,91	-16,61±6,27	-12±11,73

IA:Protezli Ampute taraf; IB: Protezli Sağlam taraf; IIA: Protezsiz Ampute taraf; IIB: Protezsiz Sağlam taraf; IIIA: Sağlıklı Nondominant taraf; IIIB: Sağlıklı Dominant taraf *Mekanik dirsek ekleminin sabit başlangıç fleksiyonu

Amputelerde protezli ve protezsiz ampute taraf ve sağlam taraf kol salınımı arasında istatistiksel olarak anlamlı fark olduğu ve ampute taraf kol salınımının daha az olduğu bulundu. Sağlıklı katılımcılarda dominant taraf ve nondominant taraf arasında kol salınımı açısından fark bulunmadı. Amputelerde protezli ve protezsiz aynı taraf karşılaştırıldığında kol salınımı açısından fark olmadığı görüldü. Ancak protezsiz iken ampute taraf kol salınımının protezli kol salınımına göre daha fazla olduğu, istatistiksel olarak fark olmadığı belirlendi. Protezli ve protezsiz amputeler, sağlıklılarla karşılaştırıldığında ampute tarafta kol salınımının azaldığı tespit edildi. Amputelerin protezli iken ampute tarafı ile, sağlıklıların nondominant tarafı dirsek maksimum ekstansiyonu arasında fark bulundu (Tablo 3).

Tablo 3. Yürüyüş sırasında omuz ve dirsek eklemlerinin kinematik analiz sonuçlarının karşılaştırılması.

	IA-IB	IIA-IIB	IIIA-IIIB	IA-IIA	IB-IIB	IA-IIIA	IB-IIIB	IIA- IIIA	IIB-IIIB
Omuz hareket sınırı	0,002*	0,004*	0,862	0,11	0,433	0,000*	0,385	0,000*	0,33
Omuz maksimum fleksiyonu	0,004*	0,034*	0,199	0,06	0,594	0,002*	0,228	0,034*	0,228
Omuz maksimum ekstansiyonu	0,019*	0,002*	0,632	0,328	0,61	0,024*	0,933	0,000*	0,949
Dirsek hareket sınırı	0,109		0,744		0,433	0,007*	0,099		0,004*
Dirsek maksimum fleksiyonu	0,593		0,041*		0,875	0,841	0,352		0,341
Dirsek maksimum ekstansiyonu	0,109		0,098		0,784	0,012*	0,220		0,117

IA:Protezli Ampute taraf; IB: Protezli Sağlam taraf; IIA: Protezsiz Ampute taraf; IIB: Protezsiz Sağlam taraf; IIIA: Sağlıklı Nondominant taraf; IIIB: Sağlıklı Dominant taraf, *p<0,05.

Amputeler sağlıklılarla karşılaştırıldığında, hız ve kadans açısından, hem protezli hem protezsiz fark bulunduğu ve yürüyüş hızı ve kadansın azaldığı görüldü. Adım genişliği açısından hem grup içi hem gruplar arası karşılaştırmada fark olmadığı gözlemlendi (Tablo 4).

Tablo 4. Yürüyüşün zaman- mesafe karakteristiklerinden yürüyüş hızı ve kadansın karşılaştırılması.

	Protezli- Protezsiz	Protezli- Sağlıklı	Protezsiz- Sağlıklı
Yürüyüş hızı	0,814	0,002*	0,009*
Kadans	0,79	0,006*	0,006*

*p<0,05.

4. SONUÇ, TARTIŞMA VE ÖNERİLER

Bu çalışmada, unilateral dirsek üstü amputasyonu olan bireylerde yürüyüş sırasında üst ekstremitelerinin kinematiklerinin protezli ve protezsiz koşullarda değiştiği ve sağlıklı bireylerden farklılaştığı gösterilmiştir. Bulgularımız, hem protezli hem de protezsiz yürüyüşte ampute tarafta kol salınımının sağlıklı bireylere kıyasla azaldığını ortaya koymaktadır. Kol salınımının yürüyüş stabilitesi, gövde rotasyonu ve enerji maliyeti

üzerindeki düzenleyici rolü göz önüne alındığında (Bruijn et al., 2010; Collins et al., 2009; Pontzer et al., 2009), bu azalmanın yürüyüşün bütüncül organizasyonunu etkileyebileceği düşünülmektedir. Ayrıca amputelerin protezli yürüyüşte ampute tarafı ile sağlıklı bireylerin nondominant tarafı arasında dirsek maksimum ekstansiyonu açısından anlamlı fark bulunması, üst ekstremité amputasyonunun yalnızca segmental değil, sistemik bir biyomekanik adaptasyona yol açtığını düşündürmektedir.

Kol salınımının azalması, amputelerde gözlenen düşük yürüyüş hızı ve kadans ile ilişkili olabilir. Literatürde kol salınımının metabolik maliyeti azalttığı ve yürüyüş verimliliğini artırdığı bildirilmektedir (Ortega et al., 2008; Umberger, 2008). Bu bağlamda amputelerde kol salınımının azalması hem hızın düşmesine katkıda bulunmakta hem de gövde ve pelvis düzeyinde kompensatuar hareketlerin artmasına neden olabilmektedir. Üst ekstremité kaybı sonrası gelişen bu kompensasyonların uzun dönemde kas-iskelet sistemi ağırları ve aşırı kullanım problemleri ile ilişkili olduğu bildirilmektedir (Burger & Vidmar, 2016; Østlie et al., 2011). Çalışmamızda sağlıklı bireylerde dominant ve nondominant taraf arasında anlamlı fark bulunmaması, gözlenen asimetrisinin amputasyona özgü bir durum olduğunu desteklemektedir.

Protez kullanımının kol salınımını belirgin şekilde artırmaması dikkat çekicidir. Literatürde protez ağırlığı, mekanik eklem tasarımı ve askı sistemlerinin üst ekstremité biyomekaniğini doğrudan etkileyebileceği bildirilmektedir (Carey et al., 2015; Resnik et al., 2019). Çalışmamıza dahil edilen bireylerin manuel kilitli dirsek eklemine sahip protez kullanmaları, doğal kol salınımını kısıtlamış olabilir. Mekanik dirsek eklemine sabit başlangıç fleksiyonu ve protezin segmental atalet özellikleri, omuz ve dirsek hareket açıklıklarını sınırlandırarak fizyolojik salınım paterninden sapmaya neden olmuş olabilir. Özellikle dirsek maksimum ekstansiyonu açısından sağlıklı bireylerle saptanan fark, mekanik dirsek tasarımının yürüyüş kinematiklerini etkileyebileceğini düşündürmektedir.

Yürüyüşün zaman-mesafe parametreleri incelendiğinde, amputelerde hem protezli hem protezsiz yürüyüşte hız ve kadansın sağlıklı bireylere göre düşük olduğu belirlenmiştir. Kol salınımının gövde açısal momentumu ile ilişkili olduğu ve yürüyüş sırasında açısal momentumun düzenlenmesinde rol oynadığı bilinmektedir (Collins et al., 2009). Buna karşın adım genişliğinde fark olmaması, bireylerin mediolateral dengeyi geniş tabanlı bir strateji ile değil, üst ekstremité ve gövde düzeyinde kompensasyonlarla sağlamaya çalıştıklarını düşündürmektedir. Bu bulgular, üst ekstremité amputasyonunun alt ekstremité parametrelerinden ziyade üst gövde ve üst ekstremité kinematığı üzerinden yürüyüşü etkileyebileceğini göstermektedir.

Klinik açıdan değerlendirildiğinde, üst ekstremité amputelerinde protez tasarımının yalnızca kavrama fonksiyonu veya estetik gereksinimler doğrultusunda değil, yürüyüş sırasında ortaya çıkan dinamik

gereksinimler dikkate alınarak planlanması gerektiği söylenebilir. Özellikle daha hafif materyaller, serbest veya yarı serbest dirsek mekanizmaları ve salınma izin veren tasarımlar yürüyüş simetrisini olumlu yönde etkileyebilir. Ayrıca rehabilitasyon programlarında kol salınım eğitimi ve gövde rotasyon kontrolüne yönelik müdahalelerin yer alması önerilebilir. Yürüyüş ekonomisinin artırılmasına yönelik egzersiz yaklaşımları da fonksiyonel sonuçları iyileştirebilir (Ortega et al., 2008; Umberger, 2008).

Bu çalışmanın bazı sınırlılıkları bulunmaktadır. Örneklem grubunun yalnızca manuel kilitli dirsek eklemli protez kullanan bireylerden oluşması, farklı protez tiplerinin karşılaştırılmasına olanak tanımamıştır. Ayrıca analizlerin iki boyutlu video temelli sistemle yapılmış olması, üç boyutlu hareket analizine kıyasla daha sınırlı kinematik veri sağlamaktadır. Üç boyutlu hareket analizi sistemlerinin segmental rotasyonları ve açısal momentum değişimlerini daha ayrıntılı ortaya koyabildiği bilinmektedir (Baker, 2006). Gelecek çalışmalarda farklı protez mekanizmalarının, özellikle mikroişlemci kontrollü dirsek sistemlerinin yürüyüş kinematiği üzerindeki etkilerinin incelenmesi; kas aktivasyon paternleri ve enerji tüketimi gibi parametrelerin değerlendirilmesi önerilmektedir.

Sonuç olarak, üst ekstremité amputasyonu yürüyüş sırasında kol salınımı ve dirsek kinematiğinde belirgin değişikliklere yol açmaktadır. Protez kullanımı bu değişiklikleri tamamen ortadan kaldırmamakta; özellikle mekanik dirsek tasarımı kol salınımını sınırlayabilmektedir. Bu nedenle üst ekstremité amputelerinde yürüyüş analizi, protez seçimi ve rehabilitasyon planlamasında dikkate alınması gereken önemli bir değerlendirme alanıdır.

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UNİLATERAL TRANSTİBİAL AMPUTASYONU OLAN BİREYLERDE FARKLI EĞİMLERDE YÜRÜYÜŞÜN ZAMAN-MESAFE PARAMETRELERİNE ETKİSİ

Dr. Fzt Ali İmran YALÇIN¹/ Dr. Fzt. Merve SARIİPEK²/ Prof. Dr. Fatma Gül YAZICIOĞLU³

¹Hacettepe Üniversitesi, Hareket Analizi ve Podiatri Uygulama ve Araştırma Merkezi (HAPUAM), Ankara Türkiye, Protez Rehabilitasyonu, Biyomekanik, fztaliyalcin@gmail.com, <https://orcid.org/0000-0002-7361-4535>

²Fizyoterapi ve Rehabilitasyon Bölümü, Ordu Üniversitesi, Ordu, Türkiye, Biyomekanik, El Rehabilitasyonu, mervesariipek@odu.edu.tr, <https://orcid.org/0000-0001-8532-0019>

³Hacettepe Üniversitesi, Fizik Tedavi ve Rehabilitasyon Fakültesi, Ankara Türkiye, Protez Rehabilitasyonu, Biyomekanik, fztaliyalcin@gmail.com, <https://orcid.org/0000-0002-1160-979X>

Özet

Alt ekstremité amputasyonu olan bireylerde rehabilitasyon ve protez uygulamaları sonrasında hedeflenen temel fonksiyon yürüyüştür. Unilateral alt ekstremité amputasyonu olan bireylerin yürüyüş sırasında ampute olmayan ekstremitéye daha fazla yük bindirdikleri, duruş fazının bu ekstremitéde uzadığı ve buna bağlı asimetrik bir yüklenme paterni sergiledikleri bildirilmektedir. Bu asimetri sekonder komplikasyonlara yol açabilmektedir. Yürüyüşün ayrıntılı olarak incelenmesi, kompensasyon mekanizmalarının ve bireylerin fonksiyonel ihtiyaçlarının belirlenmesine katkı sağlamaktadır. Ancak unilateral transtibial amputasyonu olan bireylerde yürüyüş kinematikğini inceleyen çalışmaların çoğulaboratuvar ortamında, düz zeminde yapılmış olup günlük yaşamda karşılaşılan çevresel koşulları yeterince yansıtmamaktadır. Bu çalışma, unilateral transtibial amputasyonu olan bireylerde farklı eğimlerde yürüyüş sırasında alt ekstremité eklemlerinde meydana gelen kinematik değişikliklerin protezli ve protezsiz ekstremité ile sağlıklı bireyler arasında farklılık gösterip göstermediğini incelemek amacıyla planlanmıştır. Araştırmaya 18-64 yaş aralığında unilateral transtibial amputasyona sahip 10 birey ile demografik özellikleri benzer sağlıklı 10 birey dahil edilmiştir. Yürüyüş sırasında üç boyutlu kinematik veriler MVN BIOMECH Awinda sistemi kullanılarak toplanmıştır. Yürüyüş koşulları %12 eğimde rampa yukarı, %12 eğimde rampa aşağı ve düz zemin olarak belirlenmiştir. Veriler Visual3D yazılımı ile analiz edilmiş ve istatistiksel değerlendirmeler SPSS 21 programı kullanılarak gerçekleştirilmiştir. Gruplar arası karşılaştırmalarda Mann-Whitney U testi, grup içi karşılaştırmalarda Wilcoxon testi kullanılmıştır. Unilateral transtibial amputasyonu olan bireylerde yürüyüş hızı ve adım uzunluğu rampa yukarı ve rampa aşağı yürüyüşte düz zemine kıyasla anlamlı olarak azalmıştır ($p<0,01$). Rampa yukarı yürüyüşte kadans azalırken adım süresi, duruş süresi ve döngü süresi artmıştır ($p<0,05$). Sağlıklı bireylerde de

benzer deęişiklikler gözlenmiştir ($p<0,01$). Ekstremiteler arası karşılaştırmalarda protezli ekstremitenin adım uzunluğu ve duruş süresi açısından diğer gruplardan anlamlı olarak farklılaştığı saptanmıştır ($p<0,05$). Sonuç olarak, farklı eğimlerde yürüyüş unilateral transtibial amputasyonu olan bireylerde zaman–mesafe parametrelerini anlamlı biçimde deęiştirmekte ve ekstremiteler arası asimetriyi daha belirgin hale getirmektedir. Bu bulgular, yürüyüş deęerlendirmelerinde eğimli zemin koşullarının göz önünde bulundurulmasının önemini vurgulamaktadır.

Anahtar kelimeler: Ampute, yürüyüş, kinematik

THE EFFECT OF DIFFERENT SLOPES ON SPATIOTEMPORAL GAIT PARAMETERS IN INDIVIDUALS WITH UNILATERAL TRANSTIBIAL AMPUTATION

Abstract

The primary functional goal of rehabilitation and prosthetic interventions in individuals with lower limb amputation is walking, a frequently performed daily activity. Individuals with unilateral lower limb amputation exhibit asymmetric loading during walking, characterized by greater load on the non-amputated limb and a prolonged stance phase, which may lead to secondary complications. Detailed gait analysis is essential for identifying compensatory strategies and understanding functional requirements. However, most studies investigating gait kinematics in individuals with unilateral transtibial amputation have focused on level-ground walking at self-selected speeds, which may not adequately represent real-life environmental demands. This study aimed to examine whether lower limb joint kinematic changes during walking on different slopes in individuals with unilateral transtibial amputation differ between the prosthetic and non-prosthetic limbs and compared with healthy individuals. Participants aged 18-64 years with unilateral transtibial amputation and healthy individuals with similar demographic characteristics were included. Three-dimensional lower extremity kinematic data were collected using the MVN BIOMECH Awinda system during level-ground, uphill (12% incline), and downhill (12% incline) walking. Data were analyzed using Visual3D software, and statistical analyses were performed with SPSS version 21. Walking speed and step length were significantly reduced during uphill and downhill walking compared with level walking in individuals with unilateral transtibial amputation ($p < 0.01$). During uphill walking, cadence decreased, while step time, stance time, and gait cycle time increased ($p < 0.05$). Similar trends were observed in healthy individuals ($p < 0.01$). Inter-limb comparisons showed that the prosthetic limb differed significantly in step length and stance time ($p < 0.05$). In conclusion, walking on inclined surfaces alters spatiotemporal gait parameters and increases inter-limb asymmetry in individuals with unilateral transtibial amputation, highlighting the importance of including slope conditions in gait assessments.

Keywords: Amputation, gait, kinematics

1. GİRİŞ

Alt ekstremitte amputasyonu olan bireylerde rehabilitasyon sürecinin ve protez uygulamalarının temel hedefi, bağımsız ve güvenli bir yürüyüş paterninin yeniden kazandırılmasıdır (Eshraghi et al., 2014; Staats, 1996). Yürüyüş, yalnızca mobilitayı değil; bireyin toplumsal katılımını, yaşam kalitesini ve uzun dönem kas-iskelet sağlığını da doğrudan etkileyen temel bir fonksiyondur. Bununla birlikte unilateral alt ekstremitte amputasyonu olan bireylerin yürüyüş sırasında yük dağılımında belirgin değişiklikler ortaya çıkmaktadır. Literatürde, bu bireylerin ampute olmayan ekstremiteye daha fazla yük aktardıkları, duruş fazının bu tarafta uzadığı ve sonuç olarak asimetrik bir yüklenme paterni geliştirdikleri bildirilmektedir (Grumillier et al., 2008; Kovač et al., 2010; Soares et al., 2009; Yoo, 2014). Gelişen bu asimetri; eklem dejenerasyonu, bel ve diz ağrısı gibi sekonder muskuloskeletal komplikasyonlara zemin hazırlayabilmektedir (Ajibade et al., 2013; Rueda et al., 2013; Yoo, 2014).

Yürüyüşün ayrıntılı biyomekanik analizi, ortaya çıkan kompensasyon stratejilerinin anlaşılmasına ve bireylerin fonksiyonel gereksinimlerinin belirlenmesine önemli katkı sağlamaktadır (Czerniecki & Gitter, 1996). Özellikle kinematik parametrelerin değerlendirilmesi, protez kullanımının alt ekstremitte eklem hareketleri üzerindeki etkilerini ortaya koymak açısından kritik öneme sahiptir. Ancak unilateral transtibial amputasyonu olan bireylerde yürüyüş kinematiğini inceleyen çalışmaların büyük bir kısmı laboratuvar ortamında ve düz zemin koşullarında gerçekleştirilmiştir (Chambers & Sutherland 2002; Czerniecki & Gitter, 1996; Rietman et al., 2002; Skinner & Effeney, 1985). Bu durum, günlük yaşamda sık karşılaşılan eğimli yüzeyler gibi çevresel değişkenlerin yürüyüş paternine etkisinin yeterince yansıtılamamasına neden olmaktadır.

Oysa gerçek yaşam ortamında bireyler yalnızca düz zeminde değil; farklı eğimlerde, değişken yüzey koşullarında ve çeşitli çevresel zorluklar altında yürümektedir. Eğimli yüzeylerde yürüyüş, eklem hareket açıklıklarını, kas aktivasyon paternlerini ve yük dağılımını önemli ölçüde değiştirebilmekte; bu değişiklikler amputasyonlu bireylerde daha belirgin kompensasyonlara yol açabilmektedir. Bu nedenle farklı eğimlerde yürüyüşün incelenmesi hem protez tasarımının geliştirilmesi hem de rehabilitasyon programlarının bireye özgü planlanması açısından klinik olarak anlamlıdır.

Bu çalışma, unilateral transtibial amputasyonu olan bireylerde farklı eğimlerde yürüyüş sırasında alt ekstremitte eklemlerinde meydana gelen kinematik değişiklikleri incelemeyi ve bu değişikliklerin protezli ekstremitte, protezsiz ekstremitte ve sağlıklı kontrol grubu arasında farklılık gösterip göstermediğini ortaya koymayı amaçlamaktadır. Bu doğrultuda elde edilecek bulguların, eğimli yüzeylerde yürüyüşe yönelik klinik değerlendirme ve müdahale stratejilerine katkı sağlaması hedeflenmektedir.

2. YÖNTEM

Araştırmaya 18-64 yaş aralığında en az 1 yıldır bir diz altı protezi kullanan, Medicare Fonksiyonel sınıflandırma sisteminden K3 ve üzeri seviyede olan, unilateral transtibial amputasyona sahip 10 birey ile demografik özellikleri benzer sağlıklı 10 birey dahil edilmiştir.

Yürüyüş sırasında üç boyutlu kinematik veriler MVN BIOMECH Awinda (Xsens Technologies B. V., Enschede, Netherlands) sistemi kullanılarak toplanmıştır. Yürüyüş değerlendirmesi Biodex Gait Trainer 2 (Biodex Inc., Shirley, New York, USA) marka yürüyüş bandı kullanılarak yapıldı. Yürüyüş koşulları yürüme bandında %0 eğimle düz koşulda, %12 eğimde rampa yukarı, %12 eğimde rampa aşağı olacak şekilde uygulandı. Veriler MVN Analyze yazılımı kullanılarak toplandı ve Visual3D (C-Motion, Inc, Germantown, MD) yazılımı ile raporlandı. İstatistiksel değerlendirmeler SPSS 21 programı kullanılarak gerçekleştirilmiştir. Gruplar arası karşılaştırmalarda Mann–Whitney U testi, grup içi karşılaştırmalarda Wilcoxon testi kullanılmıştır.

3. BULGULAR

Çalışmaya dahil edilen bireyler demografik ve antropometrik özellikler bakımından benzerdi (Tablo 1). Bireylerin protezlerine ve amputasyonlarına yönelik bulgular Tablo 2’ de verildi.

Tablo 1. Katılımcı özellikleri

	Ampute (X±SS)	Sağlıklı (X±SS)	p
Yaş (yıl)	36,5±10,33	33,70±6,27	0,761
Boy (cm)	173,7±9,67	177,5±5,75	0,209
Vücut Ağırlığı (kg)	77,85±11,44	78,80±11,87	0,545

Tablo 2. Amputasyon ve proteze ait bilgiler

Amputasyon nedeni	Travma	6 (60)
	Vasküler nedenler	3 (30)
	Konjenital	1 (10)
Protez tipi	Modüler	10 (100)
Suspansiyon Sistemi	Aktif vakum	7 (70)
	Pasif Vakum	2 (20)
	Klasik	1 (10)
Protez Ayak	K3-K4 Karbon Ayak	10 (100)

Bireylerin farklı eğimlerdeki yürüyüş kinematiklerine ait bulgular Tablo 3’te verildi. Unilateral transtibial amputasyonu olan bireylerde yürüyüş hızı ve adım uzunluğu rampa yukarı ve rampa aşağı yürüyüşte düz zemine kıyasla anlamlı olarak azalmıştır ($p<0,01$). Rampa yukarı yürüyüşte kadans azalırken adım süresi, duruş süresi ve döngü süresi artmıştır ($p<0,05$). Sağlıklı bireylerde de benzer değişiklikler gözlenmiştir ($p<0,01$)

(Tablo 4). Ekstremiteler arası karşılaştırmalarda protezli ekstremitenin adım uzunluğu ve duruş süresi açısından diğer gruplardan anlamlı olarak farklılaştığı saptanmıştır ($p<0,05$) (Tablo 5) .

Tablo 3. Amputelerin farklı eğimlerde yürüyüşün zaman mesafe parametrelerinin karşılaştırılması

	Parametre	Düz	Rampa yukarı	Rampa aşağı	Düz- Rampa yukarı (p)*	Düz- Rampa aşağı (p)*
Ampute	Hız (m/sn)	0,66(0,61-0,88)	0,63(0,55-0,75)	0,56(0,44-0,75)	0,007	0,005
	Kadans (Adım/dk)	98,00(88,75-104,00)	93,00(83,25-96,00)	102,00(98,75-106,00)	0,010	0,109
Protezli taraf	Adım Uzunluğu(cm)	0,45(0,38-0,53)	0,44(0,41-0,52)	0,36(0,19-0,43)	0,007	0,005
	Adım Süresi(sn)	0,60(0,57-0,66)	0,63(0,59-0,71)	0,56(0,53-0,60)	0,028	0,609
	Duruş Süresi(sn)	0,83(0,79-0,94)	0,88(0,84-0,98)	0,78(0,77-0,84)	0,032	0,474
	Sallanma Süresi(sn)	0,38(0,35-0,42)	0,42(0,38-0,46)	0,36(0,33-0,38)	0,306	0,036
	Döngü Süresi(sn)	1,22(1,14-1,35)	1,29(1,25-1,43)	1,18(1,10-1,23)	0,012	0,753
Etkilenmemiş taraf	Adım Uzunluğu(cm)	0,41(0,37-0,51)	0,38(0,34-0,45)	0,34(0,31-0,42)	0,007	0,005
	Adım Süresi(sn)	0,62(0,57-0,69)	0,67(0,64-0,72)	0,60(0,57-0,62)	0,015	0,232
	Duruş Süresi(sn)	0,84(0,80-0,97)	0,90(0,87-1,11)	0,80(0,76-0,88)	0,092	0,953
	Sallanma Süresi(sn)	0,38(0,34-0,39)	0,38(0,36-0,38)	0,34(0,31-0,36)	0,310	0,012
	Döngü Süresi(sn)	1,22(1,16-1,36)	1,29(1,25-1,44)	1,16(1,10-1,21)	0,011	0,400

Tablo 4. Sağlıklı bireylerin farklı eğimlerde yürüyüşün zaman mesafe parametrelerinin karşılaştırılması

Parametre	Düz	Rampa yukarı	Rampa aşağı	Düz-Rampa yukarı (p)*	Düz-Rampa aşağı (p)*
Hız (m/sn)	0,94(0,84-1,08)	0,83(0,78-0,91)	0,79(0,71-0,90)	0,005	0,005
Kadans (Adım/dk)	102,00(98,00-106,50)	95,00(88,50-102,50)	107,50(102,75-112,00)	0,009	0,959
Adım Uzunluğu(cm)	0,55(0,52-0,61)	0,53(0,48-0,57)	0,45(0,40-0,49)	0,005	0,005
Adım Süresi(sn)	0,59(0,56-0,61)	0,63(0,58-0,67)	0,56(0,54-0,59)	0,009	0,878
Duruş Süresi(sn)	0,78(0,75-0,85)	0,85(0,76-0,94)	0,75(0,70-0,79)	0,102	0,919
Sallanma Süresi(sn)	0,37(0,36-0,39)	0,39(0,37-0,42)	0,36(0,35-0,39)	0,058	0,384
Döngü Süresi(sn)	1,17(1,11-1,22)	1,26(1,16-1,35)	1,12(1,07-1,16)	0,009	0,959

Tablo 5. Farklı eğimlerde yürüyüşün zaman mesafe parametrelerinin ekstremiteler arası karşılaştırması

Parametre	Protezli-Etkilenmemiş (p)*	Protezli-Sağlıklı (p)**	Etkilenmemiş-Sağlıklı (p)**
Düz			
Adım Uzunluğu(cm)	0,066	0,544	0,140
Adım Süresi(sn)	0,007	0,405	0,007
Duruş Süresi(sn)	0,067	0,069	0,014
Sallanma Süresi(sn)	0,537	0,149	0,305
Döngü Süresi(sn)	0,942	0,049	0,034
Rampa yukarı			
Adım Uzunluğu(cm)	0,008	0,015	0,008
Adım Süresi(sn)	0,079	0,495	0,150
Duruş Süresi(sn)	0,005	0,363	0,112
Sallanma Süresi(sn)	0,059	0,426	0,102
Döngü Süresi(sn)	0,655	0,325	0,325
Rampa aşağı			
Adım Uzunluğu(cm)	0,292	0,089	0,161
Adım Süresi(sn)	0,041	0,970	0,056
Duruş Süresi(sn)	0,020	0,058	0,028
Sallanma Süresi(sn)	0,015	0,518	0,044
Döngü Süresi(sn)	0,317	0,120	0,343

4. SONUÇ, TARTIŞMA VE ÖNERİLER

Farklı eğimlerde yürüyüşün zaman-mesafe parametreleri incelendiğinde, tüm bireylerde eğim değişikliği ile birlikte yürüyüş hızının azaldığı; en yüksek hızın düz zeminde, en düşük hızın ise rampa aşağı yürüyüşte olduğu görülmüştür. Vrieling ve Langlois'nun çalışmalarında da benzer sonuçlar bildirilmiş olmakla birlikte, bu çalışmalarda bireylerin daha yüksek hızlarda yürüdüğü görülmektedir (Langlois et al., 2014; Vrieling et al., 2008). Bu farklılığın, çalışmamızda daha yüksek eğim derecelerinin kullanılmış olmasından kaynaklanabileceği düşünülmektedir. Kadansın rampa çıkarken anlamlı şekilde azaldığı, rampa inerken ise anlamlı fark olmamakla birlikte artış eğilimi gösterdiği belirlenmiştir. Rampa çıkarken kadans ve adım uzunluğundaki azalma, hızdaki düşüş ile uyumludur ve Doyle ve arkadaşlarının bulgularını desteklemektedir (Doyle et al., 2015). Rampa inerken hızın en düşük olmasına rağmen kadansta belirgin azalma görülmemesi, bu durumun adım uzunluğundaki belirgin azalmadan kaynaklandığını düşündürmektedir. En yüksek adım uzunluğunun düz zeminde, en düşük adım uzunluğunun ise rampa inerken elde edilmesi bu yorumu desteklemektedir. Diğer zaman parametreleri de benzer eğilim göstermiştir.

Ekstremiteler arası karşılaştırmada, özellikle rampa çıkarken tüm ekstremiteler arasında anlamlı fark bulunmuştur. Bu durumun, ampute bireylerde protezli tarafta duruş fazının kısılmasına bağlı olarak adım uzunluğunda ortaya çıkan farklılıktan ve sağlıklı grubun daha yüksek hızlarda yürütmesine bağlı olarak daha

büyük adım uzunluğu değerlerine sahip olmasından kaynaklandığı düşünülmektedir. Benzer farklılıklar rampa inerken duruş ve sallanma sürelerinde de görülmüş olup, bu durumun hem amputasyon grubundaki asimetric yüklenme paterninden hem de sağlıklı grubun daha kısa faz sürelerine sahip olmasından kaynaklandığı değerlendirilmektedir.

Sonuç olarak, farklı eğimlerde yürüyüş unilateral transtibial amputasyonu olan bireylerde zaman–mesafe parametrelerini anlamlı biçimde değiştirmekte ve ekstremiteler arası asimetriyi daha belirgin hale getirmektedir. Bu bulgular, yürüyüş değerlendirmelerinde eğimli zemin koşullarının göz önünde bulundurulmasının önemini vurgulamaktadır.

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EPIXS YAZILIMI KULLANILARAK METFORMİNİN FOTON ETKİLEŞİM PARAMETRELERİNİN İNCELENMESİ

Dr. Öğr. Üyesi Halime ERZEN YILDIZ¹/ Dr. Hamza TUNÇ²/ Prof. Dr. Berna OTO³

¹Van Yüzüncü Yıl Üniversitesi, Sağlık Hizmetleri Meslek Yüksekokulu, Tıbbi Hizmetler ve Teknikler Bölümü, Van, Türkiye, halimeyildiz@yyu.edu.tr, ORCID ID: <https://orcid.org/0000-0002-0603-1815>

²Van Yüzüncü Yıl Üniversitesi, Muradiye Meslek Yüksekokulu, Tıbbi Hizmetler ve Teknikler Bölümü, Van, Türkiye, hamzatunc@yyu.edu.tr, ORCID ID: <https://orcid.org/0000-0002-2787-8126>

³Van Yüzüncü Yıl Üniversitesi, Denizcilik Fakültesi, Gemi Makineleri Mühendisliği Bölümü, Van, Türkiye, bpekgoz@yyu.edu.tr, ORCID ID: <https://orcid.org/0000-0003-4565-1790>

Özet

Metformin (1,1-dimetilbiguanid hidroklorür), en yaygın kullanılan oral antidiyabetik ilaçlardan biri olup, tip 2 diabetes mellitus tedavisinde güvenli, etkili ve iyi tolere edilen bir terapötik ajan olarak kabul edilmektedir. Moleküler formülü $C_4H_{11}N_5$ olan metformin, başlangıçta Galega officinalis bitkisinden elde edilen doğal bir bileşik olan galeginden türetilmiş bir biguanid türevidir. Metformin, kan şekeri kontrolündeki yerleşik rolünün yanı sıra, çeşitli metabolik ve klinik durumlarda potansiyel uygulamaları nedeniyle giderek artan bir ilgi görmektedir. Tıbbi, endüstriyel ve bilimsel alanlarda iyonlaştırıcı radyasyon kullanımının yaygınlaşması, farmasötik bileşiklerin radyasyon etkileşim özelliklerinin değerlendirilmesinin önemini ortaya koymuştur. Bu çalışmada, metforminin foton etkileşim parametreleri teorik olarak incelenmiştir. EpiXS yazılım paketi kullanılarak, 1 keV ile 100 GeV arasındaki geniş bir foton enerji aralığında kütle zayıflatma katsayısı (MAC), etkin atom numarası (Z_{eff}) ve etkin elektron yoğunluğu (N_{eff}) hesaplanmıştır. Elde edilen sonuçlar, metforminin düşük atom numaralı organik bileşiklere özgü radyasyon etkileşim özellikleri sergilediğini göstermektedir. Düşük enerji bölgesinde fotoelektrik soğurma baskın olup, yüksek MAC ve Z_{eff} değerlerine yol açmakta; bu değerler enerji arttıkça hızla azalmaktadır. Orta enerji aralığında ise Compton saçılması temel etkileşim mekanizması haline gelmekte ve parametrelerde görece kararlı değerler gözlenmektedir. Yüksek enerji bölgesinde çift oluşumu süreci, hesaplanan parametrelerde hafif bir artışa neden olmaktadır. Elektron yoğunluğunun enerjiye bağlı değişimi de bu etkileşim mekanizmalarıyla uyumlu olarak üç farklı bölge ortaya koymuştur.

Bu bulgular, metforminin radyasyon etkileşim davranışı hakkında değerli bilgiler sunmakta ve ilacın radyasyonla ilişkili tıbbi ve bilimsel uygulamalardaki potansiyel öneminin anlaşılmasına katkı sağlamaktadır.

Anahtar kelimeler: Metformin, radyasyon etkileşimi, kütle zayıflatma katsayısı, etkin atom numarası

INVESTIGATION OF PHOTON INTERACTION PARAMETERS OF METFORMIN USING EPIXS SOFTWARE

Abstract

Metformin (1,1-dimethylbiguanide hydrochloride) is one of the most widely used oral antidiabetic drugs and is recognized as a safe, effective, and well-tolerated therapeutic agent for the treatment of type 2 diabetes mellitus. With the molecular formula $C_4H_{11}N_5$, metformin is a biguanide derivative originally developed from galegine, a natural compound obtained from the plant *Galega officinalis*. In addition to its established role in glycemic control, metformin has attracted increasing attention for potential applications in various metabolic and clinical conditions. The growing use of ionizing radiation in medical, industrial, and scientific fields has highlighted the importance of evaluating the radiation interaction properties of pharmaceutical compounds. In this study, the photon interaction parameters of metformin were theoretically investigated. Using the EpiXS software package, the mass attenuation coefficient (MAC), effective atomic number (Z_{eff}), and effective electron density (N_{eff}) were calculated over a broad photon energy range from 1 keV to 100 GeV. The results demonstrate that metformin exhibits radiation interaction characteristics typical of low atomic number organic compounds. In the low-energy region, photoelectric absorption is dominant, leading to high MAC and Z_{eff} values that decrease rapidly with increasing energy. In the intermediate energy range, Compton scattering becomes the primary interaction mechanism, resulting in relatively stable parameter values. At higher energies, the pair production process contributes to a slight increase in the calculated parameters. The energy dependence of electron density also revealed three distinct regions consistent with these interaction mechanisms. These findings provide valuable insight into the radiation interaction behavior of metformin and contribute to the understanding of its potential relevance in radiation-related medical and scientific applications.

Keywords: Metformin, Radiation interaction, Mass attenuation coefficient, Effective atomic number

1. Introduction

Metformin (1,1-dimethylbiguanide hydrochloride) is one of the most widely used and extensively studied pharmaceutical agents in modern medicine. Its history reflects a remarkable journey from herbal origins to global clinical importance. The glucose-lowering potential of metformin was first recognized in the 1920s; however, this discovery was largely overlooked for decades. The compound was rediscovered in the 1940s during investigations on antimalarial agents and was later introduced in 1957 for the treatment of adult-onset diabetes. Although initially considered less potent than other biguanides, metformin survived the withdrawal of phenformin and buformin in the late 1970s due to their association with lactic acidosis. Continuous clinical use and research during the 1980s and 1990s eventually established metformin as a safe, effective, and unique therapeutic agent. Following its introduction into the United States in 1995 and the publication of the UK Prospective Diabetes Study (UKPDS) results in 1998, metformin became the first-line treatment for type 2 diabetes mellitus. Today, it is being evaluated for a variety of additional clinical indications beyond glycemic control (Bailey, 2017).

Metformin is chemically classified as a biguanide derivative and originates from galegine, a natural guanidine-based compound obtained from the plant *Galega officinalis*. The molecular formula of metformin is $C_4H_{11}N_5$, reflecting its nitrogen-rich biguanide structure. Early investigations in the 1920s revealed the glucose-lowering properties of galegine; however, its clinical application was limited due to toxicity. Synthetic biguanide derivatives such as metformin and phenformin were subsequently developed and introduced into clinical practice in the 1950s. Structurally, metformin consists of two coupled guanidine groups with additional substitutions, distinguishing it from most modern drugs that are designed to target specific molecular pathways. The chemical structure of metformin is illustrated in Figure 1, highlighting its characteristic biguanide framework. Unlike many contemporary pharmaceuticals, metformin was not originally designed for a specific biological mechanism, yet it has become one of the most effective and widely prescribed antidiabetic agents (Bailey, 2017; Rena et al., 2017).

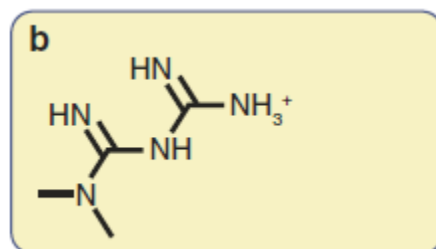


Figure 1. Molecular structure of metformin ($C_4H_{11}N_5$).

Diabetes mellitus is a chronic metabolic disorder characterized by elevated blood glucose levels due to impaired insulin secretion or insulin resistance. Persistent hyperglycemia leads to severe complications including cardiovascular disease, neuropathy, nephropathy, and retinopathy. Metformin plays a central role in the management of type 2 diabetes by improving insulin sensitivity, reducing hepatic glucose production, and decreasing intestinal glucose absorption. In addition to its antidiabetic activity, metformin has been used in the prevention of diabetes in high-risk individuals and in the treatment of polycystic ovarian syndrome. Although concerns regarding adverse effects such as lactic acidosis previously limited its use, recent studies have demonstrated that these risks are minimal when proper clinical guidelines are followed. Furthermore, emerging evidence suggests that metformin may possess renoprotective and other beneficial properties beyond glycemic control (Nasri and Rafieian-Kopaei, 2014).

The interaction of ionizing radiation with matter has become an increasingly important research area due to the widespread use of nuclear radiation in medical imaging, radiotherapy, industry, and scientific applications. Ionizing radiation can cause significant biological damage through direct interaction with cellular macromolecules such as DNA, lipids, and proteins, or indirectly through the generation of reactive oxygen species. Consequently, the identification of radioprotective agents and effective shielding materials is of great interest. Numerous studies have investigated the radiation interaction properties of pharmaceutical compounds, including chemotherapeutic, anti-inflammatory, and antiviral drugs. Parameters such as mass attenuation coefficient (MAC), effective atomic number (Z_{eff}), and effective electron density (N_{eff}) are essential for understanding the behavior of materials under gamma and neutron irradiation. Computational tools such as EpiXS and NGCal have been successfully employed to evaluate these parameters for various biologically active compounds (Hiremath et al., 2024).

The stability of pharmaceutical products under ionizing radiation is also an important issue. Exposure of drugs to gamma or X-ray radiation may lead to chemical degradation, formation of toxic by-products, and reduction in therapeutic efficacy. Therefore, the development of effective radiation shielding systems for the storage, transportation, and protection of drugs in clinical environments has gained increasing attention. Polymer materials are widely used in the packaging of pharmaceutical products. It has been demonstrated that materials containing polymer-based composites and inorganic additives such as zinc oxide can provide significant gamma-ray attenuation without compromising structural properties and can be successfully utilized in various radiation protection applications (Marashdeh et al., 2025).

Despite the extensive clinical and pharmacological research on metformin, studies investigating its radiation interaction properties are extremely limited. Determination of parameters such as mass attenuation coefficient, effective atomic number, and electron density can provide valuable insight into the potential radioprotective behavior of metformin and its suitability in radiation-related medical applications. In this study, the radiation interaction parameters of metformin were evaluated using the EpiXS software package. The mass attenuation coefficient (MAC), effective atomic number (Z_{eff}), and effective electron density (N_{eff}) of metformin were calculated over a wide photon energy range extending from 1 keV to 100 GeV. The objective of this work is to analyze the variation of these parameters across this broad energy spectrum and to assess the potential significance of metformin from a radiation physics perspective.

2. Material and Methods

Investigated drug were analyzed in terms of theoretical photon interaction parameters, specifically the mass attenuation coefficient (MAC), effective atomic number (Z_{eff}), and electron density (N_{el}), within an energy range of 1 keV to 100 GeV. These parameters were obtained using the EpiXS software package. The EpiXS program enables the computation of photon interaction characteristics such as MAC, Z_{eff} , and N_{el} for elements, organic compounds, and composite materials across a broad energy spectrum, providing reliable results for various types of materials (Hila et al., 2020; Hila et al., 2021).

3. Results and Discussion

The variation of the mass attenuation coefficient (MAC) of metformin ($\text{C}_4\text{H}_{11}\text{N}_5$) as a function of photon energy is presented in Figure 2 over a wide energy range from 1 keV to 100 GeV. The obtained curve exhibits the typical behavior expected for organic compounds composed of low atomic number elements. In the low-energy region (approximately 1 keV–100 keV), the MAC shows very high values and decreases sharply with increasing photon energy. This steep decline is attributed to the dominance of the photoelectric absorption process, which is highly dependent on photon energy and atomic number. Since photoelectric interaction is inversely proportional to approximately the third power of energy, a rapid reduction in MAC is observed in this region.

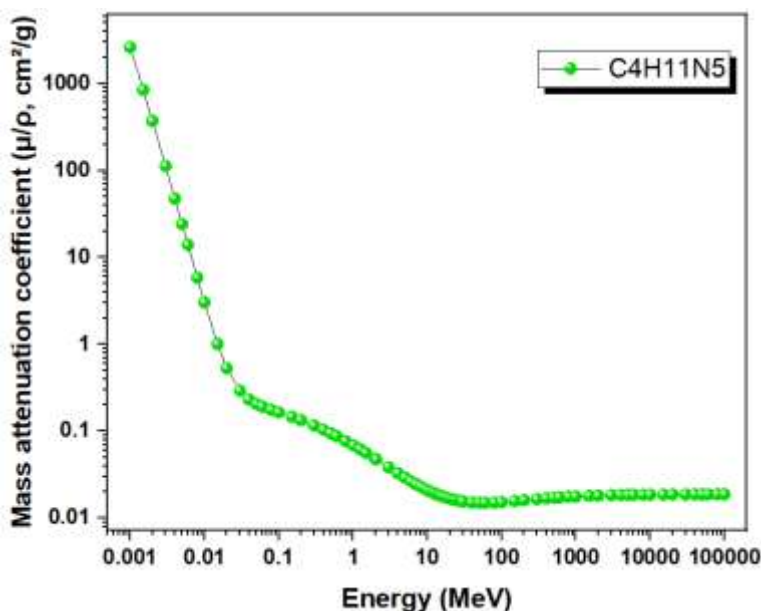


Figure 2. Variation of the mass attenuation coefficient (MAC) of $C_4H_{11}N_5$ as a function of photon energy.

In the intermediate energy range (approximately 0.1–10 MeV), the decrease in MAC becomes much more gradual, and the curve approaches a relatively stable plateau. This behavior indicates that Compton scattering is the predominant interaction mechanism in this energy interval. Compton scattering depends mainly on the electron density of the material rather than its atomic number; therefore, the attenuation coefficient does not vary significantly with energy. The relatively constant MAC values in this region suggest that metformin exhibits moderate and predictable photon interaction characteristics within the energy range commonly encountered in medical imaging and radiotherapy applications.

At higher photon energies (above approximately 10 MeV), the MAC reaches very low values and remains nearly constant with a slight increasing tendency toward 100 GeV. This behavior corresponds to the pair production process becoming the dominant interaction mechanism. In this region, the attenuation capability of metformin is considerably reduced, as expected for a low-Z organic compound. The overall trend of the curve demonstrates that metformin provides effective attenuation at low photon energies, moderate interaction at intermediate energies, and minimal attenuation at very high energies. The observed energy-dependent behavior of MAC is fully consistent with theoretical expectations for organic materials and confirms that metformin follows the standard radiation interaction pattern governed by photoelectric absorption, Compton scattering, and pair production in their respective energy regions. These results provide fundamental insight into the photon interaction properties of metformin and support further evaluation of its potential relevance in radiation-related applications.

The variation of the effective atomic number (Z_{eff}) of metformin ($\text{C}_4\text{H}_{11}\text{N}_5$) as a function of photon energy is presented in Figure 3. The obtained curve clearly demonstrates three distinct energy regions corresponding to the dominant photon interaction mechanisms. In the low-energy region (approximately 1 keV–100 keV), Z_{eff} exhibits relatively high values and decreases sharply with increasing photon energy. This behavior is attributed to the dominance of the photoelectric absorption process, which is strongly dependent on atomic number and photon energy. In the intermediate energy range (approximately 0.1–10 MeV), Z_{eff} reaches its minimum values and remains nearly constant over a wide energy interval. This plateau-like behavior indicates that Compton scattering is the predominant interaction mechanism in this region, where the interaction probability depends mainly on electron density rather than atomic number. As a result, the effective atomic number shows only minor variations with energy. At higher photon energies (above approximately 10 MeV), Z_{eff} gradually increases and approaches a stable. This trend corresponds to the increasing contribution of the pair production process, which becomes the dominant interaction mechanism at high energies. The overall energy-dependent behavior of Z_{eff} is consistent with theoretical expectations and confirms that metformin exhibits typical radiation interaction characteristics of low-Z organic compounds. These findings support the reliability of the calculated radiation interaction parameters and provide useful insight into the photon interaction properties of metformin.

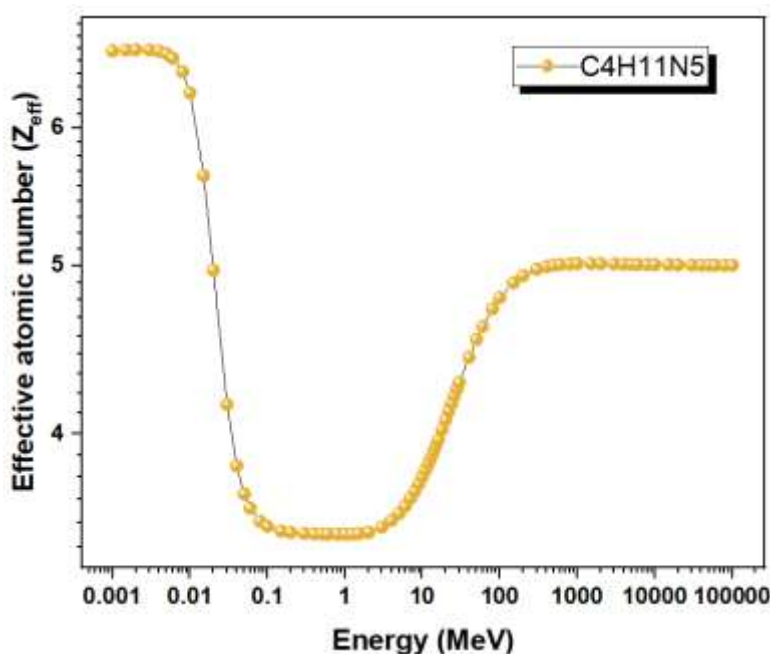


Figure 3. Energy dependence of the effective atomic number (Z_{eff}) of $\text{C}_4\text{H}_{11}\text{N}_5$.

Figure 4 illustrates the variation of electron density as a function of energy for the compound $C_4H_{11}N_5$. The horizontal axis represents energy in MeV on a logarithmic scale, while the vertical axis shows electron density expressed as $N_{el} \times 10^{23}/\text{times}$. As observed in Figure 4, three distinct regions can be identified on the curve. In the very low-energy range, approximately between 0.001 and 0.01 MeV, the electron density remains relatively high and almost constant, which is consistent with the dominance of the photoelectric effect at low energies. With increasing energy beyond about 0.01 MeV, Figure 4 shows a sharp decline in electron density, reaching a minimum around the 0.1–1 MeV region. This part of the curve represents a transition zone where different interaction mechanisms begin to take effect. At higher energies, above roughly 10 MeV, the trend displayed in Figure 4 reverses and the electron density begins to increase again, eventually stabilizing into a nearly constant plateau after approximately 100 MeV. This behavior reflects the growing influence of processes such as Compton scattering and pair production. Overall, Figure 4 clearly demonstrates how the interaction characteristics of the material vary significantly with changing energy levels.

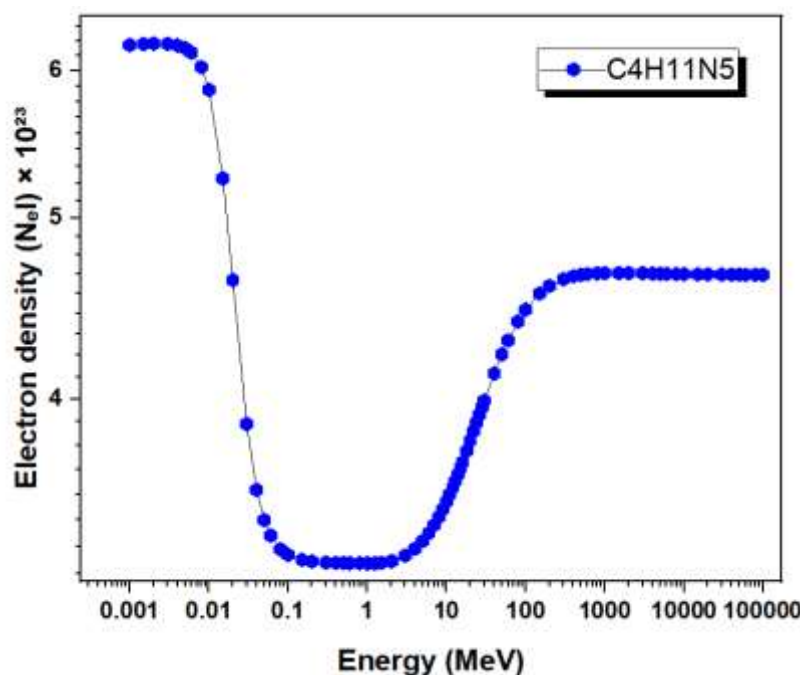


Figure 4. Variation of Electron Density with Photon Energy in $C_4H_{11}N_5$ Compound

4. Conclusion

In this study, the photon interaction properties of metformin ($C_4H_{11}N_5$) were systematically investigated over a wide energy range using the EpiXS computational software. The calculated parameters, including the mass attenuation coefficient, effective atomic number, and effective electron density, revealed that metformin

exhibits radiation interaction behavior typical of low-Z organic compounds. The results demonstrated that photoelectric absorption dominates in the low-energy region, Compton scattering is predominant at intermediate energies, and pair production becomes significant at higher energies. These findings confirm that the energy-dependent trends of metformin follow well-established theoretical expectations. The obtained data provide fundamental insight into the interaction of metformin with ionizing radiation and contribute to the limited literature on the radiation physics characteristics of pharmaceutical compounds. Although metformin is primarily known as an antidiabetic drug, understanding its radiation interaction parameters may be valuable for evaluating its stability, storage conditions, and potential behavior in radiation-related medical environments. Overall, this study offers a useful reference for future investigations and highlights the importance of assessing commonly used drugs from a radiation physics perspective.

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COMPARATIVE ANALYSIS OF DIFFERENT CONVOLUTIONAL NEURAL NETWORK BACKBONES OF U-NET ARCHITECTURE FOR LIVER SEGMENTATION IN COMPUTED TOMOGRAPHY IMAGES

Assist. Prof. Dr., Esin Ayşe ZAIMOĞLU¹ / Lecturer Dr., Havva Gül KOÇER² / Assist. Prof. Dr., Birkan BÜYÜKARIKAN³

¹ Sakarya University, Faculty of Computer and Information Sciences, Department of Information Systems Engineering, Sakarya-Türkiye, esinzaimoglu@sakarya.edu.tr, 0000-0001-9688-9868

² Selçuk University, Rectorate, Konya-Türkiye, hgul@selcuk.edu.tr, 0000-0003-4083-722X

³ Isparta University of Applied Sciences, Uluborlu Selahattin Karasoy Vocational School, Department of Computer Sciences, Isparta-Türkiye, birkanbuyukarikan@isparta.edu.tr, 0000-0002-9703-9678

Abstract

Liver segmentation is critically important for accurately calculating organ volume and locating lesions/tumors. Obtaining reliable segmentation from computed tomography (CT) images improves the accuracy of clinical decision-making and significantly reduces specialists' workload. Therefore, automated and highly accurate liver segmentation methods have become an indispensable part of medical imaging. Deep learning approaches have achieved successful results in this field thanks to their ability to automatically learn discriminative features from images. The aim of this study is liver segmentation from CT images using a deep learning approach. In this context, different Convolutional Neural Network (CNN) architectures, such as the standard U-Net architecture, one of the deep learning approaches, and ResNet18, DenseNet121, MobileNetV2, and EfficientNet-B0, were used as the backbones in the encoder section of the U-Net architecture. The study used an open-access dataset consisting of 100 grayscale CT images downloaded from the Kaggle platform and their corresponding binary segmentation masks. Within this scope, 80% of the dataset was allocated for training and 20% for testing. In this study, a loss function consisting of the sum of Binary Cross Entropy (BCE) and Dice Loss was chosen. According to the experimental results, the standard U-Net model achieved Dice scores of 0.9352, Intersection over Union (IoU) of 0.8848, and Recall rate of 0.9897. The EfficientNet-B0 backbone U-Net model achieved a Dice score of 0.9796, an IoU of 0.9602, and a Recall rate 0.9812, and had the highest overall segmentation accuracy. On the other hand, the ResNet18 backbone U-Net model achieved a Dice score of 0.9651, an IoU of 0.9930, and a Recall rate of 0.9962. This model provided the highest level of segmentation in terms of complete identification of liver regions. These findings demonstrate that using different CNN backbones with the U-Net architecture improves segmentation success.

Keywords: Liver, Computed Tomography images, Segmentation, U-Net, Convolutional Neural Networks

BİLGİSAYARLI TOMOGRAFİ GÖRÜNTÜLERİNDE KARACİĞER SEGMENTASYONU İÇİN U-NET MİMARİSİNİN FARKLI EVRİŞİMSEL SİNİR AĞI OMURGALARININ KARŞILAŞTIRMALI ANALİZİ

Özet

Karaciğer segmentasyonu, organ hacminin doğru biçimde hesaplanması ve lezyon/tümörlerin konumlandırılması açısından kritik bir öneme sahiptir. Bilgisayarlı tomografi (CT) görüntülerinden güvenilir segmentasyon elde edilmesi, klinik karar verme sürecinin doğruluğunu artırmakta ve uzmanların iş yükünü önemli ölçüde azaltmaktadır. Dolayısıyla, otomatik ve yüksek doğruluklu karaciğer segmentasyon yöntemleri, tıbbi görüntülemenin vazgeçilmez bir parçası haline gelmiştir. Derin öğrenme yaklaşımları görüntülerden ayırt edici özellikleri otomatik olarak öğrenebilme yetenekleri sayesinde bu alanda başarılı sonuçlar elde etmiştir. Bu çalışmanın amacı, derin öğrenme yaklaşımı kullanılarak CT görüntülerinden karaciğer segmentasyonudur. Bu kapsamda, derin öğrenme yaklaşımlarından biri olan standart U-Net mimarisi ve U-Net mimarisinin kodlayıcı bölümüne omurga olarak entegre edilen ResNet18, DenseNet121, MobileNetV2 ve EfficientNet-B0 gibi farklı Evrişimsel Sinir Ağı (CNN) mimarileri kullanılmıştır. Çalışmada, Kaggle platformundan indirilen, 100 adet gri tonlamalı BT görüntüsü ile bu görüntülere ait ikili segmentasyon maskelerinden oluşan açık erişimli bir veriseti kullanılmıştır. Bu kapsamda verisetinin %80'i eğitim ve %20'si test olacak şekilde ayrılmıştır. Çalışmada, kayıp fonksiyonu olarak İkili Çapraz Entropi (BCE) ve Dice Kaybının toplamından oluşan bir kayıp fonksiyonu tercih edilmiştir. Deneysel sonuçlara göre, standart U-Net modeli 0.9352 oranında Dice skoru, 0.8848 oranında Birleşim Üzerinde Kesişim (IoU) ve 0.9897 geri çağırma değerlerini elde etmiştir. EfficientNet-B0 omurgalı U-Net modeli ise 0.9796 Dice skoru, 0.9602 IoU ve 0.9812 oranında geri çağırma değerlerine ulaşmış ve genel segmentasyon doğruluğu açısından en yüksek Dice skorunu elde eden model olmuştur. Öte yandan, ResNet18 omurgalı U-Net modeli 0.9651 oranında Dice skoru, 0.9930 oranında IoU ve 0.9962 oranında geri çağırma değerleri elde etmiştir. Bu model, karaciğer bölgelerinin eksiksiz biçimde tespit edilmesi açısından en yüksek segmentasyon seviyesini sağlamıştır. Elde edilen bu bulgular, farklı CNN omurgalarının U-Net mimarisi ile kullanılmasının segmentasyon başarısını artırdığını göstermektedir.

Anahtar kelimeler: Karaciğer, Bilgisayarlı Tomografi görüntüleri, Segmentasyon, U-Net, Evrişimsel Sinir Ağları

1. INTRODUCTION

The metabolism of fat, protein, vitamins, and hormones is significantly influenced by the liver, the largest internal organ. Additionally, this organ has secretory, excretory, and biotransformation functions (Sandhiya et al., 2024; Yerra & Drosatos, 2023). In fact, liver diseases account for two million deaths every year, accounting for 4% of total global deaths. Early diagnosis of liver disease is crucial for determining the 5-year survival rate of patients with liver cancer (Devarbhavi et al., 2023). Thus, it is essential to identify and control liver diseases in their early stages to prevent the high economic burden associated with managing the complications of advanced diseases that require hospitalization and emergency care. In this case, it is important to have a proper understanding of liver structure in order to effectively diagnose and manage liver diseases (Valla & Cazals-Hatem, 2018).

In modern clinical practice, Computed Tomography (CT) scanning is commonly used in the diagnosis and treatment of liver pathologies, in addition to patient history and physical examination, owing to its high resolution and cross-sectional information in imaging the liver (Chaichana et al., 2021; Kumar & Vinod Kumar, 2024). Liver CT image segmentation is typically done manually by radiologists using visual assistance. But this approach takes a lot of time and is subject to expert disagreements. Precise liver segmentation enables the detection of liver atrophy, calculation of liver volume, and planning of liver transplantation and resections. Therefore, different liver diseases, including tumor identification, can be assessed (Huo et al., 2019; Kavur et al., 2019; Kumar & Vinod Kumar, 2024; Ng et al., 2020; Niño et al., 2024). In addition, liver segmentation presents various challenges such as inter-patient variability of organ size and shape, low contrast of the liver from adjacent structures such as the spleen and stomach, blurred boundaries, and noisy images. Therefore, it is necessary to employ various approaches (Anwar et al., 2025; Wang et al., 2022).

The deep learning (DL) approach, which has become widespread in computer vision applications, has transformed medical image segmentation from manual methods to automated systems (Jiang et al., 2022). This transformation significantly reduces specialists' workload and speeds up the diagnosis process. It also ensures more objective results. Among these approaches, Fully Convolutional Networks (FCN) (Long et al., 2015), U-Net (Ronneberger et al., 2015), DeepLabV3 (Chen et al., 2018), and Autoencoder Neural Networks (AED) (Budak et al., 2020) stand out.

Thanks to its symmetric encoder-decoder structure and skip connections, the U-Net architecture is widely accepted in the literature for its ability to effectively capture detailed structural patterns in medical images (Anwar et al., 2025; Wang et al., 2022). However, the U-Net' feature extraction capacity may be insufficient for

challenging tasks, such as detecting small tumors and handling the complex morphology of the liver. Therefore, the motivation of the study is to improve feature extraction capacity and thus segmentation performance by using different and more powerful Convolutional Neural Network (CNN) backbones in the encoder layers of the U-Net.

This study aims to segment the liver from CT images using a DL approach. Pre-trained CNN architectures such as ResNet18, DenseNet-121, MobileNetV2, and EfficientNet-B0 were evaluated in the encoder section of the U-Net architecture. The CT Liver dataset from the Kaggle platform was used, and the dataset was split into 80% for training and 20% for testing. It was found that a combined loss function consisting of the sum of the Binary Cross Entropy (BCE) and Dice loss scores was preferable. The Dice score, Intersection over Union (IoU), and Recall metrics were used to evaluate this study.

The main contributions of this study are: (1) revealing the performance differences between U-Net models with pre-trained backbones and standard U-Net, and (2) determining the most efficient backbone architecture in terms of computational cost and accuracy balance in liver segmentation.

2. RELATED WORK

Liver segmentation is the process of separating the liver and its lesions or vascular structures from the background and other organs in medical images (Devarbhavi et al., 2023). Early approaches in this field relied on traditional image processing techniques such as thresholding, region growing, active contour models, and clustering. However, these methods are often inadequate in cases of low contrast, anatomical variation, and image noise, require a high degree of manual intervention, and have limited generalization capabilities (Niño et al., 2024). These limitations have led researchers to seek more robust and automated solutions.

With DL, FCN has become a turning point in liver segmentation, is a fundamental DL architecture that has replaced traditional methods in liver and tumor segmentation and has made a significant impact in this field by performing pixel-level classification. It has ensured that the network operates in a fully convolutional structure by converting the fully connected layers used in the CNN architecture into convolutional layers. Thus, FCN processes the entire image in a single pass, determining whether each pixel is liver or background, thereby helping to accurately delineate liver boundaries (Chlebus et al., 2018; Pang et al., 2019; Shukla et al., 2022; Tian et al., 2023).

Following FCN, the most widely accepted architecture in medical image segmentation has been the U-Net. There are numerous studies in literature that utilize the standard U-Net and its variants. For example, Ayalew et al. (2021) reduced the number of filters in the convolutional blocks of the standard U-Net architecture and

restructured the network by adding batch normalization and dropout layers. Their proposed model achieved Dice scores of 0.96 for liver segmentation, 0.74 for tumor segmentation within the liver, and 0.63 for tumor segmentation directly from abdominal CT images. Rahman et al. (2022) proposed a method for segmenting the liver and tumors from CT image volumes using a hybrid ResUNet model that combines ResNet and U-Net models. Evaluated on the 3D-IRCADB01 dataset, this method achieved a maximum true value accuracy of 99.55% for liver segmentation. Sheela et al. (2025) proposed an approach using ResNet-based U-Net architecture. The proposed approach was evaluated on a dataset consisting of 130 CT images of liver cancer and achieved an accuracy of 98%.

Anwar et al. (2025) used a U-Net architecture enhanced with the DenseNet121 encoder to perform liver segmentation on the 3D-IRCADb-01 and LiTS datasets. Their suggested approach obtained Dice scores of 98.1% on the LiTS dataset and 96.5% on the 3D-IRCADb-01 dataset. On the other hand, Özcan et al. (2023) achieved Dice and Jaccard scores of 97.86% and 96.10%, respectively, on the CHAOS dataset with their proposed Adding Inception Module-UNet model. Wang et al. (2022) proposed the EAR-U-Net model using the EfficientNetB4 architecture. This model achieved Dice scores of 0.9595 on the LiTS17 dataset and 0.9623 on the SLiver07 dataset.

3. MATERIALS AND METHODS

3.1. Dataset Description

In this study, the CT Liver: Digital Medical Images for Liver Extraction dataset, available on the Kaggle platform and open access, was used. This dataset has been used for the detection of various liver diseases, including hepatitis, liver tumors, and autoimmune liver diseases (Harb, 2025). The images and their segmentation masks (ground truth) are shown in Figure 1. The dataset contains 100 grayscale images and their segmentation masks in black-and-white format. All images are 512×512 pixels.



Figure 1. Images and masks used in the dataset, (a) Sample images, (b) Segmentation masks of sample images

3.2. U-Net Architecture

Ronneberger et al. (2015) for biomedical image segmentation problems, is a fully convolutional DL architecture. This architecture is widely used in medical imaging because it can successfully segment structural details with limited labeled data. The U-Net architecture consists of two parts: an encoder and a decoder. In the encoder, the spatial dimension of the image is gradually reduced through successive convolutions and max pooling, while the depth is increased to learn more abstract features. In the decoder, spatial resolution is increased again via upsampling and convolutional operations, and pixel-level classification is performed (Ronneberger et al., 2015). Furthermore, U-Net has pixel-level precision. Classifying each pixel provides millimeter-level details critical for surgical planning. U-Net enhances segmentation quality by leveraging context from high-resolution feature maps (Tran et al., 2020).

In the literature, U-Net is found not only in its standard form but also with various architectural hybridizations. The integration of advanced methodologies such as hybrid DL techniques has further increased the

effectiveness of U-Net models. Therefore, in this study, the encoder structure was strengthened by using different CNN backbones in addition to the standard U-Net architecture. In this context, ResNet18 (He et al., 2016), DenseNet121 (Huang et al., 2017), MobileNetV2 (Sandler et al., 2018), and EfficientNet-B0 (Tan & Le, 2019) architectures were preferred. These CNN architectures have been integrated as backbones in the encoder section of U-Net.

3.3. Proposed Approach

In this study, models integrating different CNN backbones into the encoder section of the standard U-Net architecture for liver segmentation were comparatively evaluated. A dataset obtained from the Kaggle platform, containing 100 liver images and ground truth (GT), was used in the study. Single-channel CT images were fed into the model as input, and the model output was a logit map representing the probability that each pixel belongs to the liver class. The model outputs were converted to probabilities using a sigmoid activation function, and a binary prediction mask was generated using a threshold of 0.5. Thus, the liver (1) and background (0) classes were separated for each pixel. The dataset was randomly split into 80% for training and 20% for testing.

In this study, a combined loss function consisting of the sum of BCE and Dice Loss scores was used as a loss function to measure the variations between the predicted values and the actual values during model training (Ayalew et al., 2021; Dong et al., 2024; Yan et al., 2024). In this study, a batch size of 8, the AdamW optimization function, and a learning rate of $1e-4$ were chosen. All models were trained for 30 epochs (Table 1).

Table 1. Parameters and values used in training the models

Parameter	Value
Number of images	100
Train: Test sets	80:20
Batch size	8
Epochs	30
Optimizer	AdamW
Loss	BCE and Dice Loss
Data Shuffle	True

3.4. Evaluation Metrics

In this study, Dice score, IoU, and recall metrics were used to evaluate liver segmentation performance. Dice is a metric that measures the overlap between the model's segmentation mask and the GT mask. This metric is calculated as shown in Equation 1. On the other hand, IoU represents the ratio of the intersection of the predicted and actual segmentation regions to their union. This metric is evaluated as in Equation 2. Recall is a metric that shows how many of the actual liver regions the model correctly detects. This metric is calculated as in Equation 3.

$$Dice\ score = \frac{2*TP}{2*TP+FP+FN} \quad (1)$$

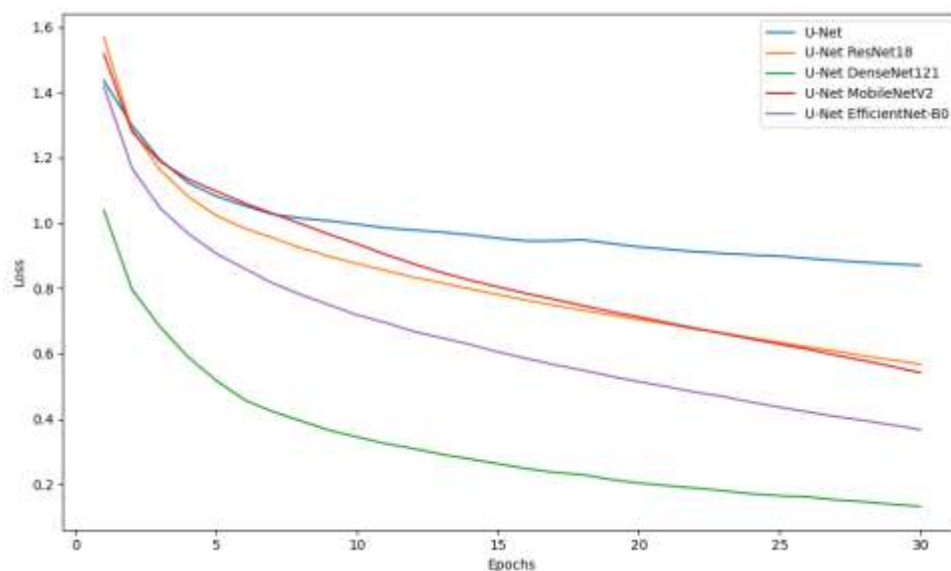
$$IoU = \frac{TP}{TP+FP+FN} \quad (2)$$

$$Recall = \frac{TP}{TP+FN} \quad (3)$$

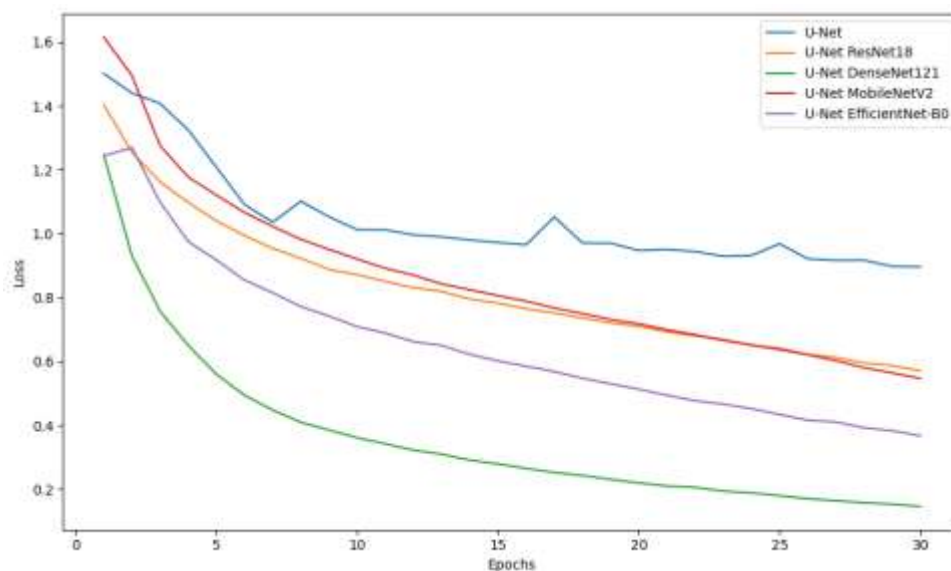
Here, TP denotes the number of true positive pixels, FP denotes the number of false positive pixels, and FN denotes the number of false negative pixels.

4. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 2 shows the loss changes during training and testing for models using ResNet18, DenseNet-121, MobileNetV2, and EfficientNet-B0 as backbone encoders with the standard U-Net. When examining the curved trends, it is observed that different CNN backbones generally have a significant effect on learning dynamics and convergence behavior. When examining the training set loss graph (Figure 2a), it is observed that the loss values of all models decrease steadily as the epoch count increases, achieving convergence. The standard U-Net architecture produced higher training losses than other models and converged more slowly. In contrast, U-Net models with DenseNet121 and EfficientNet-B0 backbones converged faster from early epochs. When evaluating the test set loss graphs (Figure 2b), it is observed that the DenseNet121 and EfficientNet-B0 backbone U-Net models have lower test loss and that this loss fluctuates less throughout training. The ResNet18 backbone model exhibited a balanced loss value on the test set. However, it achieved higher values than EfficientNet-B0 and DenseNet121.



(a)



(b)

Figure 2. Loss changes graphs, (a) Training set, (b) Test set

Table 2 presents the segmentation performance of U-Net models trained with different CNN backbones. The standard U-Net model achieved a Dice score of 0.9352, an IoU of 0.8848, and a Recall of 0.9897. Although this model demonstrated high segmentation performance, it performed worse than backbone-based U-Net models. The U-Net model created with the ResNet18 backbone achieved a Dice score of 0.9651, an IoU of 0.9930, and a Recall of 0.9962. Furthermore, this model achieved the highest performance in terms of overlap (IoU) and

true liver region detection (Recall). The Dice score, IoU, and recall values of the DenseNet121 backbone U-Net model are 0.9794, 0.9598, and 0.9851, respectively. The Dice score, IoU, and recall values of the U-Net model with the MobileNetV2 backbone were 0.9662, 0.9354, and 0.9807, respectively. The U-Net architecture with the EfficientNet-B0 backbone achieved a Dice score of 0.9796, an IoU of 0.9602, and a Recall of 0.9812. Moreover, this model is distinguished by the overall segmentation accuracy achieved by the Dice score.

Table 2. Performance results of U-Net-based models on the test set

Model	Dice score	IoU	Recall
U-Net	0.9352	0.8848	0.9897
ResNet18 backbone U-Net	0.9651	0.9930	0.9962
DenseNet121 backbone U-Net	0.9794	0.9598	0.9851
MobileNetV2 backbone U-Net	0.9662	0.9354	0.9807
EfficientNet-B0 backbone U-Net	0.9796	0.9602	0.9812

The highest results are in bold font

Figure 3 provides a visual comparison of liver segmentation results obtained using different U-Net models. In the example liver in Figure 3, the models correctly distinguish the liver region in general. However, there are significant performance differences in boundary accuracy and in the capture of small anatomical details.

In the outputs of the standard U-Net model, the liver boundaries were blurred in some areas (Figure 3a). In the U-Net model with the ResNet18 backbone, the liver boundaries were more sharply defined (Figure 3b). In the U-Net model with the DenseNet121 backbone, the segmentation mask overlapped with the GT at a high rate (Figure 3c). The U-Net model with the MobileNetV2 backbone produced false positives in border regions and limited detail loss (Figure 3d). When evaluating the U-Net model trained on EfficientNet-B0, the liver borders were segmented in a smooth, anatomically more realistic manner (Figure 3e).

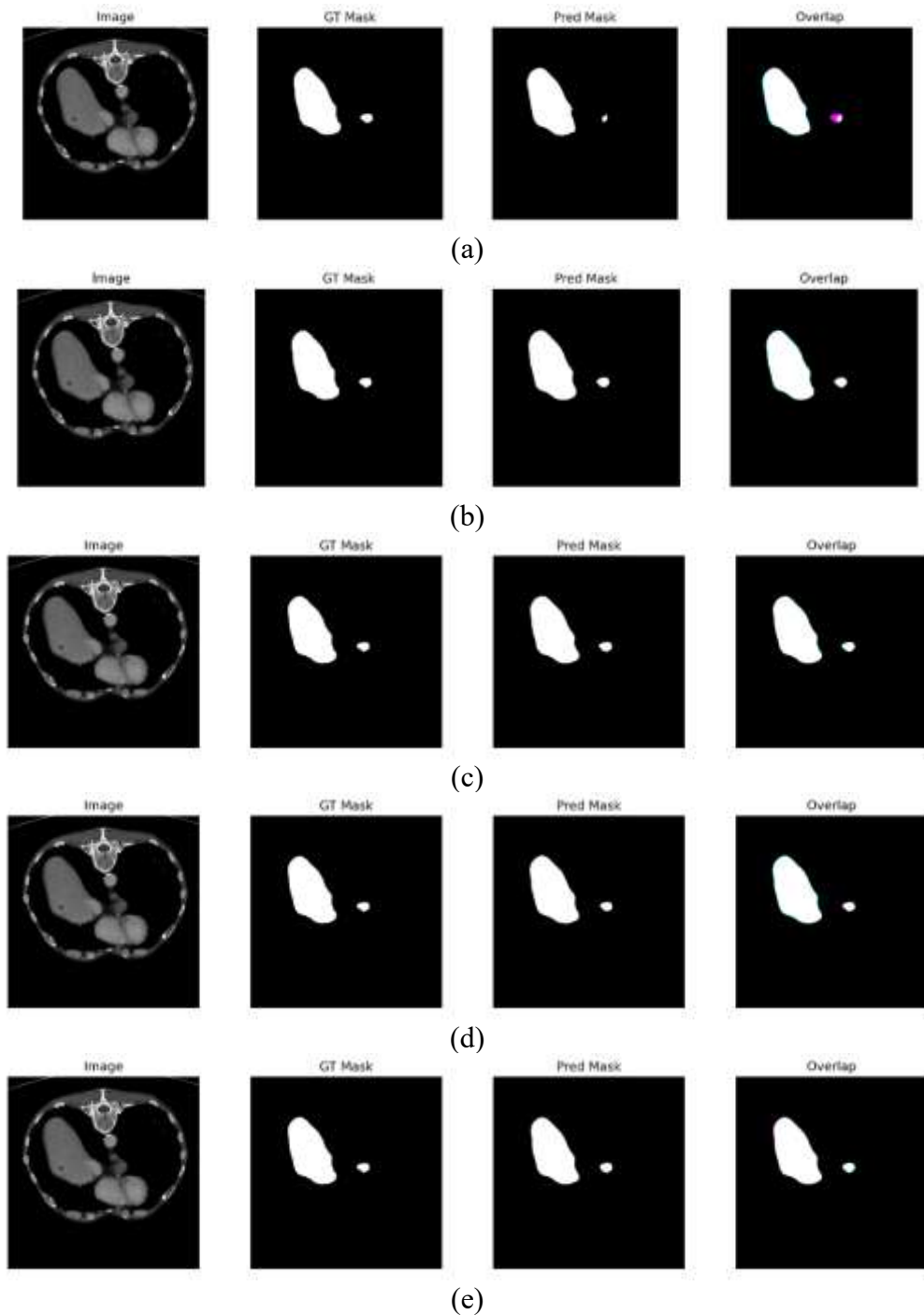


Figure 3. Liver segmentation outputs of different U-Net-based models on a sample image (Original CT Image (Image), Ground Truth Mask (GT Mask), Model Prediction (Pred Mask), and Overlap Visualization. In the overlap visual, correctly predicted pixels (TP) are shown in white, missed pixels (FN) in magenta, and falsely added pixels (FP) in cyan), (a) Standard U-Net, (b) ResNet18 backbone U-Net, (c) DenseNet121 backbone U-Net, (d) MobileNetV2 backbone U-Net, (e) EfficientNet-B0 backbone U-Net

The performance of U-Net-based models proposed in the literature is reported in Table 3. Ayalew et al. (2021) reported a Dice score of 0.96 with their proposed U-Net-based model. Rahman et al. (2022) achieved the highest accuracy of 99.55% in the ResUNet model. Anwar et al. (2025) reported a Dice score of 96.5% on the 3D-IRCADb-01 dataset and a Dice score of 98.1% on the LiTS dataset using a U-Net architecture enhanced with a DenseNet121 encoder. Sheela et al. (2025) proposed a ResNet-based U-Net model that achieved 98% accuracy. Özcan et al. (2023) achieved a Dice score of 97.86% and a Jaccard score of 96.10% on the CHAOS dataset using the AIM-Unet model. Wang et al. (2022) reported that the EAR-U-Net model achieved Dice scores of 0.9595 on the LiTS17 dataset and 0.9623 on the SLiver07 dataset.

The EfficientNet-B0 and ResNet18 backbone U-Net models used in this study achieved high Dice score, IoU, and Recall values comparable to those reported in the literature on much larger datasets, despite being trained on a limited dataset of only 100 CT images. The EfficientNet-B0 backbone U-Net model showed the potential of this architecture's representation capacity by attaining a high Dice score of 0.9796 and IoU of 0.9602. The ResNet18 backbone U-Net model achieved a Recall of 0.9962. This shows that the liver was segmented almost completely. The result highlights the potential of U-Net architectures with advanced CNN backbones for clinical applications with limited data.

Table 3. Comparison of liver segmentation studies in the current literature

Reference	Dataset	Model and Results	Results
Ayalew et al. (2021)	3D-IRCADb01 and LiTS	U-Net	Dice score: 0.96
Rahman et al. (2022)	3D-IRCADB01	ResUNet model	Accuracy: 99.55%
Anwar et al. (2025)	3D-IRCADb-01 and LiTS datasets	U-Net DenseNet model	3D-IRCADb-01: Dice score 96.5% and LiTS: Dice score 98.1%
Özcan et al. (2023)	CHAOS	AIM-Unet	Dice score 97.86% and Jaccard score 96.10%
Wang et al. (2022)	LiTS17 and SLiver07	EAR-U-Net	LiTS17: Dice score 0.9595 and SLiver07 Dice score 0.9623
Sheela et al. (2025)	130 CT images of liver cancer	ResNet-based U-Net	Accuracy: 98%
This study	100 CT images	EfficientNet-B0 backbone U-Net	Dice score: 0.9796, IoU: 0.9602, and Recall: 0.9812
This study	100 CT images	ResNet18 backbone U-Net	Dice score: 0.9651, IoU: 0.9930, and Recall: 0.9962

5. RESULTS AND FUTURE WORK

In this research, U-Net architectures trained with various CNN backbones, including ResNet18, DenseNet121, MobileNetV2, and EfficientNet-B0, as well as the traditional U-Net model, were employed for segmenting the liver from CT. In the research, 100 images were employed as the dataset, and 80% were for training set and 20% for test set.

Based on the experimental results, the model with the EfficientNet-B0 backbone had the highest overall accuracy in the segmentation task with a Dice score of 0.9796. The model with the ResNet18 backbone showed the best performance in the accurate detection of the liver with IoU and Recall of 0.9930 and 0.9962, respectively. In the overall evaluation, the EfficientNet-B0 backbone U-Net model achieved the highest Dice score, while the ResNet18 backbone U-Net model excelled in IoU and recall metrics. These results indicate that the targeted performance metric should be considered when selecting a model for different clinical scenarios. In future work, it is intended to test the models on larger and 3D datasets.

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UNMANNED AERIAL VEHICLE (UAV) CONTROLLER DESIGN IN SIMULINK ENVIRONMENT

Mehmet Haktan Turun^{1,*}, Kamil Çetin^{1,2,#}

¹İzmir Katip Çelebi University, Faculty of Engineering and Architecture, Department of Electrical and Electronics Engineering, İzmir, Türkiye

² İzmir Katip Çelebi University, Akıllı Fabrika Sistemleri Araştırma ve Uygulama Merkezi, İzmir, Türkiye

*Email: mhaktanturun@gmail.com | *ORCID: 0009-0007-0065-4281

#Email: kamil.cetin@ikcu.edu.tr | #ORCID: 0000-0003-1029-5626

Abstract

Current unmanned aerial vehicle (UAV) control systems face some challenges during flight in terms of rapid response and stability in challenging weather conditions. This study aims to investigate the position and orientation control of a UAV using a four-rotor unmanned aerial vehicle model created in a simulation environment, and to design a PID (Proportional-Integral-Derivative) controller. In this context, a closed-loop control structure was created using a ready-made UAV model available in the MATLAB/Simulink environment. Position and orientation variables obtained from the UAV in the simulation environment were used as feedback, and the system was built upon this structure. A PID controller was designed and integrated into the model for position and orientation control. In the simulation environment, a reference trajectory was given to the UAV, and the performance of the designed controller was tested by tracking this trajectory. The controller's performance was analyzed based on performance criteria such as trajectory tracking accuracy and stability. In addition, the controller's robustness under external disturbances defined in the simulation was evaluated. The results show that with appropriate parameter adjustments, the PID controller can provide stable and effective performance in the position and orientation control of the UAV. This simulation-based study offers an important evaluation framework for analyzing controller performance before moving on to real system applications.

Keywords: UAV, Simulink, Controller Design, PID

SIMULINK ORTAMINDA İNSANSIZ HAVA ARACI (İHA) KONTROLCÜ TASARIMI

Mehmet Haktan Turun^{1,*}, Kamil Çetin^{1,2,#}

¹İzmir Katip Çelebi University, Faculty of Engineering and Architecture, Department of Electrical and Electronics Engineering, İzmir, Türkiye

² İzmir Katip Çelebi University, Akıllı Fabrika Sistemleri Araştırma ve Uygulama Merkezi, İzmir, Türkiye

*Email: mhaktanturun@gmail.com | *ORCID: 0009-0007-0065-4281

#Email: kamil.cetin@ikcu.edu.tr | #ORCID: 0000-0003-1029-5626

Özet

Mevcut insansız hava aracı (İHA) kontrol sistemlerinde, zorlu hava koşulları altında hızlı tepki verme ve uçuş stabilitesinin korunması açısından çeşitli zorluklar ortaya çıkabilmektedir. Bu çalışma, İHA'nın konum ve yönelim kontrolünün simülasyon ortamında oluşturulan dört rotorlu bir insansız hava aracı modeli kullanılarak incelenmesini ve PID kontrolcü tasarımının gerçekleştirilmesini amaçlamaktadır. Bu kapsamda, MATLAB/Simulink ortamında bulunan hazır bir İHA modeli kullanılarak kapalı çevrim kontrol yapısı oluşturulmuştur. Simülasyon ortamında İHA'dan elde edilen konum ve yönelim durum değişkenleri geri besleme olarak kullanılmış ve sistem bu yapı üzerine kurulmuştur. Konum ve yönelim kontrolü için PID (Proportional–Integral–Derivative) kontrolcü tasarlanmış ve modele entegre edilmiştir. Çalışılan simülasyon ortamında İHA'ya referans bir yörünge verilmiş ve tasarlanan kontrolcünün performansı, bu yörüngeyi takip edecek şekilde test edilmiştir. Kontrolcünün performansı; yörünge takip doğruluğu, aşım miktarı ve kararlılık gibi performans kriterleri üzerinden analiz edilmiştir. Ayrıca simülasyonda tanımlanan dış bozucular altında kontrolcünün dayanıklılığı değerlendirilmiştir. Elde edilen sonuçlar, uygun parametre ayarlamaları ile PID kontrolcünün İHA'nın konum ve yönelim kontrolünde kararlı ve etkili bir performans sağlayabildiğini göstermektedir. Simülasyon tabanlı bu çalışma, gerçek sistem uygulamalarına geçmeden önce kontrolcü performansının analiz edilmesi açısından önemli bir değerlendirme altyapısı sunmaktadır.

Anahtar kelimeler: İHA, Simulink, Kontrolcü Tasarımı, PID

1. INTRODUCTION

Unmanned aerial vehicles (UAVs) have become an important area of research in both military and civilian applications in recent years. Quadrotor-type platforms are widely preferred due to their vertical takeoff and landing (VTOL) capability, hovering ability, and relatively simple mechanical structure. The ability to independently control rotor speeds enables the system to perform both positional and orientation movements in three-dimensional space. However, despite having six degrees of freedom, quadrotor systems only have four independent control inputs. This underactuated structure and nonlinear dynamics complicate system stabilization and precise reference tracking (Mahony et al., 2012).

The most used method to stabilize this complex dynamic structure is controller design. Modeling the quadrotor's behavior under gravitational effects and aerodynamic forces directly affects the sensitivity of the control architecture (Salih et al., 2010). Due to its structural simplicity, applicability, and relatively easy parameter tuning, the PID controller remains a widely preferred approach (Li & Li, 2011; Salih et al., 2010).

The PID controller is sufficient for stable flight and reference tracking performance with appropriate parameter settings (Li & Li, 2011). The PID controller can provide adequate performance, especially during hovering and at low speeds. However, uncertainties in system parameters and model accuracy have significant effects on control performance. Therefore, the design and tuning process of the PID controller requires careful analysis (Garcia et al., 2012).

In this study, a classical PID controller design was implemented using a ready-made quadrotor model available in the MATLAB/Simulink environment. The control structure was configured to regulate the system's altitude and orientation dynamics, and the reference tracking performance was evaluated in the simulation environment. The results obtained were analyzed in terms of overshoot, settling time, and stability criteria performance, and the effectiveness of the PID control approach on quadrotor stabilization was demonstrated.

2. METHODOLOGY

This section introduces the control design process of the Parrot Mambo quadcopter model, implemented using the Quadcopter Project, a ready-to-use development package available in MATLAB/Simulink.

In this study, a PID control algorithm was integrated into the existing dynamic model. Control parameters were defined and tested to match the system dynamics. The system behavior obtained in the simulation environment was recorded, and the controller's performance was analyzed.

2.1. Simulation Environment

The simulation used in this study utilized the ready-to-use Parrot Mambo quadcopter model available in the MATLAB/Simulink environment, which is part of the Quadcopter Project developed by MathWorks (MathWorks, n.d.). The Parrot Mambo model, with its lightweight structure and high maneuverability, provides a suitable reference platform for testing control algorithms in a safe, repeatable, and systematic manner. The model has a six-degree-of-freedom (6-DOF) nonlinear dynamic structure and is controlled via rotor speeds.

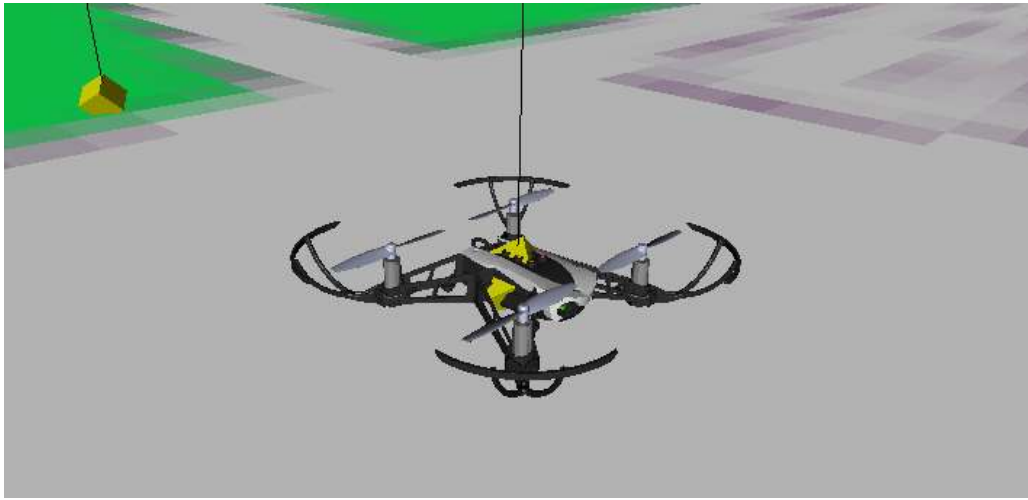


Figure 3. Parrot Mambo Quadcopter

The quadrotor's coordinate system is modeled according to standard body frame and inertial frame reference frames defined in the Simulink environment. The system includes three-axis position (x , y , z) and three-axis orientation (roll, pitch, yaw) movements.

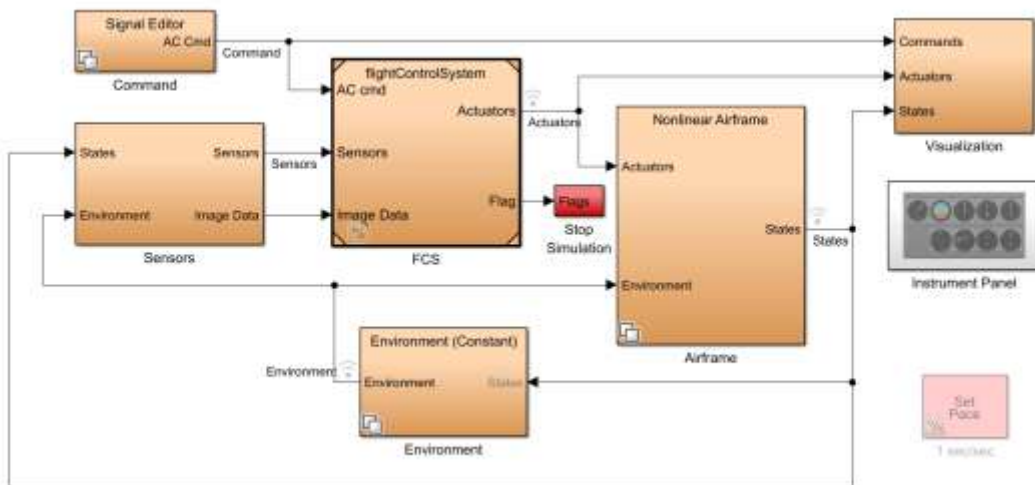


Figure 4. Overall block diagram of the UAV simulation environment

The simulation has a modular structure and consists of five main subsystems:

- Command Unit
- Flight Control System (FCS)
- Airframe
- Environment
- Sensors

2.1.1. Command Unit

The command unit is responsible for generating and transmitting the reference commands followed by the quadrotor to the flight control system. The simulation environment allows for multiple command sources. These sources include reference signals generated via the Signal Editor, joystick-based manual inputs, pre-recorded data files (.mat), and spreadsheet-based command data. The desired command source is selected via the system parameter, and the selected commands are transmitted to the flight control system as AC Cmd signals.

2.1.2. Flight Control System (FCS)

The Flight Control System (FCS) is the main system component that enables the quadrotor to follow given reference commands and maintain stable behavior in the simulation environment. As shown in Figure 3, the FCS processes reference values from the command unit and sensor measurements to generate control signals for the motors. The state estimation mechanism within the system calculates the vehicle's position, speed, and orientation information in real-time using raw sensor data. This mechanism enables continuous monitoring of the flight status, allowing for reliable and stable execution of the control process.

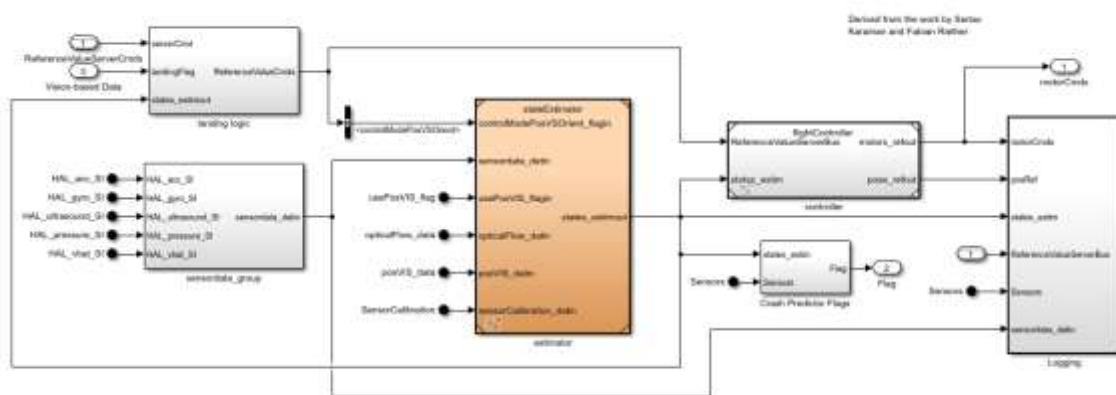


Figure 5. Estimator and controller structure of the flight control system.

The FCS within the simulation infrastructure includes an advanced state estimation mechanism to determine the system's flight status in real-time. Raw measurement data from the sensors is processed through this estimation structure to calculate the quadrotor's position, speed, and orientation information. These estimations allow for continuous monitoring of the system during flight and reliable control.

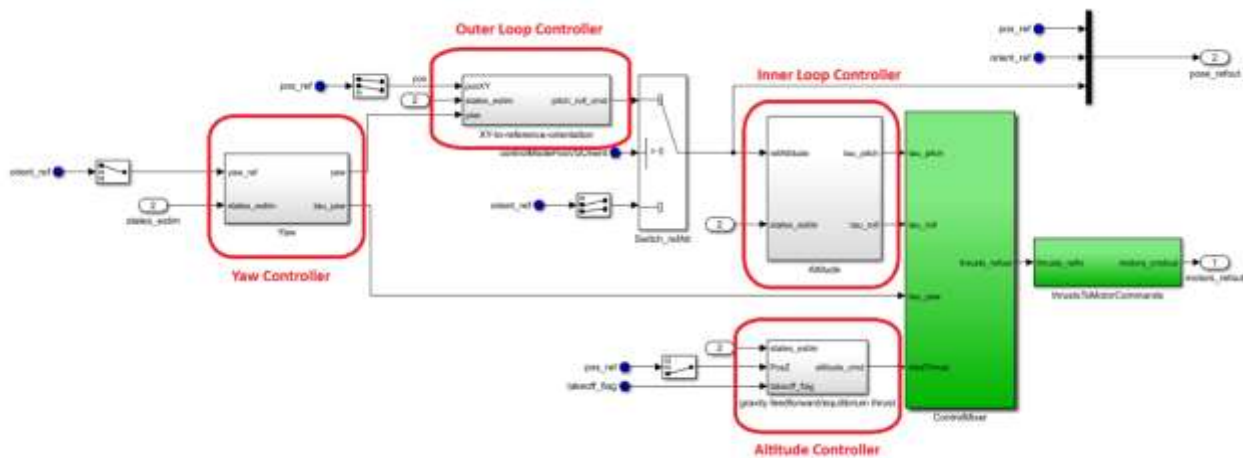


Figure 6. Block diagram of the cascaded flight control architecture

The FCS structure is based on the concept of cascaded control loops to optimize control performance. This multi-layered structure consists of the following basic units:

- **Outer Loop Controller:** Minimizes position (x, y) errors and generates the necessary reference attitude (pitch/roll) commands for the inner loop.
- **Inner Loop Controller:** Manages the vehicle's attitude dynamics and determines the engine torque τ values.
- **Yaw Controller:** Controls the vehicle's orientation (yaw), regulating its rotational movements around the vertical axis.
- **Altitude Controller:** Manages the quadrotor's altitude, ensuring a stable flight height on the vertical axis.
- **Control Mixer:** Combines the calculated torque and thrust commands to generate the final signals for the four motors.

2.1.3. Airframe

A nonlinear 6 degrees of freedom (6DOF) body model was used in the simulation. This model simultaneously calculates the translational and rotational movements of the quadrotor around its center of mass. The thrust forces and moments generated by the engines are evaluated together with aerodynamic effects and mass-inertial parameters to create the system dynamics.

The nonlinear body model more accurately represents real flight conditions and allows for a realistic analysis of controller performance.

2.1.4. Environment

The environmental subsystem includes the main environmental factors that affect the quadrotor during flight into the model. Altitude-dependent acceleration is calculated using the WGS84 reference system and transferred to the navigation frame. Temperature, pressure, density, and speed of sound parameters are calculated as a function of altitude and shared with the body model. Furthermore, magnetic field components are determined using the World Magnetic Model (WMM). These environmental effects interact with the body model and the flight control system.

2.1.5. Sensors

The sensor subsystem produces realistic sensor outputs by considering the quadrotor's dynamic state variables and environmental effects. Acceleration, angular velocity, and altitude measurements are obtained via the IMU and pressure sensor and transmitted to the flight control system via the sensor data bus. This data is used as fundamental feedback inputs in state prediction and control processes.

In addition, the system can generate optical flow and visual sensor outputs. These components enable the support of motion and position perception in the simulation environment.

2.2. Controller Design

2.2.1. Quadrotor Dynamics

The nonlinear dynamic model of the quadrotor used in this study is based on the formulation presented in (Herrera et al., 2015).

The quadrotor has twelve states, which are the following:

$$\begin{aligned}
 X &= [x \ \dot{x} \ y \ \dot{y} \ z \ \dot{z} \ \phi \ \dot{\phi} \ \theta \ \dot{\theta} \ \psi \ \dot{\psi}] \\
 \ddot{x} &= \frac{\cos(\phi) \sin(\theta) \cos(\psi) + \sin(\phi) \sin(\psi)}{m} U_1 \\
 \ddot{y} &= \frac{\cos(\phi) \sin(\theta) \sin(\psi) - \sin(\phi) \cos(\psi)}{m} U_1 \\
 \ddot{z} &= -g + \frac{\cos(\phi) \cos(\theta)}{m} U_1 \\
 \ddot{\phi} &= \dot{\phi} \dot{\psi} \left(\frac{I_y - I_z}{I_x} \right) - \frac{J_r}{I_x} \dot{\theta} \Omega + \frac{l}{I_x} U_2
 \end{aligned}$$

$$\ddot{\theta} = \dot{\phi}\dot{\psi}\left(\frac{I_z - I_x}{I_y}\right) + \frac{J_r}{I_y}\dot{\theta}\Omega + \frac{l}{I_y}U_3$$

$$\ddot{\psi} = \dot{\theta}\dot{\phi}\left(\frac{I_x - I_y}{I_z}\right) + \frac{1}{I_z}U_4$$

In the equations above, the control inputs U_1 represent the total thrust force produced by the rotors; U_2 , U_3 and U_4 represent the control moments corresponding to the roll, pitch, and yaw movements, respectively. Among the parameters characterizing the physical structure of the vehicle, m represents the total mass, J_r the rotor inertia, and I_x , I_y , and I_z represent the moments of inertia of the quadrotor along the major axes.

The input signals U_1 , U_2 , U_3 , and U_4 are defined as follows:

$$U_1 = b(\Omega_1^2 + \Omega_2^2 + \Omega_3^2 + \Omega_4^2)$$

$$U_2 = b(-\Omega_2^2 + \Omega_4^2)$$

$$U_3 = b(-\Omega_1^2 + \Omega_3^2)$$

$$U_4 = d(-\Omega_1^2 + \Omega_2^2 - \Omega_3^2 + \Omega_4^2)$$

Ω_1 , Ω_2 , Ω_3 , Ω_4 are the angular speed for each rotor.

The factor Ω is determined as follows:

$$\Omega = -\Omega_1 + \Omega_2 - \Omega_3 + \Omega_4$$

2.2.2. PID Controller

The general form of the PID controller is as follows:

$$U = k_p e + k_i \int e + k_d \dot{e}$$

- k_p is the gain of the proportional term.
- k_i is the gain of the proportional term.
- k_d is the gain of the derivative term.
- e is the error, defined as the difference between the reference value and the measured output.
- $\dot{e}$ is the derivative of the error.

The PID control architecture implemented in this study follows the formulation presented in (Noordin et al., 2020).

2.2.3. Altitude Controller

For altitude control, the PID structure is applied to the vertical error $e_z = z_d - z$ with an additional gravity compensation term included to counteract the vehicle weight.

$$U_z = k_p e_z + k_i \int e_z + k_d \dot{e}_z + mg$$

2.2.4. Attitude and Yaw Controllers

The same PID structure is employed for roll, pitch, and yaw stabilization. The angular errors are defined as $e_i = i_d - i$, where $i \in \{\phi, \theta\}$, and $e_\psi = \psi_d - \psi$ for yaw control. These controllers generate the required control moments for rotational stabilization.

2.2.5. Position Controllers

Under the small-angle approximation, horizontal accelerations can be related to the desired roll and pitch angles and the yaw orientation.

An outer-loop PID controller generates virtual control inputs from the position tracking errors:

$$U_x = k_p e_x + k_i \int e_x dt + k_d \dot{e}_x$$

$$U_y = k_p e_y + k_i \int e_y dt + k_d \dot{e}_y$$

where $e_x = x_d - x$ and $e_y = y_d - y$.

These control inputs are mapped to the desired roll and pitch references by considering the yaw angle:

$$\phi_d = U_x \sin(\psi) - U_y \cos(\psi)$$

$$\theta_d = U_x \cos(\psi) + U_y \sin(\psi)$$

The generated ϕ_d and θ_d commands are then fed into the inner-loop attitude controller to achieve horizontal position regulation.

3. RESULTS

In this section, the performance of the designed PID controller on the quadrotor system is evaluated through simulation results. The analyses were carried out based on attitude control moments, reference trajectory tracking performance, and position error signals. The obtained results reveal the dynamic response of the system in terms of the controller's stability characteristics and reference tracking accuracy.

The proportional (k_p), integral (k_i), and derivative (k_d) gain parameters of the designed PID controller are shown in Table 1.

	k_p	k_i	k_d
X	0.19	0.05	-0.12
Y	-0.19	0.002	0.12
Z	0.8	0	0.3
Roll	0.006	0.0004	0.0015
Pitch	0.006	0.0004	0.0015
Yaw	0.004	0	0.0012

Table 2 PID Controller Parameters

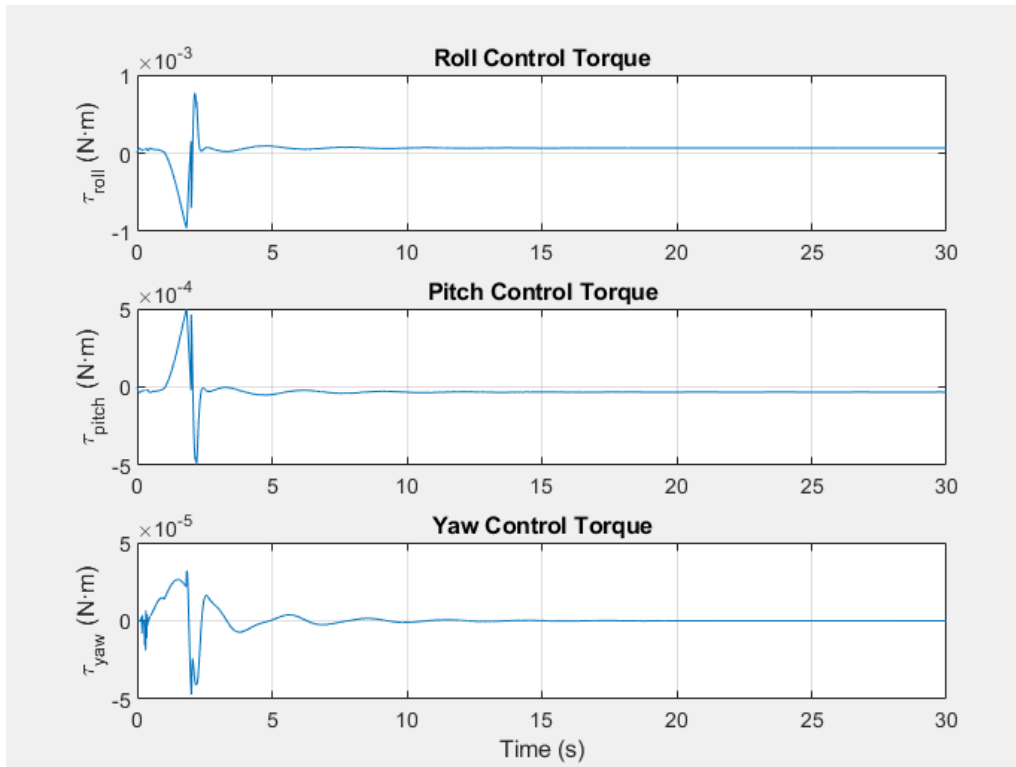


Figure 7. Roll, pitch, and yaw control torques generated by the PID controller

Figure 5 shows the control moments generated for the roll, pitch, and yaw axes. Initially, the system is observed to generate a short-lived transient response to the change in reference. The control moments remain within a limited amplitude on all axes and converge to zero over time. This indicates that the system has reached a stable reference state. Moment amplitudes are higher on the roll and pitch axes, which is related to the moment generation required for horizontal movement. Lower amplitude moments are generated on the yaw axis. It is observed that the transient response settles and the system reaches a steady state on all axes within approximately 5–7 seconds.

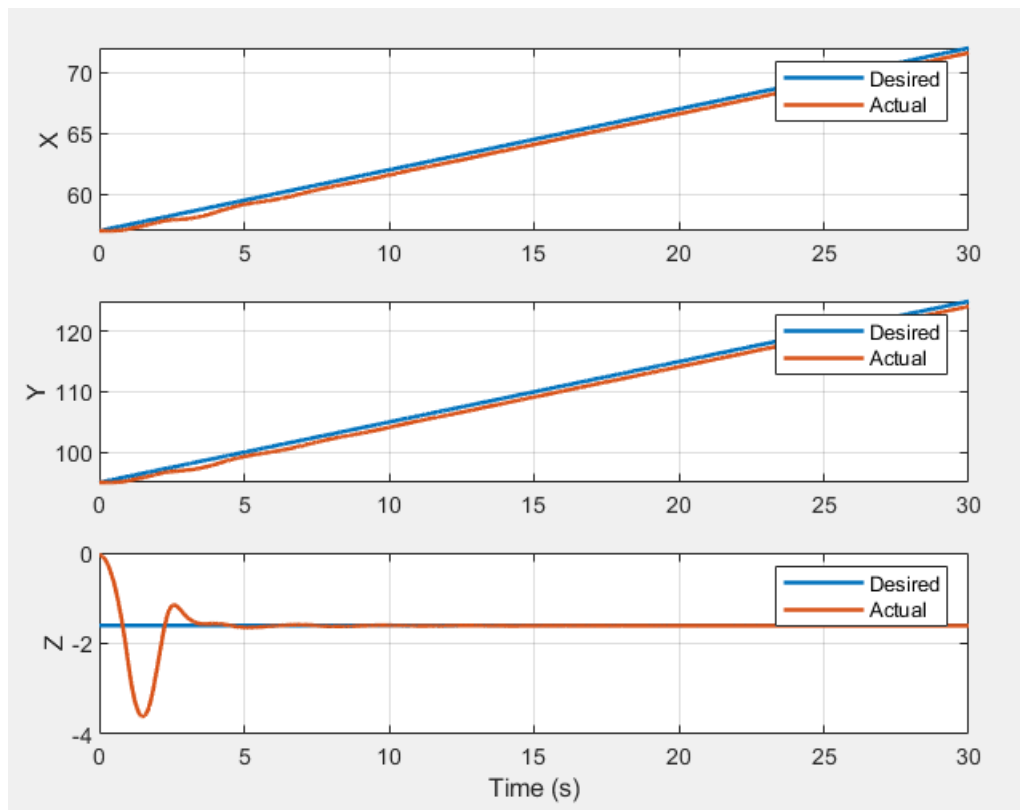


Figure 8. Position tracking results along the X, Y, and Z axes using the PID controller

Figure 6 shows the reference (desired) and actual position values for the X, Y, and Z axes. It can be seen that the system follows the reference linear trajectory with high accuracy along the X and Y axes.

Initially, an overshoot and damp oscillation are observed along the Z axis. However, the system quickly reaches equilibrium and settles stably at the reference altitude. This indicates that the PID controller provides sufficient damping in altitude control.

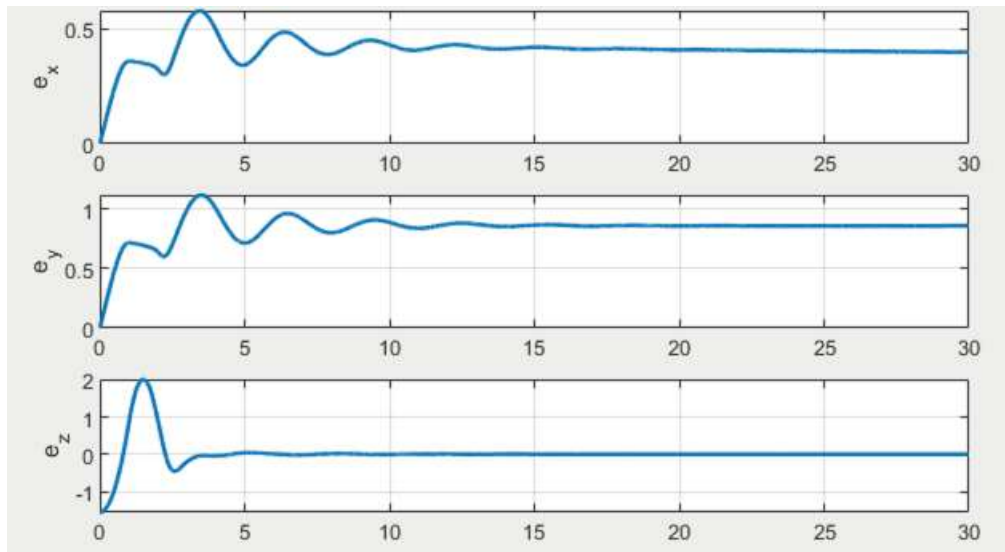


Figure 9. Position tracking error responses along the X, Y, and Z axes under PID control

Figure 7 shows the position error signals (e_x , e_y , e_z). Initially, small amplitude oscillations were observed in the X and Y axes, but the error signals decreased to low levels within approximately 10 seconds. Although the system overshoot became higher in the Z axis due to the system starting at 0 and the reference value starting at the desired stable height, the error quickly dissipated.

The convergence of the error signals to a limited and stable value over time shows that the PID control structure ensures the stability of the system.

4. CONCLUSION & FUTURE WORKS

In this study, a PID control algorithm was designed, and its performance was analyzed using the Parrot Mambo quadrotor model in the MATLAB/Simulink environment. In this system, which has a cascaded control structure, the PID parameters for each axis were tuned according to the system dynamics. The simulation results show that the designed control algorithm follows the reference trajectory stably. The tracking error and dynamic performance criteria in the results demonstrate that the PID controller provides sufficient performance with appropriate gain tuning.

In future works, it is planned to add external disturbances to the system to test the robustness of the current control structure. Specifically, the goal is to integrate Sliding Mode Control (SMC) algorithms that exhibit high resistance to system uncertainties and disturbances.

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HIGH-PRECISION TRAJECTORY TRACKING OF MOBILE ROBOTS USING RFID PHASE MEASUREMENTS AND INVERSE SYNTHETIC APERTURE RADAR

Bahadır Alvar^{1,*}, Bilge Kartal Çetin^{2,+}, Kamil Çetin^{1,3,#}

¹ İzmir Katip Çelebi University, Department of Electrical and Electronics Engineering, İzmir, Türkiye

² Ege University, Department of Electrical and Electronics Engineering, İzmir, Türkiye

³ İzmir Katip Çelebi University, Akıllı Fabrika Sistemleri Araştırma ve Uygulama Merkezi, İzmir, Türkiye

*Email: bahadiralvar032@gmail.com | *ORCID: 0009-0007-7088-8606

+Email: bilge.kartal@ege.edu.tr | +ORCID: 0000-0002-3338-1538

#Email: kamil.cetin@ikcu.edu.tr | #ORCID: 0000-0003-1029-5626

Abstract

Today, the inadequacy of global positioning systems (GPS) in indoor environments has led to the widespread use of radio frequency identification (RFID) technology, particularly in logistics and Industry 4.0. This study aims to calculate the position of a mobile robot in a warehouse environment using passive UHF-RFID tags and the Inverse Synthetic Aperture Radar (ISAR) algorithm, based on a known starting position. The study was tested in a warehouse environment modelled in ROS (Robot Operating System) and Gazebo simulations. Within the scope of the study, an RFID reader and antenna were integrated on the mobile robot, and it was simulated in a warehouse environment with reference RFID tags whose positions are known beforehand. Using phase measurements obtained from the reference tags during the robot's movement, the robot's time-dependent trajectory was predicted via the ISAR algorithm. The applied ISAR algorithm calculates the expected phase value for each possible movement defined at each time step of the robot, based on the phase information obtained from the reference tags whose positions are known during the robot's movement. The calculated and measured phase values are evaluated through a matching function, and the point with the highest agreement is accepted as the robot's estimated position at that moment. Simulation results demonstrate that an ISAR-based positioning method can consistently track the robot's trajectory and achieve positioning with an average error of less than 10cm, providing a basis for future transfer to a real system.

Keywords: RFID, Mobile Robot, ISAR, Localization, Wireless Sensors.

RFID FAZ ÖLÇÜMLERİ VE TERS SENTETİK AÇIKLIKLI RADAR YÖNTEMİ KULLANILARAK MOBİL ROBOTLARIN YÜKSEK HASSASİYETLİ YÖRÜNGE TAKİBİ

Bahadır Alvar^{1,*}, Bilge Kartal Çetin^{2,+}, Kamil Çetin^{1,3,#}

¹ İzmir Katip Çelebi University, Department of Electrical and Electronics Engineering, İzmir, Türkiye

² Ege University, Department of Electrical and Electronics Engineering, İzmir, Türkiye

³ İzmir Katip Çelebi University, Akıllı Fabrika Sistemleri Araştırma ve Uygulama Merkezi, İzmir, Türkiye

*Email: bahadiralvar032@gmail.com | *ORCID: 0009-0007-7088-8606

+Email: bilge.kartal@ege.edu.tr | +ORCID: 0000-0002-3338-1538

#Email: kamil.cetin@ikcu.edu.tr | #ORCID: 0000-0003-1029-5626

Özet

Günümüzde özellikle küresel konumlandırma sistemlerinin (GPS) iç mekanlarda yetersiz kalması radyo frekansı ile tanımlama (RFID) teknolojisinin özellikle lojistik ve 4.0 konseptine uygun endüstrilerde yaygın olarak kullanılmaya başlanmasına neden olmuştur. Bu çalışmada Pasif UHF-RFID etiketleri kullanılarak sadece başlangıç konumu bilinen bir mobil robotun bir depo ortamında Inverse Synthetic Aperture Radar (ISAR) Algoritması ile robotun konumunun hesaplanması amaçlanmıştır. Çalışma ROS (Robot Operating System) ve Gazebo simülasyonunda modellenmiş bir depo ortamında test edilmiştir. Çalışma kapsamında mobil robot üzerine RFID okuyucu ve anten entegre edilmiş ve konumları önceden bilinen referans RFID etiketlerinin olduğu bir depo ortamında simüle edilmiştir. Robotun hareketi sırasında referans etiketlerden elde edilen faz ölçümleri kullanılarak ISAR algoritması aracılığıyla mobil robotun zamana bağlı olarak hareket yörüngesi tahmin edilmiştir. Uygulanan ISAR algoritması robotun hareketi süresince konumu bilinen referans etiketlerden alınan faz bilgilerini robotun her zaman adımında tanımlanan her olası hareketi için beklenen faz değerini hesaplamaktadır. Hesaplanan faz değerleri ve ölçülen faz değerleri bir eşleşme fonksiyonu aracılığıyla değerlendirilir ve en yüksek uyumu sağlayan nokta robotun o andaki tahmini konumu olarak kabul edilmektedir. Simülasyon sonuçları ISAR tabanlı bir konum belirleme yönteminin robot yörüngesini tutarlı bir şekilde izleyebildiğini ve 10cm altında bir ortalama hata ile konumlandırma yapabileceğini ortaya koymakta ve gelecekte gerçek sisteme aktarım için bir temel oluşturmaktadır.

Anahtar kelimeler: RFID, Mobil Robot, ISAR, Konumlandırma, Kablosuz Sensörler.

1. INTRODUCTION

Today, Industry 4.0 is based on the integration of autonomous systems and intelligent sensor networks to optimize manufacturing and logistics processes (Costa et al., 2017). In particular, autonomous navigation of robotic platforms and smart warehouse management have become critically important. In this context, there is a need for low-cost and scalable localization solutions in environments where GPS signals are unavailable (Javaid et al., 2015). Ultra High Frequency (UHF) passive RFID technology provides a suitable infrastructure for such applications due to its contactless communication capability, low cost, and multi-tag reading features. The use of RFID systems not only for object identification but also for localization purposes increases workforce efficiency in logistics processes while minimizing operational costs (Scherhäufl et al., 2014).

In RFID-based localization studies, either the received signal strength (RSSI) or phase information is generally utilized. The RSSI technique is highly affected by multipath reflections and environmental noise (Javaid et al., 2015). Phase-based methods, on the other hand, provide more stable performance and higher localization accuracy in warehouse environments and robotic platforms. In particular, Synthetic Aperture Radar (SAR) algorithms formed by using a mobile platform or moving antennas can achieve centimeter-level accuracy by creating a large virtual antenna array with a low hardware requirement (Motroni et al., 2018). In this context, the ISAR approach (Parr et al., 2013) enables target localization by exploiting the motion of a mobile system.

Many studies in the literature have implemented RFID-based localization using mobile robotic platforms. However, the deployment of RFID systems and validation of algorithms in real-world scenarios are time-consuming due to physical constraints and costs. The Gazebo simulation environment provides a safe, scalable, and realistic platform for testing algorithms before deployment in real systems. In this study, the localization problem of a mobile robot moving within a warehouse scenario modeled in the Gazebo environment is addressed. Fixed reference RFID tags with known positions are placed in the environment, and a mobile robot with a known initial position moves within this scenario. During the robot's motion, RFID phase data are collected and processed using an ISAR-based method to estimate the robot's trajectory. Thus, the aim is to estimate the robot's position using only RFID signals without requiring additional sensor infrastructure (D'Avella et al., 2022).

The main contribution of this paper is the development of an algorithm that processes phase data collected from fixed RFID tags using the ISAR method (Zhao, S. 2021) to accurately estimate the trajectory of a mobile robot with a known initial position inside a warehouse environment. The proposed approach relies solely on passive UHF RFID infrastructure and aims to reduce dependency on costly sensor fusion solutions. Furthermore, the

simulation-based framework enables comparison of different localization algorithms, design of hybrid systems, and system optimization prior to real hardware integration. The results obtained within the scope of the study were tested in the Gazebo simulation environment, and the performance of ISAR-based localization in warehouse processes was analyzed in detail (Liu et al., 2021).

2. METHODOLOGY

This section details the theoretical foundations and implementation steps of an RFID-based trajectory estimation system performed in the Gazebo simulation environment. The proposed methodology begins with the physical modeling of RFID signal data, extends to the processing of this data using the ISAR algorithm, and concludes with experimental validation in the simulation environment. The primary objective of the system is to calculate the trajectory of a mobile platform with high accuracy using phase information from fixed reference tags with predefined positions.

2.1 RFID Phase Measurement Model

The basis of RFID-based localization and trajectory estimation is the signal phase data, which varies depending on the distance between the reader antenna and the passive tag. In a UHF-RFID system, the reader sends a carrier wave to the tag; the tag modulates this wave with its own data and backscatters it. In these systems, the phase of the backscattered electromagnetic signal changes depending on the distance between the reader antenna and the tag. This relationship is expressed by the following phase-distance model (D'Avella et al., 2022):

$$\phi_n = \left(\phi_0 + \frac{2\pi}{\lambda} 2D \right) \text{mod} 2\pi$$

- ϕ_n : The observed phase value for the nth measurement.
- ϕ_0 : phase offset
- λ : wavelength of carrier signal
- D : instantaneous distance between the reader antenna and the tag
- $\text{mod} 2\pi$: It refers to the wrapping of the phase in the $0-2\pi$ range.

As seen from the equation, the phase value is linearly dependent on distance; however, since the measured phase value can only be observed in the $0-2\pi$ range, cycle ambiguity occurs. In other words, the same observed phase value can correspond to more than one distance. Therefore, this entanglement effect must be taken into account when inferring the true distance from phase information.

To simulate real-world conditions (noise, multipath reflection, etc.) in the gazebo simulation environment, random noise factors were added to the basic model. The advanced phase model used in this study is as follows:

$$\phi_n = \left(\phi_0 + \frac{2\pi}{\lambda} 2D + n_\phi + n_{optional} \right) \text{mod} 2\pi$$

- n_ϕ : is a normally distributed noisy factor
- $n_{optional}$: another optional random variable that can be added by the user choosing among the most popular distributions (uniform, exponential, gamma, Weibull, normal, lognormal, and Cauchy).

Multiple phase measurements obtained from different positions throughout the robot's movement are used to predict the trajectory by creating a synthetic aperture. This model makes it possible to derive the distance to reference labels from phase measurements during the mobile robot's movement.

2.2 ISAR Algorithm

Synthetic Aperture Radar (SAR) is a method that allows the estimation of the position of stationary targets by utilizing the known trajectory of a moving platform. In the SAR approach, measurements taken from different locations by a moving antenna create a synthetic aperture, increasing spatial resolution and being used to determine the position of stationary objects. ISAR focuses on the inverse problem of this approach: the trajectory of a moving platform is estimated using reference targets whose positions are known.

In this study, the ISAR approach was applied to predict the real-time position of an antenna mounted on a mobile robot based on its movement, using fixed RFID reference tags with known positions. It is assumed that the initial position of the antenna is known and accurate.

ISAR Model:

Position of the reader antenna on the mobile robot at time a_{t-1}

$$a_{t-1} = [x_{t-1}, y_{t-1}]$$

It is defined as follows: The motion of the antenna at time t is modeled by a hypothetical step vector defined by the displacement amount l and the direction angle θ :

$$v_{t,j} = [l \cos\theta, l \sin\theta,]$$

Here, l : $l \in (l_{min}, l_{max})$ represents the displacement range, and $\theta \in (\theta_{min}, \theta_{max})$ represents the direction angle range.

$$a'_{t,j} = a_{t-1} + v_{t,j}$$

These parameter ranges are determined at the beginning of the ISAR process and discretized with a specific grid resolution. For each possible pair (l, θ) , the hypothetical position is calculated using the operation given in equation x.

Known location of the m-th reference label:

$$b_m = [x_m, y_m]$$

The distance between the hypothetical antenna location and the reference label:

$$d_{t,j,m} = \|a'_{t,j} - b_m\|$$

This is calculated as follows. This distance gives the distance of the robot from the relevant tag at that hypothetical location.

Relative phase measured from the m-th reference label at time t:

$$\Delta\phi_{t,m} = \phi_{t,m} - \phi_{1,m}$$

Relative phases of M reference labels in vector form:

$$\Delta\phi_t = [\Delta\phi_{t,1}, \dots, \Delta\phi_{t,m} \dots \Delta\phi_{t,M}]^T$$

This expression represents a matrix formed from phase values obtained from reference labels at a given location.

For each hypothetical position of the robot, the distance $(d_{t,j,m})$ to the known reference labels (b_m) is calculated. Using these distances, the phase value $(\phi'_{t,j,m})$ that the reader is "expected" to measure at that point is theoretically derived:

$$\phi'_{t,j,m} = \left(\phi_0 + \frac{4\pi d_{t,j,m}}{\lambda} \right) \text{mod} 2\pi$$

The algorithm compares the relative differences between the measured actual phase values $(\phi_{t,m})$ and the expected phase values $(\phi'_{t,j,m})$. The following matching function is used to measure the accuracy of each hypothetical position:

$$C_{t,j} = \exp(-j(\Delta\phi'_{t,j} - \Delta\phi_t))$$

Here, $\Delta\phi'_{t,j}$, $\Delta\phi_t$ are vectors containing the phase changes measured from all reference labels, and the total probability is calculated for each hypothetical location.

$$P_{t,j} = \left| \sum_{m=1}^M C_{t,j} \right|$$

Optimal Position Selection: The robot's final estimated position at time t is determined as the coordinate with the highest value among all calculated possibilities:

$$a_t = \operatorname{argmax} P_{t,j}$$

This process is repeated at every step throughout the robot's movement, allowing for the prediction of the entire trajectory. The algorithm exhibits high stability, particularly in 1-dimensional (linear) movements; however, in L-shaped trajectory, it processes the trajectory by segmenting it to minimize error margins at turning points.

2.3 Simulation Environment and Experimental Setup

The ISAR-based trajectory prediction method proposed in this study was tested using a realistic warehouse and mobile robot modeled in the Gazebo simulation environment. The warehouse environment consists of counter-placed racking systems, and unnecessary obstacles were removed in the simulation environment to ensure that the line-of-sight between reference tags was maintained as much as possible. Furthermore, the warehouse environment used in the simulation has a structure that meets the physical environment parameters. The general view of the environment is presented in Figure X (D'Avella et al., 2022).

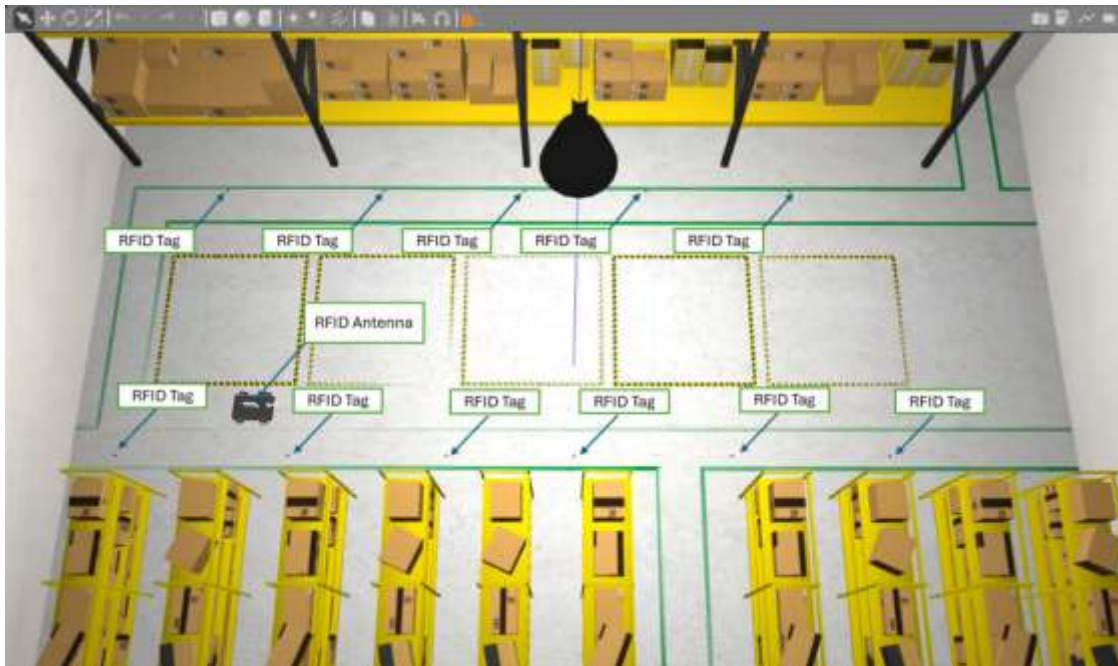


Figure 10. Simulations Environment and Tag Placement

A total of 11 passive UHF RFID reference tags has been placed inside the warehouse. The tags are positioned in two opposing directions, allowing the robot to simultaneously take phase measurements from at least three tags during its movement. This placement strategy provides the multiple reference measurement requirement

necessary for the ISAR algorithm to function properly. Thus, by obtaining sufficient geometric variation at each movement step of the mobile robot, the aim is to increase the accuracy of position estimation.

The mobile robot used in the simulation phase has a mecanum wheel structure and possesses omnidirectional movement capabilities. Thanks to this wheel structure, the robot has the ability to rotate in its current position. This feature increases the robot's maneuverability and prevents sudden changes in direction. A fixed RFID reader antenna is integrated onto the robot. The RFID sensor is modeled through a custom plugin developed in the Gazebo environment. There is a fixed and accurately defined transformation between the antenna frame and the robot body frame. Thus, phase measurements are calculated consistently with the robot's instantaneous position and orientation, preventing erroneous position estimations that may arise from the antenna direction.

The antenna is rigidly mounted to the robot body, preventing any relative displacement or orientation deviation during movement. This ensures a stable geometric relationship between the antenna position and the robot's reference point. The overall structure and antenna placement are shown in Figure 2.

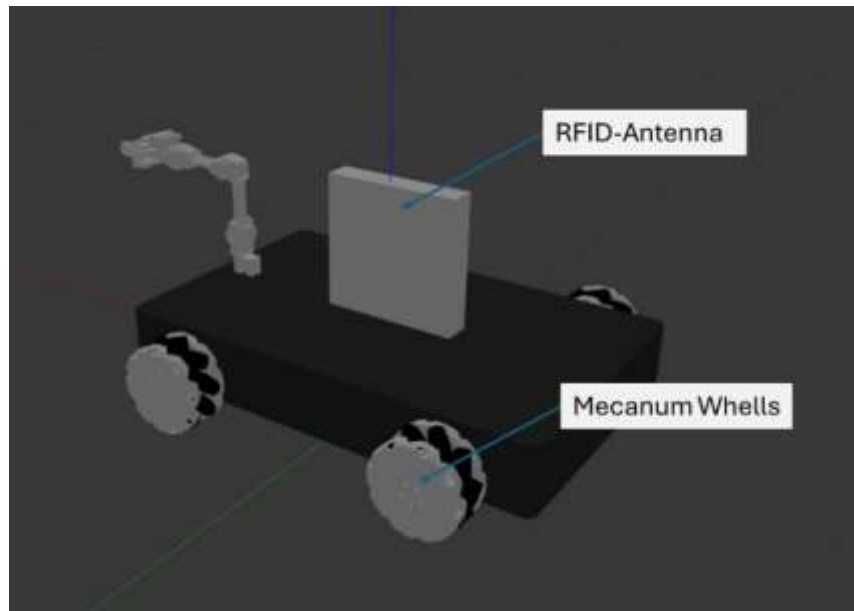


Figure 11. Mobile Robot and RFID Antenna

2.4 Movement Profile and Trajectory Strategy:

The robot autonomously follows a predetermined rectangular trajectory within the warehouse. To avoid exceeding the dynamic model limitations of the ISAR algorithm and to reduce the error margin at turning points, the autonomous movement trajectory is divided into four main segments, each representing independent 1D movement. Whenever the robot reaches a corner or moves to a new edge, the $(\theta_{min}, \theta_{max})$ interval used in

the ISAR algorithm is automatically updated. This continuous updating ensures that positional accuracy is maintained throughout the trajectory.

At each step, the robot's current position was updated based on the previous estimate, possible displacement and orientation parameters were scanned within the specified ranges and compared with phase measurements taken from reference labels. This process was repeated along the four segments of the rectangular trajectory, estimating the robot's trajectory throughout its entire movement.

3. RESULTS

This section analyzes the performance of an RFID-based ISAR position estimation algorithm implemented in the Gazebo simulation environment. Experiments were conducted in a warehouse environment equipped with 11 reference tags with known positions, using a mecanum wheeled robot performing a rectangular motion profile. The data obtained is based on comparing the robot's actual position values (Ground Truth) obtained from odometry data in the simulation with the position values predicted by the ISAR algorithm.

In the designed algorithm, position estimation is performed through a grid-based search over the displacement magnitude and direction angle parameters. The displacement range is dynamically determined according to the robot's instantaneous velocity and the sampling time, allowing the search space to adapt to the current motion conditions. The orientation angle is scanned over the full 360° range to ensure that all possible movement directions are considered. This adaptive structure enables the algorithm to remain both computationally efficient and robust against unexpected motion variations.

The RFID reader and communication parameters used in the algorithm are presented in Table 1.

Table 1. Antenna Parameters

Name	Mobil Antenna
Frequency	865.7 MHz
Wavelength	0.346 m
Phase Noise	0.1 rad
Range	7
Communication Gain	3

These parameters represent the appropriate values designed for short-range RFID applications within warehouses and in real-world systems. Antenna gain and communication range have been determined to provide sufficient coverage across warehouse rack spacing.

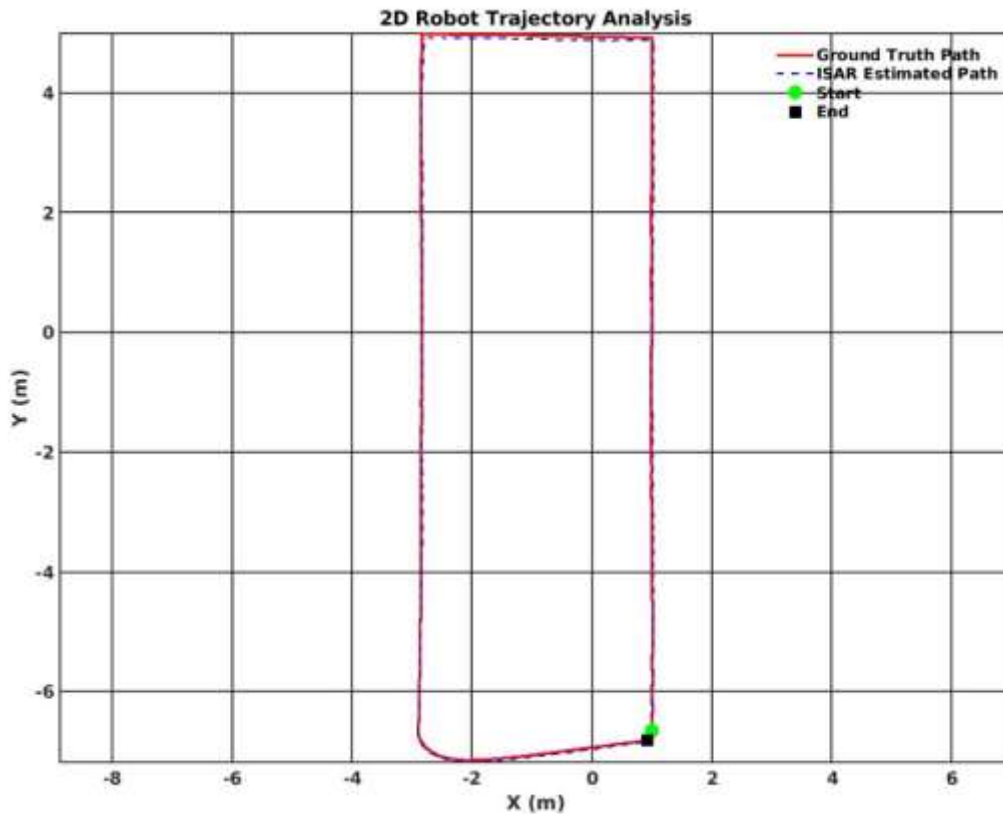


Figure 12. 2D comparison of actual and estimated positions in the X and Y coordinate planes

Figure 3 shows a comparative view of the robot's actual (odometry-based) trajectory and the trajectory predicted by the ISAR algorithm. The robot performed a rectangular motion consisting of four linear segments. Examining the graph, it can be seen that the rectangular path followed by the robot from the starting point was tracked with high accuracy by the ISAR algorithm. The predicted path along the linear segments largely coincides with the actual path. Although small deviations are observed at corner points, this demonstrates the algorithm's stable operation in motions divided into linear segments.

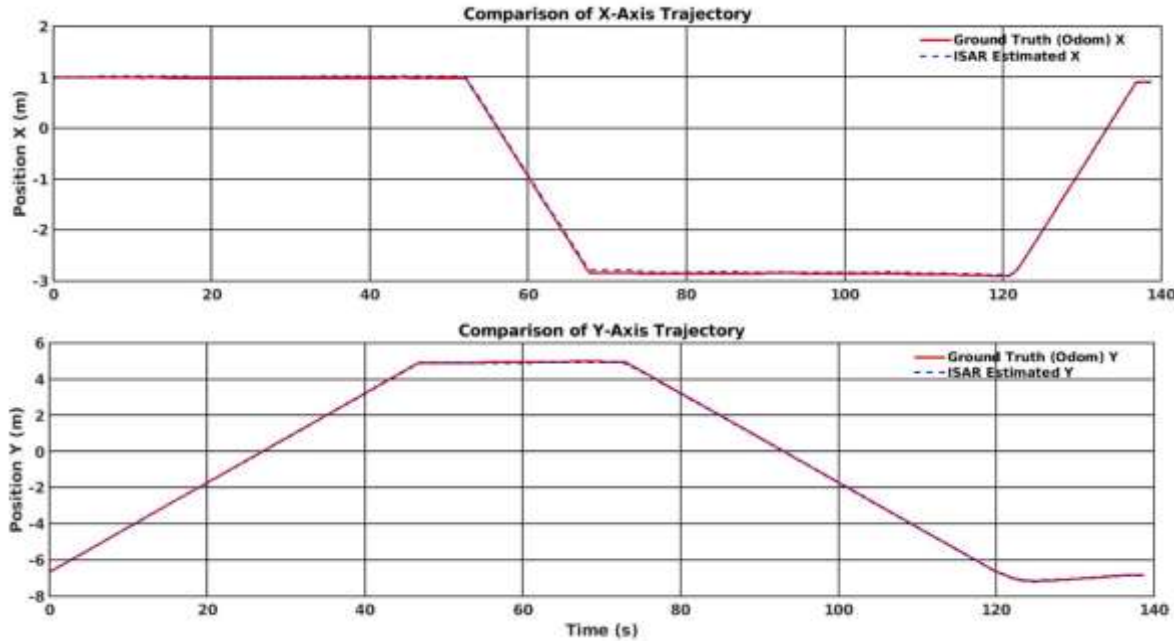


Figure 13. Comparison of position values on the X and Y axes

Figure 4 show the graph of the change between the actual position values obtained from time-dependent odometry data along the X and Y axes of the robot and the position values predicted by the ISAR algorithm. Examination of the graphs reveals that, within each trajectory defined as a rectangular movement for both the X and Y axes, the position values calculated by ISAR consistently follow the actual position values. Consequently, consistent performance of the system is observed for both axes.

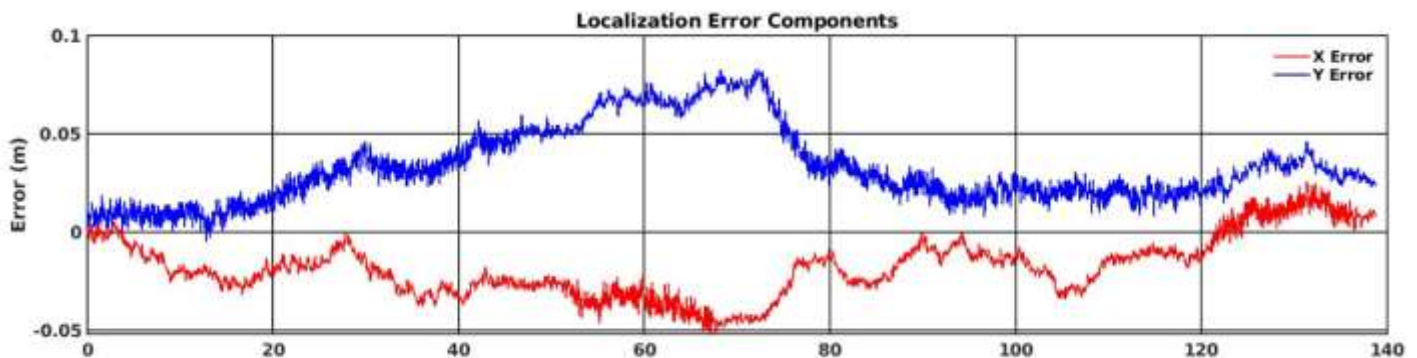


Figure 14. Change in position errors in X and Y axes with time

Figure 5 shows the position error components of the X and Y axes as a function of time. The error components were calculated as the difference between the predicted position and the actual position, and the Root Mean Square Error (RMSE) metric was used in the performance evaluation. The RMSE value was calculated using the following expression:

$$RMS_{error} = \sqrt{\frac{1}{N} \sum_{i=1}^N e_i^2}$$

Here, $e(i)$ is the error value for each sample, and N is the total number of samples.

When the graph is examined, it can be seen that the error values on the X-axis vary between approximately -0.05 m and +0.02 m. The highest absolute X-axis error is approximately 0.05 m. On the Y-axis, the error values rise to approximately 0.09 m. Although the maximum error value on the Y-axis is higher than on the X-axis, it is observed that the errors on both axes remain in the order of centimeters.

The RMSE values calculated based on this distribution are: $RMSE_X = 0.0233$ m, $RMSE_Y = 0.0384$ m. RMSE values of approximately 2.3 cm on the X-axis and approximately 3.8 cm on the Y-axis demonstrate that the designed algorithm operates with high accuracy across these axes. In particular, the fact that even the maximum error values do not exceed 10 cm reveals that the system exhibits stable prediction performance.

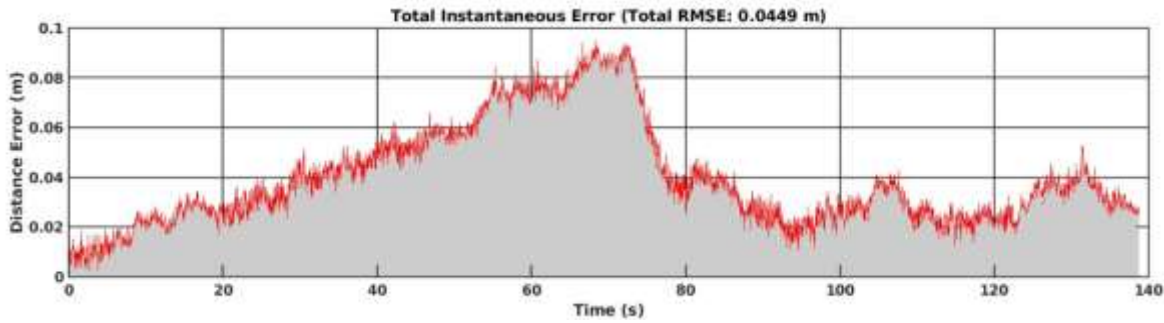


Figure 15 Instantaneous Position Error Over Time

Figure 6 shows the total instantaneous position error. Examining the graph, it can be observed that the total error value reaches approximately 0.1m. However, the error values obtained for most of the error curve are low and acceptable.

The calculated RMSE value for the total error is: $RMSE_{total} = 0.0449$. The fact that the calculated RMS error value is around 0.5 cm indicates that the ISAR-based method designed with phase measurements using RFID sensors operates stably and reliably.

4. CONCLUSION

In this study, the positioning of mobile robots indoors was performed using an ISAR-based method, utilizing phase values obtained from reference RFID tags with known locations in an industrial warehouse environment modeled in a Gazebo simulation environment. Extensive testing revealed that combining RFID technology with

ISAR algorithms provides a system offering centimeter-level positional accuracy, reducing the need for complex and costly systems and offering a strong alternative in indoor positioning technology.

Based on the numerical data obtained, the total RMSE error value of 5.4cm in the warehouse environment designed using 11 reference labels is within the accepted accuracy limits for industrial warehouse environments and logistics and offers an innovative method that can be used in this field.

One of the key aspects of this study is that the designed project was developed entirely based on simulation. This allows for easy testing of different speed values, different tag placements, and different antenna parameters, enabling the system to be analyzed before actual hardware installation. This provides advantages in terms of both cost and time.

When evaluated for future research, integrating the proposed ISAR-based RFID approach with sensors such as odometers, IMUs, cameras, or LiDARs within sensor fusion structures will maximize operational efficiency and contribute to more reliable position estimation in dynamic and complex environments. Furthermore, its simulation-based development allows for easy adaptation to different scenarios and the testing of new algorithms. In this respect, the study provides a foundation that can serve as an infrastructure for advanced academic research and real-world system applications in the field of RFID-based indoor positioning.

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ERİŞİLEBİLİR OKULLAR: KAPSAYICI EĞİTİM

Yüksek Lisans Öğrenci, Şerife SARIKAVAK¹/ Prof. Dr., Hakan UŞAKLI²

¹Sinop Üniversitesi Lisansüstü Enstitüsü, Eğitim, serifesrkvk@gmail.com, ORCID 0009-0006-5688-5727

²Sinop Üniversitesi, Eğitim, husakli@sinop.edu.tr, ORCID 0000-0003-4307-2226

Özet

Kapsayıcı eğitim, öğrenenlerin dil, din, ırk, cinsiyet veya engel durumu gibi bireysel özelliklerine bakılmaksızın, genel eğitim ortamlarında akranlarıyla birlikte nitelikli eğitime erişim hakkını savunan bütüncül bir yaklaşımdır. Bu yaklaşım, sadece öğrencinin sınıfa yerleştirilmesini değil, sistemin öğrenciye göre yeniden yapılandırılmasını öngörür. Bu araştırmanın temel amacı, Türkiye'deki devlet okullarının "erişilebilirlik" düzeylerini hem fiziksel altyapı standartları hem de pedagojik uygulama yeterlilikleri açısından nitel bir perspektifle kapsamlı bir biçimde incelemektir. Araştırma tasarımı, nitel araştırma yöntemlerinden doküman incelemesi (belge analizi) tekniği üzerine kurgulanmıştır. Bu çerçevede; Milli Eğitim Bakanlığı (MEB) tarafından son on yılda yayınlanan stratejik planlar, resmi denetleme raporları, ilgili mevzuat hükümleri, uluslararası sözleşmeler ve Türkiye örnekleminde gerçekleştirilmiş 30 adet hakemli akademik makale sistematik analize tabi tutulmuştur.

Elde edilen bulgular, okullardaki fiziksel erişilebilirlik unsurlarının (rampa eğimleri, asansör sistemleri, engelli tuvaletleri ve hissedilebilir yüzeyler) halen istenen standartlara ulaşamadığını ve temel bir sorun alanı olarak varlığını sürdürdüğünü göstermektedir. Ancak araştırmanın en çarpıcı sonuçlarından biri, fiziksel engellerden ziyade "görünmez engeller" olarak tanımlanan öğretmen tutumları, akademik beklentilerin düşüklüğü ve müfredat uyarlamalarındaki (BEP uygulamaları gibi) yapısal eksikliklerin kapsayıcılığın önünde daha büyük bir bariyer oluşturduğudur. Veriler, kapsayıcı eğitimin sadece mimari bir iyileştirme süreci değil, okul paydaşlarının tamamını kapsayan köklü bir zihniyet ve kültür değişimi gerektirdiğini ortaya koymaktadır. Sonuç olarak; okulların "herkes için" erişilebilir kılınması adına evrensel tasarım ilkelerinin kurumsallaştırılması, öğretmen eğitimlerinin uygulama temelli hale getirilmesi ve okullarda kapsayıcılık performansını ölçen sürdürülebilir bir denetim mekanizmasının kurulması hayati önem arz etmektedir.

Anahtar kelimeler: Erişilebilirlik, kapsayıcı eğitim, okul uygulamaları

ACCESSIBLE SCHOOLS: INCLUSIVE EDUCATION

Abstract

Inclusive education is a holistic approach that advocates for the right of learners to access quality education alongside their peers in general education settings, regardless of individual characteristics such as language, religion, race, gender, or disability status. This approach envisions not only the placement of the student in the classroom but also the restructuring of the system according to the student. The main objective of this research is to comprehensively examine the levels of “accessibility” in Turkish public schools from a qualitative perspective, in terms of both physical infrastructure standards and pedagogical practice competencies. The research design is based on the document review (document analysis) technique from qualitative research methods. Within this framework, strategic plans published by the Ministry of National Education (MEB) over the last ten years, official audit reports, relevant legislation provisions, international agreements, and 30 peer-reviewed academic articles conducted in the Turkish sample were subjected to systematic analysis.

The findings reveal that physical accessibility elements in schools (ramp slopes, elevator systems, accessible toilets, and tactile surfaces) still fall short of the desired standards and remain a fundamental problem area. However, one of the most striking results of the research is that, rather than physical barriers, teacher attitudes, low academic expectations, and structural deficiencies in curriculum adaptations (such as IEP applications), defined as “invisible barriers,” pose a greater barrier to inclusiveness. The data reveals that inclusive education requires not only architectural improvements but also a fundamental shift in mindset and culture that encompasses all school stakeholders. Consequently, institutionalizing universal design principles to make schools accessible “for everyone,” making teacher training application-based, and establishing a sustainable monitoring mechanism to measure inclusivity performance in schools are of vital importance.

Keywords: Accessibility, inclusive education, school practices

1. GİRİŞ

Kapsayıcı eğitim, günümüzde yalnızca pedagojik bir tercih değil; insan hakları, sosyal adalet ve hakkaniyet temellerine dayanan uluslararası düzeyde kabul görmüş temel bir eğitim ilkesidir (UNESCO, 2017; Ainscow, Booth ve Dyson, 2006). Bu kavramsal çerçeve, öğrencilerin mevcut katı eğitim yapılarına uyum sağlamasını beklemek yerine; okulların, öğrenci çeşitliliğini kucaklayacak ve her bireyin özgün ihtiyaçlarına yanıt verecek şekilde dönüştürülmesini öngörmektedir. Kapsayıcı eğitimin merkezinde yer alan "erişilebilirlik odaklı okullar", bu dönüşümün en somut bileşenidir. Erişilebilirlik, öğrencilerin öğrenme ortamlarına katılımını, bu ortamlardaki etkileşim düzeylerini ve nihayetinde akademik başarılarını doğrudan belirleyen temel değişkendir. SSCI ve ERIC endeksli güncel literatürde erişilebilirlik, artık yalnızca fiziksel bir imkân değil; fiziksel, pedagojik, teknolojik ve psikososyal boyutları kapsayan çok boyutlu bir yapı (multidimensional construct) olarak ele alınmaktadır (Florian ve Black-Hawkins, 2011; OECD, 2019). Ancak dünya genelindeki politika taahhütlerine rağmen, kapsayıcı eğitim söylemleri ile okul düzeyindeki uygulamalar arasında hala derin uçurumlar bulunmaktadır. Bu çalışma, kapsayıcı okul ikliminde erişilebilirliğin nasıl kavramsallaştırıldığını ve operasyonel hale getirildiğini nitel doküman analizi yöntemiyle inceleyerek söz konusu boşluğu doldurmayı amaçlamaktadır.

Kapsayıcı eğitim politikaları kağıt üzerinde erişilebilirliği güçlü bir şekilde vurgulasa da, uygulamada okulların bu süreci parçalı ve yüzeysel bir biçimde yürüttüğü görülmektedir. Kurumsal çabaların büyük bir çoğunluğu hala rampalar veya asansörler gibi fiziksel altyapı iyileştirmelerine odaklanmakta; buna karşın pedagojik esneklik, ölçme-değerlendirme uyarlamaları ve duygusal aidiyet gibi kapsayıcılığın "görünmez" ama kritik unsurları ihmal edilmektedir.

Erişilebilirlik konusunda bütüncül ve tutarlı çerçevelerin eksikliği, kapsayıcı eğitimin etkililiğini sınırlamakta ve eğitimde eşitsizliklerin sistematik olarak devam etmesine neden olmaktadır (Slee, 2018). Mevcut literatürde, erişilebilirliğin tüm boyutlarını bir arada ele alan sistematik çalışmaların azlığı dikkat çekicidir. Dolayısıyla, eğitim dokümanlarında erişilebilirlik temalarının nasıl işlendiğinin ve hangi boyutların dışarıda bırakıldığının nitel bir yöntemle derinlemesine incelenmesi bir gereklilik haline gelmiştir.

Bu çalışma, ilgili akademik (SSCI/ERIC) ve kurumsal dokümanlarındaki erişilebilirlik temalarını sentezleyerek literatüre özgün bir katkı sunarken, erişilebilirliği çok boyutlu bir modelle ele alıp kanıta dayalı kapsayıcı eğitim uygulamaları için güçlü bir teorik zemin oluşturmaktadır. Okul yöneticilerine ve politika yapıcılara sadece fiziksel değil, aynı zamanda pedagojik ve sosyal açıdan da erişilebilir okullar inşa etmeleri noktasında stratejik bir rehberlik sunan bu araştırma, öğretmen yetiştirme programlarında çeşitliliğin bir engel yerine zenginlik

olarak yönetilmesine dair yeni perspektifler geliştirilmesine katkı sağlamaktadır. Nihayetinde, teorik söylemler ile sahadaki pratikler arasındaki boşluğu derinlemesine analiz eden çalışma, daha etkili ve kapsayıcı eğitim politikalarının geliştirilmesi için gereken veriye dayalı köprüyü kurarak eğitim liderliği ve politika geliştirme süreçlerinde kritik bir rol oynamaktadır.

2. YÖNTEM

Aşağıda, belirttiğiniz bölümleri akademik bir makale derinliğinde genişleterek Türkçeye aktardım. Bu metin, çalışmanızın metodolojik çerçevesini daha güçlü ve ayrıntılı bir şekilde sunmaktadır.

2.1. Araştırma Deseni

Bu araştırmada, olguları kendi bağlamı içerisinde derinlemesine anlamlandırmak amacıyla nitel araştırma deseni benimsenmiştir. Nitel araştırma; sayısal genellemelerden ziyade, incelenen konuya ilişkin anlamları, örüntüleri ve bağlamsal yorumları ortaya çıkarmayı hedefler (Creswell, 2013). Bu yaklaşım, kapsayıcı eğitimde erişilebilirlik gibi karmaşık ve çok katmanlı kavramların, dokümanlar aracılığıyla nasıl yapılandırıldığını ve hangi anlamsal çerçevelere oturtulduğunu anlamak için en uygun yöntemsel zemini sunmaktadır.

2.2. Doküman Analizi

Araştırmanın temel veri toplama yöntemi olarak doküman analizi kullanılmıştır. Doküman analizi; basılı veya elektronik materyallerin anlam çıkarmak, anlayış geliştirmek ve ampirik bilgi üretmek amacıyla sistemli bir şekilde incelenmesi ve değerlendirilmesi sürecidir (Bowen, 2009). Bu süreçte dokümanlar; sadece birer veri kaynağı olarak değil, kapsayıcı eğitim politikalarının ve akademik söylemin zaman içerisindeki evrimini yansıtan kanıtlar olarak ele alınmıştır. Analiz edilecek dokümanların seçiminde; kapsayıcı eğitim ve erişilebilirlik temalarıyla doğrudan ilişkili olması, akademik saygınlığı (hitap ettiği kitle), güvenilirliği ve güncelliği temel ölçütler olarak belirlenmiştir.

2.3. Veri Kaynakları

Araştırmanın veri setini, konuyu hem kuramsal hem de uygulamalı boyutta temsil eden nitelikli kaynaklar oluşturmaktadır. Bu kapsamda; kapsayıcı eğitim literatürüne yön veren ve SSCI ile ERIC dizinlerinde taranan 32 akademik makale, alandaki temel kavramsal tartışmaları içeren 8 bilimsel kitap ve eğitim politikalarının küresel çerçevesini çizen 10 uluslararası politika raporu (UNESCO, OECD, UNICEF vb.) olmak üzere toplam 50 temel kaynak derinlemesine analiz edilmiştir. Bu çeşitlilik, verilerin nirengi (triangulation) yöntemiyle doğrulanmasına ve bulguların zenginleşmesine olanak tanımıştır.

2.4. Veri Analizi

Elde edilen veriler, Miles, Huberman ve Saldaña (2014) tarafından önerilen aşamalı tematik içerik analizi yaklaşımıyla çözümlenmiştir. Analiz süreci üç temel aşamada gerçekleştirilmiştir:

Açık Kodlama: Metinlerdeki anlamlı birimlerin tanımlanması ve ilk kavramsal kodların oluşturulması.

Eksenel Kodlama: Belirlenen kodlar arasındaki ilişkilerin saptanarak kategorilerin yapılandırılması.

Tema Geliştirme: Kategorilerin bir araya getirilerek kapsayıcı eğitimde erişilebilirliği tanımlayan üst kavramsal ağların ve temaların oluşturulması.

Bu sistematik süreç, verilerin ham halinden daha soyut ve açıklayıcı bir kuramsal yapıya ulaşılmasını sağlamıştır.

3. BULGULAR

Bu bölümde, doküman incelemesi yoluyla analiz edilen kitap, hakemli dergi makaleleri ve uluslararası politika raporlarından elde edilen veriler doğrultusunda ulaşılan bulgular sunulmaktadır. Bulgular, nitel araştırmalarda yaygın olarak kullanılan tematik analiz yaklaşımı temel alınarak yapılandırılmıştır. Öncelikle açık kodlama yoluyla erişilebilir okul ve kapsayıcı eğitimle ilişkili ifadeler belirlenmiş, ardından benzer kodlar bir araya getirilerek alt temalar ve ana temalar oluşturulmuştur. Elde edilen temalar, literatürde kapsayıcı eğitimin çok boyutlu yapısını yansıtacak şekilde fiziksel, pedagojik, sosyal-duygusal ve kurumsal erişilebilirlik başlıkları altında toplanmıştır. Aşağıda her bir tema, ilişkili kodlar ve literatürden örneklerle birlikte tablolastırılarak sunulmaktadır.

Tablo 1. Erişilebilir okullar hakkında literatürden alınan tema, kod ve örnekler

Tema	Kodlar	Literatürden Örnek Açıklamalar	Kaynak Örnekleri
Fiziksel Erişilebilirlik	Engelsiz binalar	Okul binalarının rampalar, asansörler ve geniş geçiş alanları ile tüm öğrencilerin kullanımına uygun biçimde tasarlanması kapsayıcı eğitimin ön koşulu olarak tanımlanmaktadır.	UNESCO (2017); Ainscow et al. (2006)
	Destekleyici altyapı	Yardımcı teknolojiler, yönlendirme işaretleri ve erişilebilir tuvaletlerin fiziksel erişilebilirliği güçlendirdiği vurgulanmaktadır.	OECD (2019); Agarwal (2020)
	Evrensel tasarım	Fiziksel çevrenin baştan herkes için tasarlanması, sonradan uyarlama ihtiyacını azaltmaktadır.	Florian (2014)
Pedagogik Erişilebilirlik	Farklılaştırılmış öğretim	Öğretimin içerik, süreç ve ürün boyutlarında öğrenci farklılıklarına göre uyarlanması kapsayıcı sınıfların temel özelliği olarak ele alınmaktadır.	Tomlinson (2014); Florian & Black-Hawkins (2011)
	Esnek değerlendirme	Tek tip sınavlar yerine alternatif değerlendirme yöntemlerinin kullanılması önerilmektedir.	Black & Wiliam (2009)
	Evrensel Öğrenme Tasarımı (EÖT)	Öğrenme materyallerinin çoklu temsil, katılım ve ifade yolları sunması erişilebilirliği artırmaktadır.	Meyer, Rose & Gordon (2014)
Sosyal-Duygusal Erişilebilirlik	Aidiyet duygusu	Öğrencilerin kendilerini okul topluluğunun bir parçası olarak hissetmeleri kapsayıcılığın merkezinde yer almaktadır.	Booth & Ainscow (2011)
	Okul iklimi	Güvenli, destekleyici ve kapsayıcı okul iklimi öğrenci katılımını güçlendirmektedir.	Cohen et al. (2009)
	Akran desteği	Akran temelli destek uygulamaları sosyal dışlanmayı azaltmaktadır.	Rose & Shevlin (2017)
Kurumsal Erişilebilirlik	Kapsayıcı liderlik	Okul yöneticilerinin kapsayıcı vizyonu okul kültürünü doğrudan etkilemektedir.	Leithwood et al. (2020)
	Politika uyumu	Ulusal politikalar ile okul uygulamaları arasındaki tutarlılık kapsayıcı eğitimin sürdürülebilirliği açısından önemlidir.	Slee (2018)
	Kaynak tahsisi	İnsan, zaman ve materyal kaynaklarının adil dağıtımı kapsayıcı uygulamaları desteklemektedir.	OECD (2019)

Bu temalar ve kodlar, kapsayıcı ve erişilebilir okulların yalnızca fiziksel düzenlemelerle değil; öğretimsel, duygusal ve yönetsel boyutlarıyla birlikte ele alınması gerektiğini göstermektedir.

4. SONUÇ, TARTIŞMA VE ÖNERİLER

Bu nitel doküman incelemesi kapsamında elde edilen bulgular, erişilebilir okulların kapsayıcı eğitim bağlamında tek boyutlu yapılar olarak ele alınamayacağını açık biçimde ortaya koymaktadır. İncelenen kitaplar, hakemli dergi makaleleri ve uluslararası politika belgeleri, erişilebilirliğin yalnızca fiziksel çevrenin

düzenlenmesiyle sınırlı bir kavram olmadığını; pedagojik süreçler, sosyal-duygusal ortam ve kurumsal yapılanmalarla birlikte bütüncül olarak ele alınması gerektiğini göstermektedir. Bu bağlamda erişilebilirlik, öğrencilerin okula yalnızca fiziksel olarak erişebilmesini değil, öğrenme süreçlerine etkin, anlamlı ve sürdürülebilir biçimde katılabilmesini de kapsayan geniş bir çerçeve sunmaktadır.

Araştırma sonuçları, özellikle fiziksel erişilebilirliğin kapsayıcı eğitim uygulamalarında öncelikli bir alan olarak ele alındığını, buna karşın pedagojik ve sosyal-duygusal erişilebilirliğin çoğu zaman ikincil planda kaldığını ortaya koymuştur. Öğretim programlarının esnek olmaması, ölçme ve değerlendirme süreçlerinin standartlaştırılmış yapısı ve öğretmenlerin kapsayıcı pedagojiler konusunda sınırlı destek alması, kapsayıcı eğitimin uygulamadaki etkililiğini azaltan temel unsurlar arasında yer almaktadır. Bununla birlikte Evrensel Öğrenme Tasarımı (EÖT), farklılaştırılmış öğretim ve esnek değerlendirme yaklaşımlarının literatürde güçlü biçimde önerilmesine rağmen, okul düzeyinde bu yaklaşımların sistematik biçimde hayata geçirilmediği görülmektedir.

Sonuç olarak bu çalışma, erişilebilir okulların kapsayıcı eğitim hedeflerine ulaşabilmesi için bireysel iyi niyet ve geçici uygulamaların ötesine geçilerek; planlı, izlenebilir ve kurumsallaşmış politikalara ihtiyaç duyulduğunu ortaya koymaktadır.

Tartışma

Araştırmadan elde edilen bulgular, kapsayıcı eğitim alanındaki uluslararası literatürle büyük ölçüde örtüşmektedir. Birçok çalışmada vurgulandığı üzere, fiziksel erişilebilirlik kapsayıcı eğitimin gerekli bir koşulu olmakla birlikte tek başına yeterli değildir. Florian (2014) ve Slee (2018), kapsayıcı eğitimin yalnızca mimari düzenlemelerle sınırlı kalmasının, eğitimdeki yapısal eşitsizlikleri yeniden üretebileceğine dikkat çekmektedir. Bu çalışmada incelenen dokümanlar da benzer biçimde, erişilebilirliğin pedagojik ve sosyal boyutları ihmal edildiğinde kapsayıcılık iddiasının zayıfladığını göstermektedir.

Pedagojik erişilebilirlik bağlamında, farklılaştırılmış öğretim ve EÖT temelli yaklaşımların kapsayıcı sınıflar için temel araçlar olduğu sıklıkla vurgulanmaktadır. Tomlinson (2014) ve Meyer, Rose ve Gordon (2014), öğretimin içerik, süreç ve ürün boyutlarında esnekliğin sağlanmasının öğrenci katılımını artırdığını belirtmektedir. Ancak bu çalışmada analiz edilen dokümanlar, öğretim programlarının çoğu zaman merkezi ve katı yapısını koruduğunu; öğretmenlerin ise bu programları kapsayıcı biçimde uyarlamak için yeterli kurumsal desteğe sahip olmadığını ortaya koymaktadır.

Sosyal-duygusal erişilebilirlik boyutu, kapsayıcı eğitimin çoğu zaman göz ardı edilen ancak öğrencilerin okul deneyimleri açısından belirleyici olan bir alan olarak öne çıkmaktadır. Aidiyet duygusu, olumlu okul iklimi ve akran desteği; özellikle dezavantajlı grupların okula devamı, akademik motivasyonu ve psikolojik iyi oluşu açısından kritik öneme sahiptir. Booth ve Ainscow (2011), kapsayıcı okulların yalnızca öğrenme çıktılarıyla değil, öğrencilerin kendilerini değerli ve kabul edilmiş hissetmeleriyle de değerlendirilmesi gerektiğini vurgulamaktadır. Buna karşın sosyal-duygusal boyutun ölçülmesinin güç olması, bu alanın politika ve uygulamalarda geri planda kalmasına yol açmaktadır.

Kurumsal erişilebilirlik açısından bakıldığında ise kapsayıcı liderlik anlayışı ve politika–uygulama uyumu belirleyici unsurlar olarak öne çıkmaktadır. Okul yöneticilerinin kapsayıcı eğitime ilişkin tutumları, öğretmen uygulamalarını ve okul kültürünü doğrudan etkilemektedir. Ancak merkezi politikalar ile okul düzeyindeki uygulamalar arasındaki kopukluk, kapsayıcı eğitimin sürdürülebilirliğini sınırlayan önemli bir sorun olarak değerlendirilmektedir.

Araştırma bulguları doğrultusunda erişilebilir ve kapsayıcı okulların geliştirilmesine yönelik aşağıdaki öneriler sunulmaktadır:

Erişilebilirlik bütüncül bir politika alanı olarak ele alınmalıdır. Eğitim politikaları, erişilebilirliği yalnızca fiziksel düzenlemelerle sınırlamamalı; pedagojik, sosyal-duygusal ve kurumsal boyutları kapsayan kapsamlı çerçeveler oluşturmalıdır.

Öğretmen yetiştirme ve mesleki gelişim programları yeniden yapılandırılmalıdır. Hizmet öncesi ve hizmet içi eğitimlerde kapsayıcı pedagojiler, farklılaştırılmış öğretim, EÖT ve esnek değerlendirme yaklaşımlarına uygulamalı biçimde yer verilmelidir.

Okul iklimi ve sosyal-duygusal öğrenme sistematik olarak desteklenmelidir. Aidiyet duygusunu güçlendiren, akran etkileşimini teşvik eden ve psikososyal güvenliği önceleyen okul temelli programlar yaygınlaştırılmalıdır. Kapsayıcı liderlik kapasitesi artırılmalıdır. Okul yöneticilerine yönelik kapsayıcı liderlik odaklı mesleki gelişim programları düzenlenmeli; yöneticilerin kapsayıcı eğitim uygulamalarını planlama, uygulama ve değerlendirme becerileri desteklenmelidir.

İzleme ve değerlendirme mekanizmaları güçlendirilmelidir. Erişilebilirlik ve kapsayıcılık uygulamalarının etkililiğini değerlendirmek amacıyla nitel ve nicel verilerin birlikte kullanıldığı izleme sistemleri kurulmalıdır. Gelecek araştırmalar teşvik edilmelidir. Öğrenci ve veli görüşlerini merkeze alan saha temelli nitel araştırmalar ile erişilebilir okul uygulamalarının uzun vadeli etkilerini inceleyen karma yöntemli çalışmalar desteklenmelidir.

Bu önerilerin hayata geçirilmesi, kapsayıcı eğitimin yalnızca politika belgelerinde yer alan bir hedef olmaktan çıkarak, okulun tüm bileşenlerine yansıyan sürdürülebilir bir uygulama alanına dönüşmesine katkı sağlayacaktır.

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BİREYSELLEŞTİRİLMİŞ EĞİTİM PROGRAMLI (BEP) ÖĞRENCİLERİNDE SOSYAL DUYGUSAL ÖĞRENME (SDÖ)

Yüksek Lisans Öğrenci, Şerife SARIKAVAK¹/ Prof. Dr., Hakan UŞAKLI²

¹Sinop Üniversitesi Lisansüstü Enstitüsü, Eğitim, serifesrkvk@gmail.com, ORCID 0009-0006-5688-5727

²Sinop Üniversitesi, Eğitim, husakli@sinop.edu.tr, ORCID 0000-0003-4307-2226

Özet

Bu araştırmanın temel amacı, sınıflarında Bireyselleştirilmiş Eğitim Programı (BEP) uygulanan öğrenciler bulunan öğretmenlerin gözlem ve deneyimlerinden yola çıkarak, bu öğrencilerin sosyal duygusal öğrenme (SDÖ) becerilerini derinlemesine analiz etmektir. Günümüz eğitim sisteminde özel gereksinimli bireylerin sadece akademik başarılarına odaklanması, onların toplumsal uyum süreçlerini kısıtlayabilmektedir.

Araştırma, nitel araştırma yaklaşımı benimsenerek, bireylerin olgulara yüklediği anlamları ortaya çıkarmayı hedefleyen fenomenolojik desen ile yürütülmüştür. Çalışma grubunu, 2024–2025 eğitim-öğretim yılında devlet okullarında görev yapan ve sınıfında en az bir BEP’li öğrenci bulunan, farklı branş ve kıdemlerden 18 öğretmen oluşturmaktadır. Veriler, araştırmacılar tarafından geliştirilen yarı yapılandırılmış görüşme formu aracılığıyla toplanmış; elde edilen veriler betimsel ve içerik analizi teknikleriyle titizlikle çözümlenmiştir. Tema, kod ve örnekler verilmiştir.

Görüşme soruları, CASEL tarafından tanımlanan sosyal duygusal öğrenmenin beş temel boyutu olan; öz farkındalık, öz yönetim, sosyal farkındalık, ilişki becerileri ve sorumlu karar verme çerçevesinde yapılandırılmıştır. Bulgular, BEP’li öğrencilerin özellikle kendi duygularını tanıma, dürtü kontrolü sağlama, empati geliştirme ve sağlıklı akran ilişkileri başlatıp sürdürme noktalarında yoğun bir destek gereksinimi duyduklarını göstermiştir. Öğretmenler, bu becerilerin kendiliğinden gelişmesini beklemenin yetersiz kalacağını; bunun yerine yapılandırılmış, planlı ve bireyselleştirilmiş müdahale programlarının gerekliliğini vurgulamışlardır. Araştırma sonuçları, BEP süreçlerinin yalnızca bilişsel hedeflerle sınırlı kalmaması, öğrencinin karakter gelişimini destekleyecek şekilde SDÖ boyutlarını da kapsayan bütüncül bir yaklaşımla tasarlanması gerektiğini ortaya koymaktadır.

Anahtar kelimeler: Bireyselleştirilmiş eğitim programı, sosyal duygusal öğrenme, öğretmen değerlendirmesi

SOCIAL-EMOTIONAL LEARNING (SEL) IN STUDENTS WITH INDIVIDUALIZED EDUCATION PROGRAMS (IEP)

Abstract

The primary objective of this study is to conduct an in-depth analysis of the social-emotional learning (SEL) skills of students enrolled in Individualized Education Programs (IEP) based on the observations and experiences of their teachers. In today's education system, focusing solely on the academic achievements of individuals with special needs can limit their social adaptation processes.

The research was conducted using a phenomenological design, which aims to reveal the meanings individuals attach to phenomena, adopting a qualitative research approach. The study group consisted of 18 teachers from different disciplines and seniority levels who worked in public schools during the 2024–2025 academic year and had at least one student with an IEP in their class. Data were collected using a semi-structured interview form developed by the researchers; the data obtained were carefully analyzed using descriptive and content analysis techniques. Themes, codes, and examples are provided.

The interview questions were structured around the five core dimensions of social-emotional learning defined by CASEL: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. The findings showed that students with IEP have a particularly strong need for support in recognizing their own emotions, exercising impulse control, developing empathy, and initiating and maintaining healthy peer relationships. Teachers emphasized that it is insufficient to expect these skills to develop spontaneously; instead, structured, planned, and individualized intervention programs are necessary. The research results reveal that IEP processes should not be limited to cognitive goals alone but should be designed with a holistic approach that also encompasses the dimensions of SEL to support the student's character development.

Keywords: Personalized education program, social-emotional learning, teacher evaluation

1. GİRİŞ

Eğitim sistemlerinin temel hedeflerinden biri, tüm öğrencilerin bilişsel, sosyal ve duygusal gelişimlerini desteklemektir. Özellikle özel gereksinimli öğrenciler için geliştirilen Bireyselleştirilmiş Eğitim Programları (BEP), akademik hedeflerin yanı sıra öğrencilerin sosyal ve duygusal gelişimlerini de kapsayan bütüncül bir yaklaşımı gerektirmektedir (Batu & Kırcaali-İftar, 2016). Sosyal duygusal öğrenme (SDÖ), bireyin kendini tanıma, duygularını yönetme, başkalarını anlama, sağlıklı ilişkiler kurma ve sorumlu kararlar alma becerilerini içeren çok boyutlu bir yapı olarak tanımlanmaktadır (CASEL, 2020).

BEP’li öğrenciler, sosyal etkileşimlerde sınırlılıklar, duygularını düzenlemede güçlükler ve akran ilişkilerinde uyum sorunları yaşayabilmektedir (Sucuoğlu & Kargın, 2014). Bu nedenle sosyal duygusal öğrenme becerilerinin değerlendirilmesi ve desteklenmesi, BEP uygulamalarının etkililiği açısından kritik bir öneme sahiptir.

1.1. Kuramsal Çerçeve

Bu araştırma, iki temel kuramsal çerçeve üzerine inşa edilmiştir:

Bronfenbrenner’ın Ekolojik Sistemler Kuramı: Bu kurama göre çocuk, içinde bulunduğu çevrelerle etkileşim halinde gelişir. BEP’li bir öğrencinin sosyal-duygusal gelişimi, "mikrosistem" olan sınıf ortamında öğretmeniyle kurduğu etkileşime bağlıdır. Dolayısıyla öğretmenin gözlemi, öğrencinin ekosistemindeki en doğrudan ve kritik veridir.

Sosyal Duygusal Öğrenme (SDÖ) Çerçevesi (CASEL): SDÖ; öz farkındalık, öz yönetim, sosyal farkındalık, ilişki becerileri ve sorumlu karar verme gibi beş temel yetkinliği içeren çok boyutlu bir yapıdır (CASEL, 2020). Bu beceriler, özel gereksinimli öğrencilerin toplumla bütünleşmesi için akademik bilgiden daha öncelikli bir gereksinim olarak kabul edilmektedir.

BEP’li öğrenciler, bilişsel süreçlerindeki farklılıklar nedeniyle sosyal ipuçlarını okuma, duyguları düzenleme ve akran etkileşimi başlatma konularında ciddi güçlüklerle karşılaşabilmektedir (Sucuoğlu & Kargın, 2014). Bu bağlamda SDÖ, sadece bir beceri seti değil, bu öğrencilerin toplumsal uyumu için stratejik bir müdahale aracıdır.

Türkiye’deki eğitim pratiği incelendiğinde, BEP süreçlerinin genellikle müfredat odaklı ve akademik kazanımlara (okuma-yazma, matematik vb.) sıkıştığı görülmektedir (MEB, 2018). Ancak güncel alanyazın, güçlü sosyal-duygusal becerilere sahip olmayan öğrencilerin akademik hedeflere ulaşmakta da zorlandığını kanıtlamaktadır (Durlak vd., 2011; OECD, 2021).

Sosyal ve duygusal ihtiyaçların ihmal edilmesi, BEP’li öğrencilerin okulda dışlanma riskiyle karşı karşıya kalmasına ve psikolojik iyi oluşlarının zedelenmesine yol açmaktadır. Bu noktada en büyük eksiklik, bu öğrencilerin sosyal-duygusal özelliklerinin sistemli bir şekilde değerlendirilmemesidir. Bu çalışma, "BEP’li öğrencilerin sosyal duygusal öğrenme becerileri öğretmen perspektifinden nasıl bir görünüm sergilemektedir?" temel sorusuna yanıt arayarak mevcut boşluğu doldurmayı amaçlamaktadır.

Bu çalışma, kuramsal ve uygulama odaklı iki temel noktada önem arz etmektedir:

Öğretmen Sesinin Görünürlüğü: BEP’in uygulayıcısı olan öğretmenlerin gözlemleri, sadece birer veri değil; sınıf içi dinamiklerin ve öğrenci ihtiyaçlarının en saf yansımasıdır.

Uygulamaya Dönüşüm: Araştırmadan elde edilecek bulgular, BEP içeriklerinin zenginleştirilmesine, okul temelli SDÖ programlarının tasarlanmasına ve öğretmen yetiştirme programlarında özel eğitimde sosyal-duygusal destek modüllerinin oluşturulmasına temel oluşturacaktır.

Katılımcı öğretmenlerin, sınıflarındaki BEP’li öğrencilerin davranış ve gelişim süreçlerini yansız ve mesleki etik çerçevesinde gözlemledikleri kabul edilmiştir.

Görüşme sürecinde katılımcıların deneyimlerini içtenlikle, dış baskılardan uzak şekilde ifade ettikleri varsayılmıştır.

Nitel veri toplama araçlarının, incelenen olguyu (SDÖ becerileri) tüm derinliğiyle ortaya çıkaracak nitelikte olduğu varsayılmaktadır.

Katılımcı Sınırlılığı: Bu araştırma, belirli bir ilde görev yapan 18 öğretmen ile sınırlıdır.

Yöntemsel Sınırlılık: Çalışma nitel bir desene sahip olduğu için bulgular evrensel olarak genellenemez; ancak benzer demografik ve eğitsel özelliklere sahip bağlamlar için derinlemesine bir "durum tasviri" sunar.

Kapsam Sınırlılığı: Veriler, öğrencilerin doğrudan gözlemlenmesinden ziyade öğretmenlerin algı ve beyanlarıyla sınırlıdır.

2. YÖNTEM

Bu bölümde araştırmanın deseni, çalışma grubu, veri toplama araçları ve verilerin analizine ilişkin ayrıntılı bilgilere yer verilmiştir.

2.1. Araştırma Deseni

Bu çalışma, nitel araştırma paradigmaları içerisinde yer alan fenomenoloji (olgu bilim) deseni ile tasarlanmıştır. Nitel araştırma, sosyal olguları içinde bulundukları bağlamda, katılımcıların bakış açısıyla anlamlandırmayı hedefler (Creswell & Poth, 2018).

Fenomenoloji deseni, bireylerin bir kavrama veya olguya ilişkin sahip oldukları ortak deneyimleri betimlemeye odaklanır. Bu araştırmada fenomen olarak "BEP"li öğrencilerin sosyal duygusal öğrenme becerileri" seçilmiştir. Bu desenin tercih edilme sebebi, öğretmenlerin sınıf içindeki canlı deneyimlerini, bu öğrencilerin sosyal-duygusal dünyalarına dair algılarını ve yükledikleri anlamları "içeriden bir bakışla" derinlemesine analiz etme gerekliliğidir.

2.2. Veri Toplama Yöntemi ve Süreci

Araştırmada veri toplama tekniği olarak yarı yapılandırılmış görüşme yöntemi kullanılmıştır. Görüşme, bireylerin deneyimlerini, tutumlarını ve düşüncelerini kendi kelimeleriyle ifade etmelerine olanak tanıyan etkileşimli bir süreçtir (Patton, 2015).

Esneklik: Yarı yapılandırılmış form, araştırmacıya önceden hazırlanmış soruları sorma imkânı verirken, aynı zamanda görüşme sırasında gelişen yeni durumlara göre ek sorular sorma esnekliği sağlar.

Derinlik: Bu yöntem, öğretmenlerin sadece "evet/hayır" gibi kısa cevaplar vermesini değil; sınıf içi anekdotlarını paylaşarak sosyal-duygusal becerilere dair somut örnekler sunmalarını mümkün kılar.

2.3. Çalışma Grubu (Katılımcılar)

Araştırmanın çalışma grubunun belirlenmesinde, nitel araştırmalarda yaygın olarak kullanılan amaçlı örnekleme yöntemlerinden "ölçüt örnekleme" kullanılmıştır.

Katılımcı Seçim Ölçütleri:

Hâlihazırda sınıfında tanısı konmuş ve resmi bir BEP'i olan en az bir öğrencinin bulunması.

Özel gereksinimli öğrenci ile en az bir eğitim dönemi boyunca etkileşimde bulunmuş olmak (deneyimin derinliği için).

Gönüllülük esasına dayalı katılım.

Bu doğrultuda çalışma grubu, farklı kademelerde (ilkokul ve ortaokul) görev yapan ve farklı branşlardan (sınıf öğretmeni ve branş öğretmenleri) gelen 18 öğretmenden oluşmaktadır. Bu çeşitlilik, fenomenin farklı perspektiflerden görülmesini sağlamıştır.

2.4. Verilerin Analizi

Toplanan verilerin çözümlenmesinde içerik analizi tekniği kullanılmıştır. İçerik analizinin temel amacı, toplanan verileri açıklayabilecek kavramlara ve ilişkilere ulaşmaktır (Yıldırım & Şimşek, 2021).

Analiz Süreci Şu Basamaklarla Yürütülmüştür:

Verilerin Ham Haliyle Metne Dönüştürülmesi: Görüşme kayıtları kelimesi kelimesine deşifre edilmiştir.

Kodlama: Veriler satır satır okunarak anlamlı kodlar (örneğin; "akran zorbalığı", "duygu düzenleme güçlüğü") çıkarılmıştır.

Kategori ve Tema Oluşturma: Birbiriyle ilişkili kodlar bir araya getirilerek kategoriler oluşturulmuş; bu kategoriler ise araştırmanın kuramsal çerçevesine (öz farkındalık, sosyal farkındalık vb.) göre üst temalar altında toplanmıştır.

Geçerlik ve Güvenirlik: Verilerin analiz sürecinde "uzman incelemesi" ve "doğrudan alıntılar" kullanılarak araştırmanın inandırıcılığı ve aktarılabilirliği artırılmıştır.

3. BULGULAR

Bu bölümde, öğretmenlerle yapılan yarı yapılandırılmış görüşmelerden elde edilen veriler içerik analizi yöntemiyle çözümlenmiş; kodlar, kategoriler ve temalar oluşturulmuştur. Analiz sürecinde öncelikle öğretmen ifadeleri açık kodlamaya tabi tutulmuş, benzer kodlar kategoriler altında birleştirilmiş ve ardından sosyal duygusal öğrenmenin beş temel alanına karşılık gelen temalar oluşturulmuştur (Yıldırım & Şimşek, 2021).

Tema 1: Öz Farkındalık Becerileri

Kategori: Duyguları Tanıma ve İfade Etme

Kodlar: Duyguları adlandıramama, duyguları sözel ifade etmede güçlük, duygularını zamanla fark etme

Öğretmen görüşleri, BEP’li öğrencilerin kendi duygularını tanıma ve sözel olarak ifade etme konusunda belirgin güçlükler yaşadığını göstermektedir. Bununla birlikte, öğretmen rehberliği ve zamanla bu becerilerde sınırlı da olsa gelişme gözlemlendiği ifade edilmiştir.

“BEP’li öğrencim ne hissettiğini sözel olarak ifade etmekte zorlanıyor ama zamanla üzgün mü, kızgın mı olduğunu ayırt etmeye başladı.” (Ö4)

Tema 2: Öz Yönetim Becerileri

Kategori: Duygusal Kontrol ve Dürtü Yönetimi

Kodlar: Öfke patlaması, sınıftan uzaklaşma isteği, sakinleşme süresinin uzunluğu

Öğretmenler, BEP’li öğrencilerin yoğun duygular yaşadıklarında bu duyguları düzenlemekte zorlandıklarını ve öz yönetim becerilerinin sınıf içi uyumu etkilediğini belirtmiştir.

“Öfkelendiğinde sınıftan çıkmak istiyor, sakinleşmesi bazen on dakikayı buluyor.” (Ö11)

Tema 3: Sosyal Farkındalık Becerileri

Kategori: Empati ve Başkalarının Duygularını Anlama

Kodlar: Akran duygularını fark edememe, empatik tepki verememe, öğretmen yönlendirmesiyle fark etme

Bulgular, BEP’li öğrencilerin başkalarının duygularını kendiliğinden fark etmekte zorlandıklarını; ancak yapılandırılmış etkinlikler ve öğretmen yönlendirmesiyle empati becerilerinin desteklenebildiğini ortaya koymaktadır.

“Arkadaşının üzgün olduğunu fark etmiyor, söyleyince anlıyor.” (Ö7)

Tema 4: İlişki Becerileri

Kategori: Akran İlişkileri ve Sosyal Etkileşim

Kodlar: Oyuna katılamama, iletişimi başlatamama, dışlanma korkusu

Öğretmen ifadeleri, BEP’li öğrencilerin akran ilişkileri kurma konusunda istekli olmalarına rağmen sosyal etkileşimi başlatma ve sürdürme noktasında desteğe ihtiyaç duyduklarını göstermektedir.

“Oyunlara katılmak istiyor ama nasıl başlayacağını bilemediği için kenarda bekliyor.” (Ö9)

Tema 5: Sorumlu Karar Verme Becerileri

Kategori: Davranış Sonuçlarını Öngörebilme

Kodlar: Ani karar verme, sonuçları düşünmeden davranma, yetişkin rehberliğine ihtiyaç

Öğretmen görüşleri, BEP’li öğrencilerin davranışlarının olası sonuçlarını öngörmeye güçlük yaşadıklarını ve karar verme süreçlerinde yetişkin desteğine ihtiyaç duyduklarını ortaya koymaktadır.

“Yaptığı davranışın sonucunu çoğu zaman düşünmeden hareket ediyor.” (Ö14)

Genel olarak bulgular, BEP’li öğrencilerin sosyal duygusal öğrenme becerilerinin beş temel alanda da (öz farkındalık, öz yönetim, sosyal farkındalık, ilişki becerileri ve sorumlu karar verme) çeşitli sınırlılıklar barındırdığını göstermektedir. Öğretmen görüşlerinden elde edilen veriler, öğrencilerin özellikle duygu düzenleme ve sosyal etkileşimi başlatma konularında yoğun desteğe ihtiyaç duyduklarını, ancak öğretmen rehberliği ve yapılandırılmış destekle bu becerilerde gelişim potansiyeli taşıdıklarını ortaya koymaktadır. Bu durum, akademik hedeflerle sınırlı kalan BEP içeriklerinin, öğrencinin okul ve toplum uyumunu doğrudan etkileyen bu sosyal-duygusal yetkinlikleri kapsayacak şekilde genişletilmesinin gerekliliğini doğrulamaktadır.

4. SONUÇ, TARTIŞMA VE ÖNERİLER

Bu bölümde, BEP’li öğrencilerin sosyal duygusal öğrenme (SDÖ) becerilerine yönelik öğretmen görüşlerinden elde edilen bulgular, ilgili alanyazın ve kuramsal çerçeve ışığında tartışılmış; uygulayıcılara ve araştırmacılara yönelik öneriler sunulmuştur.

4.1. Sonuç ve Tartışma

Araştırma sonuçları, BEP’li öğrencilerin SDÖ becerilerinin tüm boyutlarında (öz farkındalık, öz yönetim, sosyal farkındalık, ilişki becerileri ve sorumlu karar verme) çeşitli düzeylerde güçlükler yaşadığını, ancak bu güçlüklerin uygun müdahalelerle esneyebildiğini göstermektedir.

Öz Farkındalık ve Öz Yönetim: Öğretmenler, öğrencilerin duygularını adlandırmada ve öfke gibi yoğun duyguları kontrol etmede zorlandıklarını belirtmiştir. Bu durum, Bronfenbrenner’ın Ekolojik Sistemler Kuramı bağlamında değerlendirildiğinde; öğrencinin mikrosistemi olan sınıfta maruz kaldığı stresörlerin, öz düzenleme becerisi zayıf olan bireyde uyum sorunlarını tetiklediği söylenebilir. Alanyazın, bu becerilerin eksikliğinin akademik odaklanmayı doğrudan engellediğini vurgulamaktadır (Durlak vd., 2011).

Sosyal Farkındalık ve İlişki Becerileri: Bulgular, öğrencilerin akran grubuna dahil olma isteği taşımalarına rağmen "sosyal girişkenlik" ve "empati" konularında rehberliğe ihtiyaç duyduklarını kanıtlamıştır. Yapılandırmacı Yaklaşım açısından bakıldığında, sosyal etkileşimin yetersizliği öğrencinin çevresinden öğreneceği bilgileri kısıtlamakta ve öğrenme yaşantısını sekteye uğratmaktadır.

Sorumlu Karar Verme: Öğrencilerin davranış sonuçlarını öngörememesi, BEP’lerdeki bilişsel hedeflerin sosyal muhakeme becerileriyle desteklenmesi gerektiğini ortaya koymaktadır.

4.2. Öneriler

Araştırmadan elde edilen sonuçlar doğrultusunda şu öneriler geliştirilmiştir:

4.2.1. Uygulamaya Yönelik Öneriler

BEP İçeriklerinin Güncellenmesi: Mevcut BEP formatları sadece akademik kazanımlarla sınırlı kalmamalı; SDÖ becerileri (duygu yönetimi, çatışma çözme vb.) programın ayrılmaz bir parçası ve resmi birer hedefi haline getirilmelidir.

Öğretmen Eğitimleri: Öğretmenlerin BEP’li öğrencilere sosyal-duygusal destek sunabilmeleri için "Kapsayıcı Eğitimde Sosyal Duygusal Öğrenme" konulu hizmet içi eğitimler ve atölye çalışmaları düzenlenmelidir.

Okul Temelli Müdahaleler: Okul psikolojik danışmanları ve sınıf öğretmenleri iş birliği yaparak, BEP’li öğrencilerin akranlarıyla etkileşimini artıracak "Akran Destek Grupları" veya "Sosyal Beceri Eğitimleri" planlamalıdır.

4.2.2. Gelecek Araştırmalara Yönelik Öneriler

Karma Yöntem Çalışmaları: Bu araştırma nitel bir desende yürütülmüştür. Gelecek çalışmalarda nicel ölçekler de kullanılarak daha geniş örneklemeler üzerinde genellenebilir sonuçlara ulaşılabilir.

Paydaş Çeşitliliği: Çalışma öğretmen görüşleriyle sınırlıdır. Gelecekteki araştırmalarda öğrenci öz-değerlendirmeleri ve ebeveyn görüşleri de sürece dahil edilerek "üçgenleme" (triangulation) yapılabilir.

Boylamsal Araştırmalar: SDÖ müdahalelerinin BEP’li öğrenciler üzerindeki uzun dönemli etkilerini inceleyen boylamsal çalışmalar planlanabilir.

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